APPENDIX I
VOLUME II
Compilation of Attachments from Comment Letters on the Recirculated Draft EIR and Draft EIR

Appendix I contains comment letter attachments that are general and do not relate to specific sections of the DEIR or RDEIR. Therefore, no responses are provided. (Public Resources Code § 21091(d); CEQA Guidelines § 15204(a)) Responses to comments and attachments requiring responses can be found in FEIR Chapter 2.

Attachments from Comment Letter 113

San Pedro Bay Ports Rail Study Update

Executive Summary

Prepared for:

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EXECUTIVE SUMMARY

I. Introduction

The San Pedro Bay Ports of Los Angeles and Long Beach (SPB) serve as the country's primary gateway to international trade. International trade is a key economic engine for the local region and the country. The Ports serve as a vital link in the goods movement chain providing products for our local market as well as those shipped by rail throughout the country.

No other port is as well positioned as the Ports of Long Beach and Los Angeles to serve our country's growing demand for international cargo. Bearing this responsibility, the SPB Ports are carefully planning the infrastructure necessary to accommodate demand while minimizing impacts to the surrounding communities. The landside transportation links are especially important since the resulting access issues have the highest potential to cause impacts to the local communities. Portions of the existing transportation system within and adjacent to the Ports are becoming constrained. Expected increases in cargo throughput will induce a considerable amount of rail and truck traffic onto this transportation system.

The Alameda Corridor opened April 15, 2002 and has generated significant improvements to the rail system's ability to efficiently carry trains from the Ports to the inland rail system with improved train speed and removal of at-grade crossings that had previously impacted traffic in the adjacent communities. Any cargo that is moved by train from the Port is a benefit to the transportation system by reducing the truck volumes and the associated congestion and diesel emissions.

The rail system serving the SPB Ports is instrumental in enabling the efficient transportation of cargo, since rail service is both economically and environmentally beneficial. Maximizing use of on-dock rail yards is part of the *SPB Ports Clean Air Action Plan*. Without on-dock rail, intermodal cargo will add to local highway congestion and diesel truck emissions as it is hauled by truck to be loaded onto trains at inland rail yards. Therefore, the Ports have developed and are continuing to pursue development of **on-dock rail yards** so that cargo can be loaded onto trains at the marine terminal without generating truck trips on the local roadways and freeways. Unlike on-dock rail yards that are dedicated to a single marine terminal, **near-dock rail yards** have logistical advantages due to their ability to serve numerous marine terminals. Near-dock facilities are within five miles of the Port and are able to provide needed intermodal capacity with greatly reduced trucking impacts, compared to more remote off-dock facilities. Other advanced technologies that could be applied to the transport of containers in lieu of heavy rail or trucks are being considered under a separate study and are not considered by this "Rail Study Update".

II. Study Goal

The goal of this "Rail Study Update" (Rail Study) is to evaluate the rail system performance and recommend enhancements to Port infrastructure. The Port of Long Beach previously conducted a *Rail Master Planning Study* (POLB, 2002) and the Port of Los Angeles conducted a *Rail Capacity Analysis* (POLA, 2003) based on year 2000 conditions. This Study incorporates changed market conditions, revised Port development plans, and modified cargo forecast based on the latest information available in 2005.

The SPB Ports were concurrently conducting the *Truck Reduction Study* and this Rail Study is considered to be a component of the *Truck Reduction Study*.

The objectives of this "Rail Study Update" are as follows:

- Establish existing conditions in 2005.
- Identify rail system deficiencies and propose necessary improvements based on rail yard capacity analyses using MPC Model, and rail network train simulation using RTS Model.
- Develop conceptual rail designs for mainline track, rail yards, operations and systems.
- Substantiate the actions required to meet rail yard demand and provide acceptable levels of service for trains on the rail network in 2010, 2015, 2020 and 2030.
- Develop a Rail Enhancement Program (REP) that coordinates conceptual improvements through a phased implementation plan with schedule and cost estimate for each project.

The goal for meeting rail yard demand is to maximize capacity and utilization of on-dock rail and supplement that capacity with near-dock facilities as necessary.

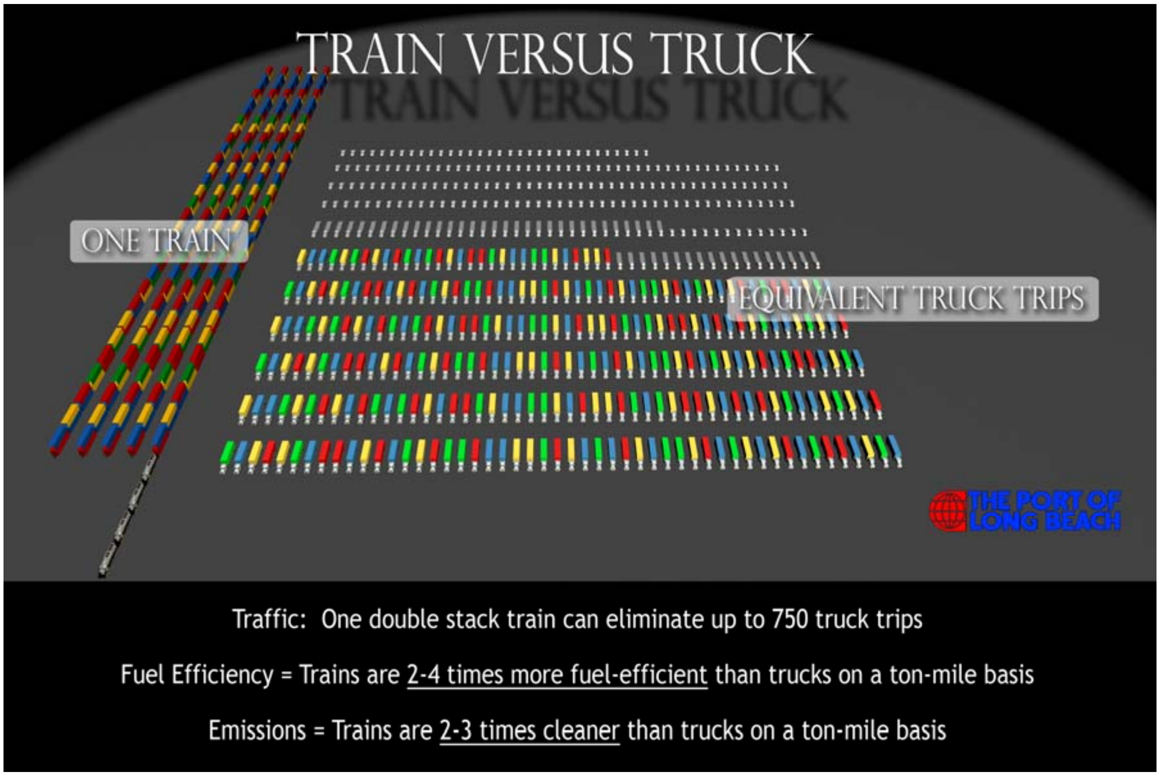
III. Benefits

Any cargo that is moved by train from the Port benefits the overall transportation system by reducing the truck trips and total truck mileage with the associated impacts. The graphic on the following page shows that each on-dock train can eliminate 750 truck trips and are at least twice as fuel efficient and clean as trucks on a ton-mile basis.

A single container ship may unload 5,000 twenty-foot equivalent units (TEU) to be delivered outside the Port boundaries by a fleet of trucks. However, the movement of cargo by trains loaded at on-dock rail yards is an effective method of reducing the truck traffic. Every train that is loaded on-dock can eliminate 750 truck trips from the highway, and a single ship call can generate five trains worth of intermodal cargo. In other words, on-dock rail can potentially eliminate 3,750 truck trips for every vessel call.

As a measure of the benefits of on-dock rail, consider the hypothetical situation where all of the REP projects are built and operating today: the level of on-dock throughput would be nearly double that of existing and would remove nearly 6,000 trucks a day from the local roadways. As cargo volumes increase, the benefits of on-dock rail will increase as well. Given 2030 cargo forecasts and full development of the REP, on-dock rail would remove nearly 29,000 truck trips daily.

Since there is currently no viable opportunity to accommodate the forecast intermodal cargo volumes elsewhere on the West Coast, a no action scenario, with regards to the REP, would result in extensive truck trips over long distances seeking out available locations for intermodal capacity. This would add millions of truck-miles to our local freeway system each day.



IV. Approach

The capacities of on-dock, near-dock and off-dock rail yards are analyzed for their ability to accommodate forecast intermodal demand. The maximum practical capacity (MPC) of existing and proposed rail facilities is estimated using a validated MPC Model. The demand for various rail yards considers cargo flow characteristics and specific requirements of direct intermodal, transload and domestic intermodal cargo.

The Port's rail system infrastructure is evaluated using the Rail Traffic Control (RTC) simulation model. Train volumes are estimated for each rail yard by the MPC Model and then the RTC Model dispatches these trains onto the Port rail network and through the Alameda Corridor. The RTC Model simulates train movements based on rail line characteristics and availability, and provides results including train transit times and train delays. Based on these results, infrastructure deficiencies are identified and engineered improvements are recommended.

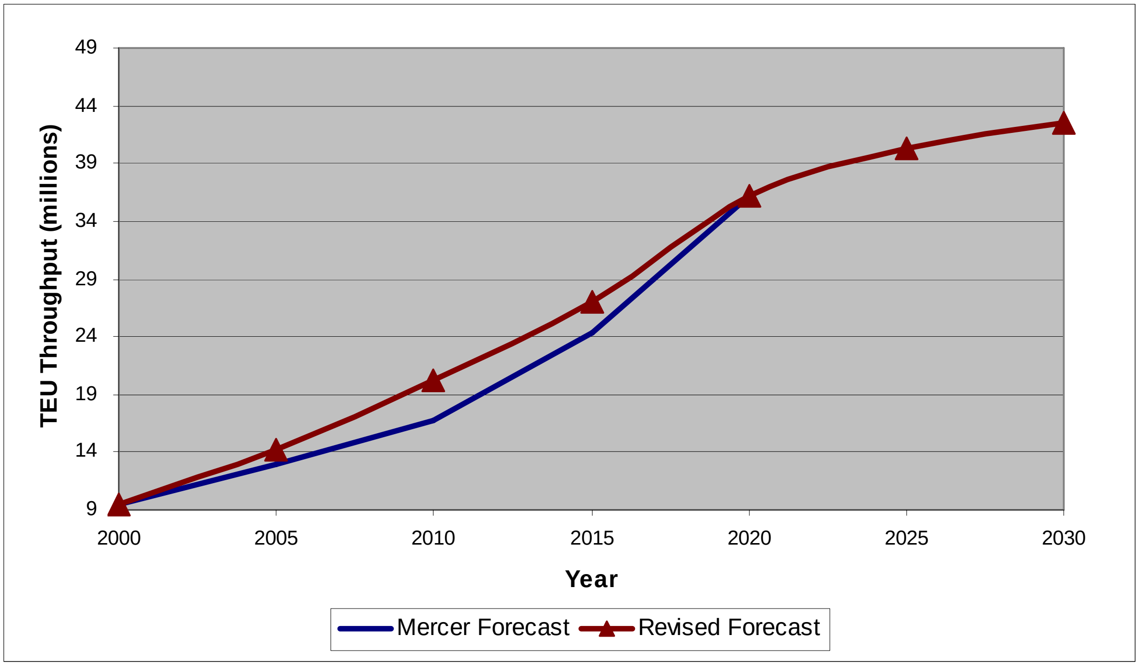
Rail yard expansion projects and infrastructure improvement projects recommended by this Study are compiled into a Rail Enhancement Program (REP) that establishes the schedule, cost and requirements of all projects in the REP. The information is also used to estimate the annual cost spread of the overall program. Finally, improvement projects are evaluated for their relative benefit/cost ratio.

The rail designs prepared by this study are conceptual. Each project design will subsequently be revised to address requirements that will be determined during environmental permitting, tenant negotiations and final engineering design.

V. Cargo Growth

The San Pedro Bay Ports Long-Term Cargo Forecast (Mercer Management, 1998) is tracking slightly lower than actual cargo volumes in 2005. The Mercer Forecast was adjusted to create a Revised Forecast based on the following: actual cargo throughput at the San Pedro Bay Ports during the period of 2000-2005. The Revised Forecast is also extended from 2020 out to 2030 considering expected continued growth rates and limited based on estimated marine terminal capacities. The Mercer Forecast and Revised Forecast are shown on **Figure 1**.

Figure 1 - SPB Ports Cargo Forecast



Values in millions of TEU	2005 Actual	2010	2015	2020	2030
Revised Cargo Forecast	**14.2**	**20.2**	**27.1**	**36.2**	**42.5**

Cargo Type

Port intermodal cargo is projected to account for at least half of the total Port throughput during the forecast horizon. The other half is destined for regional markets. Port intermodal cargo has two components, as follows:

Direct Intermodal: is moved directly between the Port and rail yards and can be handled on-dock, near-dock or off-dock. Direct intermodal is expected to account for 40 percent of Port cargo.

Transload Intermodal: is rehandled through a warehouse somewhere between the Port and rail yards. Transload cargo is never handled on-dock due to the requirement to be transported off the marine terminal to a warehouse.

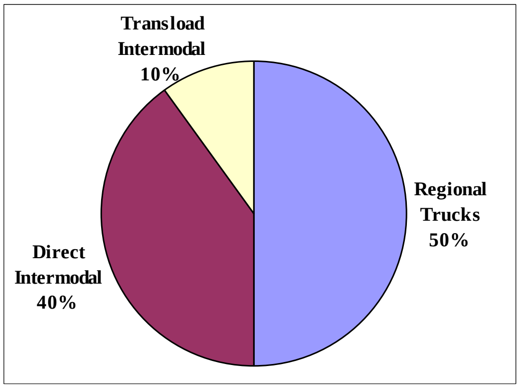


Figure 2 – SPB Ports Cargo Breakdown

Regional Cargo: is transported almost exclusively by truck, although there are proposals to use shuttle trains to transport some regional cargo to an inland distribution facility. **Figure 2** shows the breakdown of these cargos with intermodal on the left side of the pie and regional to the right.

VI. Rail Yards Supporting San Pedro Bay Ports

Port intermodal cargo can be transferred to trains at any of three types of rail yards:

On-dock Rail: On-dock is defined as a rail yard located within the marine terminal. A marine terminal also has wharf, container storage areas, administration and support buildings and truck processing gates. The on-dock rail yard allows cargo to be transported without any gate transaction and without dispatching trucks onto local roadways. One disadvantage is that the rail yard encroaches on the container yard acreage and impedes traffic flow within the marine terminal, potentially reducing the throughput capacity of the terminal. However, given environmental benefits and through careful planning to minimize capacity constraints, the Ports are pursuing on-dock rail to the fullest extent possible. On-dock throughput is increasing each year and handled 24% of the total San Pedro Bay cargo in 2006.

Near-dock Rail: Near-dock is defined as a rail yard located outside of the marine terminals that requires a short truck trip (within 5 miles). Their advantage is the ability to combine cargo from various marine terminals and build trains that efficiently transport cargo to specific destinations throughout the country. The only existing near-dock rail yard for the San Pedro Bay Complex is the Intermodal Container Transfer Facility (ICTF). It is operated by Union Pacific Railroad on Port of Los Angeles property located north of Sepulveda Boulevard and east of Alameda Street. The Ports are contemplating other near-dock facilities to help meet the demand for efficient rail transport. Currently, ICTF handles 8 percent of the total San Pedro Bay cargo in 2006.

Off-dock Rail: Off-dock rail yards are located more remotely (greater than 5 miles) from marine terminals. Currently, off-dock rail yards that handle containers from the San Pedro Bay Ports are located near downtown Los Angeles, approximately 25 miles away. Both the BNSF Railway and Union Pacific Railroad have off-dock facilities that handle Port containers. These rail yards contribute significant truck miles to some of the most congested roadways in the region. Off-dock rail yards handled approximately 11 percent of the total San Pedro Bay cargo in 2006, down from 15 percent and 14 percent in 2003 and 2004, respectively.

The recent history of on-dock, near-dock and off-dock throughput is provided in **Table 1**.

Table 1: SPB Direct Intermodal – Actual Throughput

(TEU)	2003	2004	2005	2006
On-Dock	**1,885,642**	**2,369,853**	**2,934,850**	**3,801,892**
Percent of Port Throughput	15.9%	18.1%	20.7%	24.1%
Near-Dock	**962,197**	**936,428**	**1,081,350**	**1,271,327**
Percent of Port Throughput	8.1%	7.1%	7.6%	8.1%
Off-Dock	**1,805,791**	**1,846,188**	**1,689,890**	**1,671,489**
Percent of Port Throughput	15.3%	14.1%	11.9%	10.6%
Total Direct Intermodal	**4,653,630**	**5,152,469**	**5,706,090**	**6,744,708**
Percent of Port Throughput	39.3%	39.3%	40.2%	42.8%
Total Port Throughput	***11,837,064***	***13,101,292***	***14,194,442***	***15,759,219***

Source: UPRR/BNSF

Table 1 includes only direct intermodal cargo, which excludes transload cargo. Transload cargo is estimated to be approximately 10 percent of total Port throughput volumes and all transload is handled off-dock.

The recent increases in rail throughput have been efficiently accommodated by the Port due to proactive construction of rail infrastructure improvements in the past. Additional investment will be needed to minimize impacts of continuing cargo growth. Development of on-dock/near-dock facilities and supporting rail infrastructure will improve intermodal efficiencies and reduce local and regional truck traffic.

On-Dock Development

On-dock rail yards are currently handling over 20 percent of Port cargo, but with cargo growth and the desire to maximize on-dock throughput, it has been proposed that these yards be expanded and new yards be developed over the next 20 years. This strategy aims to efficiently handle international cargo while minimizing environmental impacts. Recent actual on-dock throughput is provided in **Table 2a** and the projected on-dock throughput associated with planned improvements (as described in REP) is provided in **Table 2b**.

Table 2a: Actual SPB On-Dock Intermodal Throughput

(millions of TEU)	2003	2004	2005	2006
POLB	**0.51**	**0.86**	**1.09**	**1.40**
Percent of POLB Throughput	11.0%	14.9%	16.3%	19.2%
POLA	**1.37**	**1.51**	**1.84**	**2.40**
Percent of POLA Throughput	19.1%	20.6%	24.6%	28.3%
Total SPB	***1.88***	***2.37***	***2.93***	***3.80***
Percent of Port Throughput	*15.9%*	*18.1%*	*20.7%*	*24.1%*

Table 2b: Projected SPB On-Dock Intermodal Throughput

(millions of TEU)	2010	2015	2020	2030
POLB	**2.27**	**4.15**	**5.49**	**6.10**
Percent of POLB Throughput	23%	32%	32%	30%
POLA	**2.79**	**4.33**	**6.25**	**6.84**
Percent of POLA Throughput	27%	31%	33%	31%
Total SPB	***5.06***	***8.47***	***11.74***	***12.94***
Percent of Port Throughput	*25%*	*31%*	*32%*	*30%*

The locations of existing and proposed Port rail yards are shown in **Figure 3**.

Figure 3 - Existing and Proposed Port Rail Yards

LEGEND

POLB Rail Yards
1 – Pier J On-Dock [1]
2 – Pier G On-Dock [1]
3 – Middle Harbor Terminal (Piers DEF) On-Dock [1]
4 – Pier A On-Dock [1]
5 – Pier S On-Dock [2]
6 – Pier T On-Dock [1]
7 – Pier B Rail Yard [1]

POLA Rail Yards
8 – TICTF Shared On-Dock [1]
9 – Pier 300 On-Dock [1]
10 – Pier 400 On-Dock [1]
11 – WBICTF On-Dock [1]
12 – WB-East (TraPac) On-Dock [2]
13 – PHL Base/Support Rail Yard [2]

Notes:
1) Reconfiguration/expansion of existing yard.
2) Construction of new rail yard.

VII. Rail Yard Capacity/Demand

Capacity of planned off-dock, near-dock and on-dock rail yards will not meet projected demand for SPB intermodal cargo. However, the Ports are considering additional potential projects as described in the subsequent "Other Potential Projects" section.

> **Direct Intermodal**: SPB intermodal cargo that is not transload.
>
> **Transload:** SPB intermodal cargo that is processed through local warehouses prior to loading onto trains at off-dock rail yards.
>
> **Domestic:** cargo transported between two points in the U.S., but unrelated to Ports.

The rail yard capacity/demand analysis indicates that demand for off-dock rail yards will outstrip the existing capacity. In fact, transload and domestic cargo alone (which cannot be handled at on-dock or near-dock rail yards) is expected to take up all existing off-dock capacity in the 2010-2015 timeframe, depending on domestic cargo growth rates (0% growth will leave capacity until 2015; 3% growth will take all capacity by 2010). Therefore, direct intermodal will need to be accommodated at on-dock or near-dock rail yards, which is also preferable from the standpoint of minimizing trucking impacts such as traffic congestion and diesel emissions.

Base and Alternative Rail Yard Capacity/Demand Scenarios

Several scenarios of on-dock development have been explored to understand their implications on rail yard capacity/demand. The MPC Scenario assumes all planned development occurs and is used as the basis for all further capacity/demand considerations in this report. The other scenarios are less optimistic and therefore result in greater capacity shortfall. The capacity shortfall, or latent demand, should be considered the amount of additional rail yard capacity needed to meet demand. The Ports are considering "Other Potential Projects" (described later) to provide this additional capacity.

MPC Scenario: This base capacity/demand analysis assumed that all projects in the REP are developed and that rail yards operate at their maximum practical capacity (MPC). The MPC Scenario assumes that on-dock rail yards use longshore labor to load and unload containers from trains. The assumption for working shifts when these operations are performed increase over time as follows: 1-shift in 2005; 2-shifts in 2010; 3-shifts in 2015 and 3-shifts with modified operating practices in 2020 and beyond. The modified operating practices assume that enhanced safety systems are implemented in all rail yards to allow loading trains while other trains are moving in the yard (when at least 30 feet away). The results from the MPC Scenario analysis are presented in **Table 3a**.

Two-Shift Scenario: The Two-Shift Scenario limits all future operating conditions to those modeled by MPC for 2010 (i.e. 1-shift in 2005 and 2-shifts in 2010 and beyond, with no change in labor practices). This assumption reduces the on-dock capacity and the ability to meet demand after 2010, as indicated in **Table 3b**. Note that this scenario still assumes all rail yard development as proposed by the REP.

No-Action Scenario: The No-Action Scenario limits all future development of on-dock rail yards, therefore retaining existing rail yard conditions. Rail yard loading is allowed to grow from 1-shift in 2005, to 2-shifts, in 2010 and 3-shifts in 2015; but no change in labor practices are assumed. This scenario further reduces the on-dock capacity and the ability to meet demand, as indicated in **Table 3c**.

Table 3a: Direct Intermodal Demand & Capacity – MPC Scenario

Direct Intermodal excludes Transload All values in millions of TEU	2005 Actual	2010	2015	2020	2030
SPB Cargo Forecast (Demand)	14.2	20.2	27.1	36.2	42.5
SPB Direct Intermodal (Demand)	5.70	8.10	10.84	14.48	17.01
POLB On-Dock Capacity [1,2]	1.09	2.27	4.15	5.49	6.10
POLA On-Dock Capacity [1,2]	1.84	2.79	4.33	6.25	6.84
SPB Off-Dock Capacity [2, 3]	1.69	0.67	0.04	0.00	0.00
SPB Near-Dock Capacity [4]	1.08	1.40	1.84	1.84	1.84
SPB Variance (negative = shortfall)	**0.0**	**-0.97**	**-0.48**	**-0.90**	**-2.23**

Footnotes:

1 *Capacity (Forecast Throughput from MPC Model) assumes all REP projects.*

2. *2005 capacity reflects actual direct intermodal at on-dock, near-dock and off-dock.*

3. *Transload (10% of SPB Ports) + domestic (no growth) consume all off-dock capacity by 2015.*

4. *No expansion of near-dock facilities is assumed, except mini-ICTF at Pier B.*

Table 3b: Direct Intermodal Demand & Capacity – 2-Shift Scenario

Direct Intermodal excludes Transload All values in millions of TEU	2005 Actual	2010	2015	2020	2030
SPB Cargo Forecast (Demand)	14.2	20.2	27.1	36.2	42.5
SPB Direct Intermodal (Demand)	5.70	8.10	10.84	14.48	17.01
POLB On-Dock Capacity [1,2]	1.09	2.27	3.98	4.90	5.15
POLA On-Dock Capacity [1,2]	1.84	2.79	4.11	4.78	4.78
SPB Off-Dock Capacity [2, 3]	1.69	0.67	0.04	0.00	0.00
SPB Near-Dock Capacity [4]	1.08	1.40	1.84	1.84	1.84
SPB Variance (negative = shortfall)	**0.0**	**-0.97**	**-0.87**	**-2.96**	**-5.24**

Footnotes: Same as Table 3a

Table 3c: Direct Intermodal Demand & Capacity – No-Action Scenario

Direct Intermodal excludes Transload All values in millions of TEU	2005 Actual	2010	2015	2020	2030
SPB Cargo Forecast (Demand)	14.2	20.2	27.1	36.2	42.5
SPB Direct Intermodal (Demand)	5.70	8.10	10.84	14.48	17.01
POLB On-Dock Capacity [1,2]	1.09	1.74	2.14	2.28	2.28
POLA On-Dock Capacity [1,2]	1.84	2.47	3.08	3.08	3.08
SPB Off-Dock Capacity [2, 3]	1.69	0.67	0.04	0.00	0.00
SPB Near-Dock Capacity [4]	1.08	1.40	1.40	1.40	1.40
SPB Variance (negative = shortfall)	**0.0**	**-1.82**	**-4.18**	**-7.72**	**-10.25**

Footnotes:

1 *Capacity (Forecast Throughput from MPC Model) assumes existing infrastructure, no REP projects.*

2. *2005 capacity reflects actual direct intermodal for on-dock, near-dock and off-dock.*

3. *Transload (10% of SPB Ports) + domestic (no growth) consume all off-dock capacity by 2015.*

4. *No expansion of near-dock facilities is assumed.*

The Study uses the MPC Scenario as the basis to analyze SPB ability to meet demand for direct intermodal capacity.

The REP had included a near-dock facility located south of the existing UPRR ICTF, which would meet the demand for direct intermodal capacity to nearly 2030, and likely beyond. However, POLA is evaluating alternative developments to ensure that the most environmentally sensitive project is selected. The near-dock facility (SCIG) is still listed on the REP (Project II.5), but is now being evaluated through a comparative analysis with “Other Potential Projects” described in the next section.

VIII. Other Potential Projects

The capacity of on-dock and near-dock rail yards programmed in the REP (excluding II.5-New Near-Dock ICTF South of Sepulveda) will not meet demand in the 2010-2030 timeframe. Additional on-dock and near-dock facilities are being considered by the Ports to meet the latent demand. These additional developments will need to be pursued to avoid the significant impacts of intermodal cargo being trucked through the Southern California region. These “Other Potential Projects” are listed in **Table 4** and further considered for their ability to meet demand and fit efficiently into the SPB Port rail network.

Table 4: Other Potential Projects to Provide Rail Yard Capacity

Name	Type	Owner	Proposed Operator	Status	Annual MPC (TEU)
POLA Terminal Island Intermodal Facility	On-Dock	POLA	tbd	Conceptual	1,400,000
POLB Pier T Mole Expansion	On-Dock	POLB	tbd	Conceptual	1,100,000
Southern California International Gateway (SCIG)	Near-Dock	POLA	BNSF	Harbor Development Permit	1,800,000
Intermodal Container Transfer Facility (ICTF) Expansion	Near-Dock	JPA	UPRR	Conceptual	1,900,000

POLA Terminal Island Intermodal Facility

POLA is evaluating the development of additional intermodal facilities on Terminal Island. The primary area of focus is south of Seaside Avenue (SR-47), including the former LAXT site. Initial conceptual layouts have been developed. This facility has not been modeled for MPC throughput or simulated with RTC to understand train access issues.

The RTC simulations of existing and planned facilities indicate that the throat from Badger Bridge to Pier 300 (CP Mole) is constrained and any additional rail traffic should be carefully studied to understand how it would affect the stability of the rail network system. The RTC simulation was used to model increased train volumes associated with a surrogate Terminal Island facility (Pier T Mole at 1.1 million TEU) and found that the rail network system would become constrained, causing unacceptable Level of Service throughout the system. It is estimated that the rail network system would become gridlocked with Terminal Island rail yard expansion greater than approximately 1.5 million TEU beyond the REP expansions.

POLB Pier T Mole Expansion

POLB is also considering the development of additional intermodal capacity on Terminal Island. The primary area of focus is the Navy Mole. The expansion onto the Mole adjacent to Pier T would create unit-train length tracks, which would be efficient and provide high capacity. However, Pier T is a single-user, on-dock facility and it must be determined how the additional capacity would be utilized. Pier T would need to generate exceptionally high volumes of intermodal cargo, or the rail yard would need to accept containers from other marine terminals.

The RTC simulation was used to model increased train volumes associated with the expanded Pier T Mole concept (at 1.1 million TEU) and found that the rail network system became constrained, causing unacceptable Level of Service throughout the system..

An additional concern, if the rail yard were to be used as a multi-user facility, is that the marine terminals that are target users are located off of Terminal Island and will therefore generate truck traffic on the Gerald Desmond Bridge and Vincent Thomas Bridge. This traffic could exceed the volumes studied under current bridge analyses.

Southern California International Gateway (SCIG)

The Port of Los Angeles has evaluated and pursued development of property immediately south of the UPRR ICTF. This development has advanced to submittal of a Harbor Development Permit with BNSF as the proposed operator. BNSF refers to the project as Southern California International Gateway (SCIG). The site, north of Pacific Coast Highway, is bounded by Dominguez Channel and Terminal Island Freeway. The facility is estimated to have capacity in excess of 1.8 million TEU provided by a densified layout with large-gauge rail mounted cranes over six tracks. SCIG is ideally located adjacent to the Alameda Corridor for train access and adjacent to both Alameda Street and Terminal Island Freeway for truck access. BNSF has proposed to make this facility as “green” (environmentally friendly) as possible.

The SCIG project was included in the REP (Project II.5) based on prior development plans, but to facilitate comparative evaluation of “Other Potential Projects,” SCIG is not included in the capacity/demand analysis; instead it is being considered on equal footing with all “Other Potential Projects” described in this section.

ICTF Expansion

UPRR is considering plans to expand their existing ICTF facility north of Sepulveda Boulevard. The planning is in the conceptual development phase. The proposed facility could have a potential throughput capacity of 3.5 million TEU (1.9 million TEU over the existing 1.6 million TEU capacity). Since the rail access to ICTF occurs north of Thenard Junction, this expansion will not impact the constrained “Texaco Slot” portion of the Port rail network.

Summary of Other Potential Projects

The rail yard capacity expansion projects proposed in the REP (excluding SCIG) will not meet the forecast demand for intermodal facilities. As shown in **Table 3a**, latent demand for direct intermodal capacity is nearly one million TEU through 2020 and increases to at least two million TEU by 2030. The latent demand through 2020 could be met by any one of the “Other Potential Projects.”

Simulation modeling shows that development of one of the “Other Potential Projects” on Terminal Island will negatively impact the Port rail network performance (unacceptable Level of Service with less than 1.5 million TEU added to the REP), and the network will not support more than one of the “Other Potential Projects” on Terminal Island (more than 1.5 million TEU added to the planned Terminal Island throughput is expected to cause unstable rail system performance).

An additional concern with the development of multi-user rail facilities on Terminal Island is that the greatest needs for intermodal rail facilities are in other areas. Therefore, a project on Terminal Island will induce truck traffic over the Gerald Desmond Bridge and Vincent Thomas Bridge, both of which are critical to the Port transportation system.

Since only one of the “Other Potential Projects” can be accommodated on Terminal Island (and then with potentially unacceptable rail network performance), SCIG, ICTF Expansion or another project off Terminal Island would be required to meet the projected intermodal demand expected by 2030. Implementation of either SCIG or the ICTF Expansion project would, by itself, approach meeting all of the demand through 2030. The near-dock facilities (e.g. SCIG and ICTF) have the advantage of accommodating cargo from any of the marine terminals that need support; they are optimally located near the Port and adjacent to the Alameda Corridor; and the site configuration allows efficient track lengths, high productivity and “green” operating systems. SCIG has the benefit of providing competitively balanced near-dock facilities to the two Class I Railroads. ICTF has the advantage of rail access upstream of the Texaco Slot bottleneck, and it also has significant support track in Dolores Yard/ICTF Support Yard.

IX. Rail Simulation Model

Dynamic simulation modeling was used to analyze mainline system performance. Rail network system performance is typically evaluated based on delay ratio (train delay divided by unimpeded running time), but to assist in interpretation of the model results, a Level of Service (LOS) grade is assigned as defined in the adjacent inset.

Level of Service (LOS)
Definition for SPB Ports Area

LOS	Delay Ratio	Delay/Traffic Description
A	0-11%	Minimal / Light Traffic
B	12-21%	Minor / Light-Moderate
C	22-29%	Moderate / Moderate
D	30-36%	High/ Heavy
E	37-42%	Significant / Unstable
F	43% +	Severe / Very Unstable

LOS of C or better is considered desirable based on experience at similar rail terminal environments and on the length of delays that were experienced by individual trains during simulation runs with those delay ratios. LOS D is undesirable and LOS E or F is considered unacceptable. Trains still reach their destination under LOS D, E or F, but delays become high with associated costs; and the system is fragile such that it cannot quickly recover from conflicts causing backups. Track outage events and maintenance will cause lasting impacts to the system performance.

The RTC Model was run with projected train volumes for each of the forecast years. These runs were similar to the previous model runs (POLB 2002/POLA 2003) except for the following:

- Pier W is not included in the planned rail yard expansions as previously modeled in 2020, although a similar Pier T Mole expansion was tested in 2030 runs herein;
- Southern California International Gateway (SCIG) is modeled as a near-dock rail yard;
- Pier B is expanded as a mini-ICTF and support yard extending north of 9th Street;
- Texaco Slot track expansion was replaced with a by-pass along the Wilmington Wye; and
- The switching operations inside of rail yards were modeled more explicitly.

Projected train volumes are indicated in **Table 5** for peak day conditions. The RTC Model was run for a four-day simulated period with each day generating the peak day train volumes.

Table 5: Peak Day Train Volumes

Train Type	2005	2010	2015	2020	2030
On-Dock Intermodal	25	42	61	96	113
Non-intermodal	25	25	25	25	25
Light Engine/Switching	30	38	40	47	55
Pier B Rail Yard	0	0	2	2	2
UP ICTF	14	14	26	26	34
SCIG	0	16	16	16	18
Shuttle Trains (Typ.)	4	10	10	10	10
Total	**98**	**145**	**180**	**222**	**257**

Findings from the RTC Model runs are similar to the previous Rail Study, except that the need for triple track to Terminal Island south of Thenard Junction (including Badger Avenue Bridge) is not critical unless one of the "Other Potential Projects" is developed on Terminal Island. The model results still indicate that Badger Bridge needs to be locked down by 2010 to maintain desirable LOS. The model supports all other rail infrastructure improvements and shows that SCIG can be supported by the Port rail network. It should be noted that the RTC Model tends to provide optimistic results.

Table 6 presents LOS results from various model runs related to train access on Terminal Island. This table is presented to illustrate the use of simulation results in determining rail network infrastructure deficiencies and solutions. Desirable conditions are achieved by conditions below the bold line and in the shaded area. **Table 6** shows the following results:

- Current train volumes – the rail network performs within desirable LOS, even with Badger Bridge lifting for vessel passage.
- 2010 train volumes – LOS is undesirable unless Badger Bridge is raised for emergencies only.
- 2015 train volumes – LOS is undesirable unless an additional track is provided from W.Thenard to Terminal Island. The previous Rail Study had indicated that extension of CTC could postpone this project, but current modeling indicates that congestion around CP Mole creates a need for the additional mainline to Terminal Island.
- 2020 train volumes – even with the additional mainline to Terminal Island, the LOS is undesirable, but has not reached unacceptable.
- Development of one of the "Other Potential Projects" on Terminal Island will result in LOS in the unacceptable range when operated in addition to SCIG. However, when SCIG switching impacts are reduced, then LOS improves, but is still in the unacceptable range.

- **Table 6: Rail Network System Performance Results**

	2005	2010	2015	2020	Other TI
Scenario *(Badger Bridge Up Time)*	**LOS *(Delay Ratio)***				
1. Bridge Lifts *(280 minutes/day)*	**C** ***(24%)***	***D****	**E** ***(38%)***		
2. Bridge Lifts for Emergency Only *(0 minutes/day)*		**C** ***(26%)***	**D** ***(34%)***	**D** ***(36%)***	
3. Scenario 2 plus Added Mainline to TI *(0 minutes/day)*			**C** ***(29%)***	**D** ***(35%)***	
4. Other Potential 1.1 MTEU Project on TI *(0 minutes/day)*					**F (44%)**
5. Scenario 4 plus reduced SCIG switching *(0 minutes/day)*					**E (37%)**
Conclusion – Badger Bridge reqmt for preferable LOS	***bridge lifts okay***	***no bridge lifts***	***triple track bridge***	***undesirable***	***unacceptable w/TI 1.1M***

*-Use previous Rail Study run data for this Bridge Lift case.
TI – indicates Terminal Island

The 2020 model results did not indicate LOS improvement with the additional track from W.Thenard to Terminal Island (including third track on Badger Avenue Bridge), which is likely due to an unidentified upstream bottleneck; it is intuitive to expect that the triple track to Terminal Island would provide significant benefits to the Port rail network performance by the 2015 to 2020 timeframe.

Terminal Island Line

The most important factors affecting Terminal Island performance are the mainline from CP W.Thenard to across Badger Bridge, and the configuration of main track crossovers and terminal leads at CP Mole. Improvements will be required for each of these to achieve acceptable rail system performance as intermodal cargo volumes increase to forecast 2015 volumes.

Allowing Badger Bridge to lift for vessel passage causes performance to decline significantly, compared with a locked-down bridge, even with the construction of second leads at terminals and some crossover reconfiguration. In 2010, lifting the bridge increases the delay ratio on Terminal Island by 35 percent.

Even with all the improvements shown in the Rail Enhancement Program list, the addition of another major rail facility, such as Pier T Mole expansion or a multi-user rail yard on the Los Angeles side of Terminal Island (“Other Potential Projects”), is shown by 2030 runs to result in a 73 percent increase in relative delays. The Level of Service under that condition is considered unacceptable.

Long Beach Line

In general, the Long Beach Line performs well through 2010. By 2015, Pier J, Pier G and Middle Harbor Terminal are significantly expanded and Pier B is providing support. The simulations indicated a need for the following improvements:

- Dual leads connecting the G/J support yard and Pier J;
- A new lead on the north side of the Pier J working tracks;
- Receiving tracks at Pier G should fully chamber unit trains off the mainline; and
- An additional track at CP Ocean Blvd from Pier F to Pier B yards.

West Basin Line

Improvements proposed to be made by 2015 improve West Basin operations, especially the lock-down of Badger Bridge. Because trains move more efficiently to and from Terminal Island, delays are less for West Basin trains. However, there may be some problems in comparing West Basin delays with those of other lines, because of the high number of PHL switch jobs competing for space at the PHL yard and on its leads. Half of all delay is incurred by PHL jobs. There are nine jobs per day using the PHL yard and leads, experiencing an average of 3.3 total hours of delay per day. There are 8 expedited trains per day, incurring only an average of one hour delay per day.

All of the West Basin planned improvements are necessary, including a second north leg of the Wye at CP Anaheim.

Grade Crossings

The RTC Model collects data on duration of roadway blockages by trains. Individual grade crossing blockage times are presented in the main report. In general, any at-grade crossing (traffic must stop when a train is present) on mainlines of the Port rail network should be grade separated or closed. The following at-grade crossings are of particular interest:

- Edison Avenue crosses the mainlines to Port of Long Beach and will experience increasing blockage times as intermodal cargo volumes grow. The road would be crossing the expanded Pier B rail yard. This crossing should be closed immediately, and is one of the REP projects.
- 9th Street crosses the mainlines to Port of Long Beach and will experience increasing blockage times as intermodal cargo volumes grow. This road would be displaced by the expanded Pier B rail yard. 9th Street should be closed and traffic rerouted onto Pier B Street, which should provide connections to Anaheim Road, the SR-47 freeway (requires new access ramps) and the SR-710 freeway.
- Rail access to Port of Los Angeles-West Basin crosses several roads in the area of Neptune Avenue and Fries Avenue. A grade separation is proposed to provide free flowing traffic over the rail in this area.
- Henry Ford Avenue in the vicinity of Dominguez Channel crosses two tracks: the south leg of the Anaheim Wye, and the Terminal Island Lead Track (TILT) on the east side of Dominguez Channel. These tracks are ancillary to the Alameda Corridor mainlines, which are grade separated on elevated structures in this area. Therefore, the blockage times caused by the lesser used at-grade tracks are not excessive. The crossing protection and traffic signal systems need to be upgraded at the Anaheim Wye.
- Reeves Avenue crossing at the Pier 400 lead tracks has significant impact on rail operations. The Ports of Long Beach and Los Angeles have a contract with PHL with a stipulation that trains will not occupy an at-grade crossing for more than 10 minutes including stopping and switching (compliant with CPUC requirements). This causes train arrivals at Pier 400 to be performed by shoving trains into the yard. This allows rail cars that do not fit on the first landing track to be disconnected and quickly pulled back to clear Reeves crossing. The remaining rail cars can then be shoved onto a second landing track after roadway traffic has cleared.

The maneuver to turn the train to enable the shove into Pier 400 (rather than pulling the train) typically involves pulling the train onto the Long Beach Lead, then up the Manual Siding; the train then reverses direction and is shoved down TILT to Pier 400. This maneuver is highly obstructive to the Port rail network and will create unacceptable Level of Service and excessive train delays by as soon as 2010. The closure of Reeves Avenue crossing would result in acceptable LOS for the rail system, along with safer operations.

X. Rail Enhancement Program

The rail yard expansion projects and rail infrastructure improvement projects that have been proposed and approved by the Ports are now developed into a Rail Enhancement Program (REP) with schedule and cost estimate for each project.

Meetings with industry stakeholders (marine terminal operators, shipping lines, and railroads) have concluded that the new rail infrastructure in the REP is needed. The industry stakeholders have requested that the REP projects be implemented to support their operations.

Pier B Rail Yard (Projects III.1 and III.2) is vital to rail operations in the Port of Long Beach and the entire SPB rail network system. The Pier B Yard currently provides storage tracks; the Phase I expansion will greatly improve its ability to perform this function, which supports many other POLB rail facilities. Phase II of the project is important because it develops unit-train length holding tracks, which can serve as a buffer for trains arriving off the Alameda Corridor or waiting to leave POLB. This buffer area will ease congestion on the Corridor as well as at on-dock rail yards. The Pier B Rail Yard-Phase II has also been evaluated for its ability to serve as a near-dock facility and this feature is recommended as beneficial to POLB marine terminals.

The rail yard expansion projects are listed in **Table 7** and rail infrastructure improvement projects are listed in **Table 8**. The projects locations are shown on **Figure 4**.

All of these REP projects are compiled together using the chart shown in **Figure 5**. The chart indicates the type of project (rail yard or rail network infrastructure); the responsible agency (Sponsor); development costs (in 2005 dollars); and development schedule. The development schedule is broken into three phases consisting of: 1) planning/environmental, 2) design/bid and 3) construction. Note that portions of the design may be performed during the planning/environmental period. Costs are also accumulated for all projects on an annual basis at the bottom of the schedule.

Rail Yard Projects

The Study proposes an ambitious program of rail yard capacity improvements including expansion of existing yards and development of new facilities. The projects are listed in **Table 7** and project locations are shown on **Figure 4**.

Table 7: List of On-Dock Rail Yard Projects

	Rail Yard Project	Sponsor	Development Cost ($ millions)
	Phase I Short-term (by end of 2007)		
	No Rail Yard Projects		
	Phase II Near-term (by end of 2010)		
II. 1	Pier A On-Dock Rail Yard Expansion to Carrack	POLB	19.6
II. 3	Pier S On-Dock Rail Yard	POLB	34.3
II. 5	New Near-Dock-South of Sepulveda (potential)	POLA	Na
II. 9	Pier G-New North Working Yard	POLB	14.1
II. 10	Pier G-South Working Yard Rehabilitation	POLB	40.7
II. 13	West Basin East-New ICTF (Phase I)	POLA	45.4
	Phase III Medium-term (by end of 2015)		
III. 5	Navy Mole Road Storage Rail Yard	POLB	10.0
III. 8	Middle Harbor Terminal Rail Yard	POLB	68.9
III. 9	Pier J On-Dock Rail Yard Reconfiguration	POLB	100.0
III. 10	Pier 400 On-Dock Rail Yard Expansion (Phase I)	POLA	33.4
III. 11	Pier 300 On-Dock Rail Yard Expansion	POLA	23.4
III. 12	Terminal Island ICTF Rail Yard Expansion	POLA	18.9
III. 13	West Basin ICTF Rail Yard Expansion (Phase I)	POLA	6.2
	Phase IV Long-term (beyond 2015)		
IV. 3	Pier A On-Dock Rail Yard East of Carrack	POLB	31.4
IV. 4	Pier 400 On-Dock Rail Yard Expansion (Phase II)	POLA	16.3
IV. 5	West Basin ICTF Rail Yard Expansion (Phase II)	POLA	12.5
IV. 6	West Basin East-ICTF Expansion (Phase II)	POLA	7.8
		Subtotal POLA Cost (millions)	$163.9
		Subtotal POLB Cost (millions)	$318.9
		Total Potential Rail Yard Cost (millions)	$482.8

Infrastructure Projects

Rail network improvement projects identified and validated through the RTC simulation efforts are listed in **Table 8** and project locations are shown on **Figure 4**.

Table 8: List of Rail Infrastructure Projects (Outside Marine Terminals)

	Rail Infrastructure Project	Sponsor	Development Cost ($ millions)
	Phase I Short-term (by end of 2007)		
I. 1	Closure of Edison Avenue Grade Crossing	POLB	0.3
I. 2	Expanded Control Points to POLB/POLA	ACTA	4.9
I. 3	Thenard Track Connection at Alameda Street/K-Pac	ACTA	4.6
	Phase II Near-term (by end of 2010)		
II. 2	Terminal Island Wye Track Realignment	POLB	3.6
II. 4	Pier B Street Realignment	POLB	12.6
II. 6	Constrain Badger Bridge Lifts	POLB/LA	1.0
II. 7	Track Realignment at Ocean Boulevard/ Harbor Scenic Drive	POLB	20.0
II. 8	Pier F Support Yard	POLB	3.4
II. 11	Double Track Access from Pier G to Pier J	POLB	1.7
II. 12	West Basin Rail Access Improvements	POLA	150.0
	Phase III Medium-term (by end of 2015)		
III. 1	Pier B Rail Yard Expansion (Phase I)	POLB	85.4
III. 2	Pier B Rail Yard Expansion (Phase II)	POLB	159.9
III. 3	Grade Separation for Reeves Crossing	POLB/LA	60.0
III. 4	Closure of Reeves At-grade Crossing	POLB/LA	1.0
III. 6	Pier 400 Second Lead Track	POLA	7.7
III. 7	Reconfiguration at CP Mole	POLB/LA	20.0
	Phase IV Long-term (beyond 2015)		
IV. 1	Triple Track Badger Bridge	ACTA	91.0
IV. 2	Triple Track South of Thenard Jct.	ACTA	16.5
		Subtotal ACTA Cost (millions)	$117.0
		Subtotal POLA Cost (millions)	$157.7
		Subtotal POLB Cost (millions)	$286.8
		Subtotal Shared POLB/LA Cost (millions)	$82.0
		Total Potential Infrastructure Cost (millions)	**$643.6**

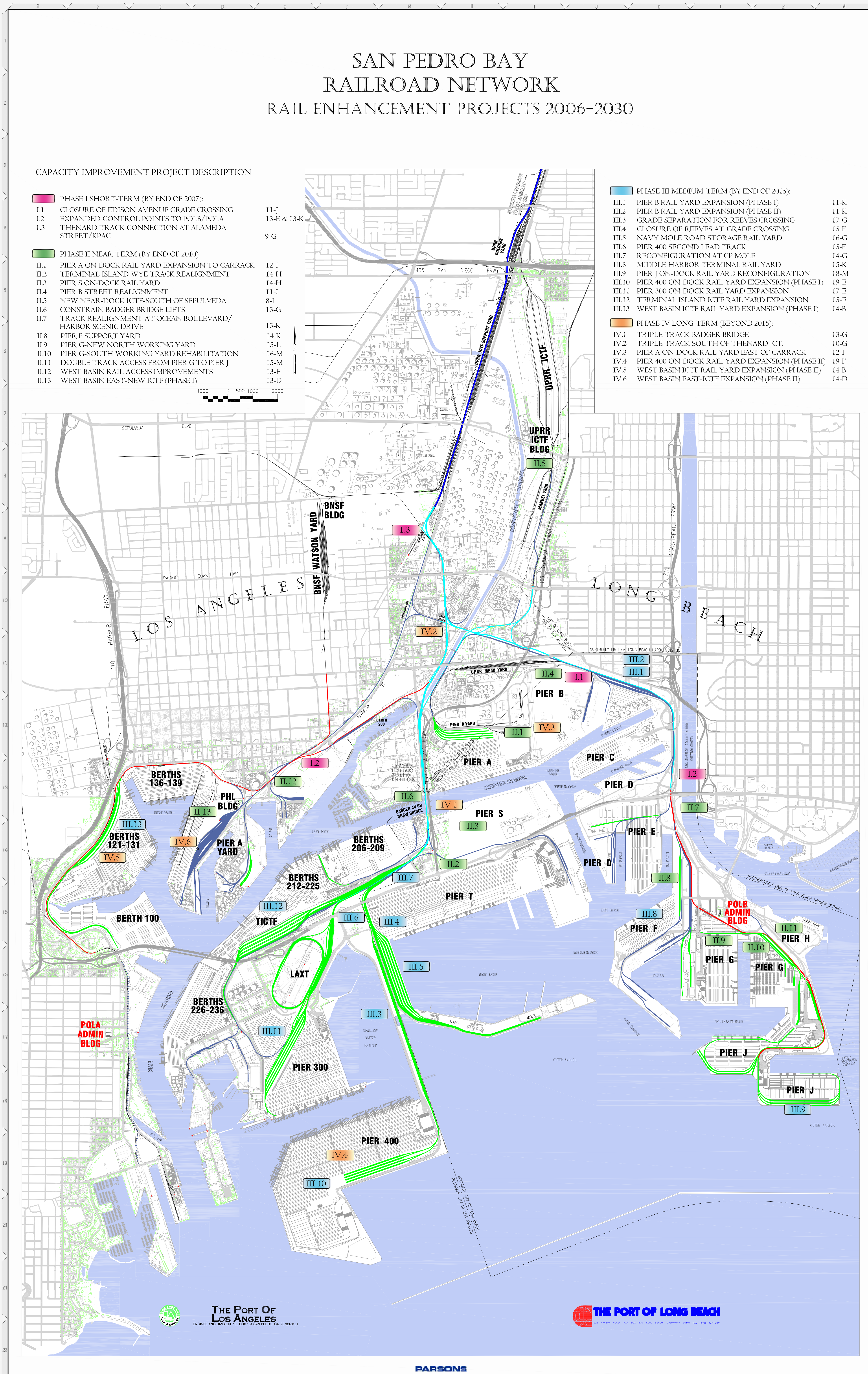
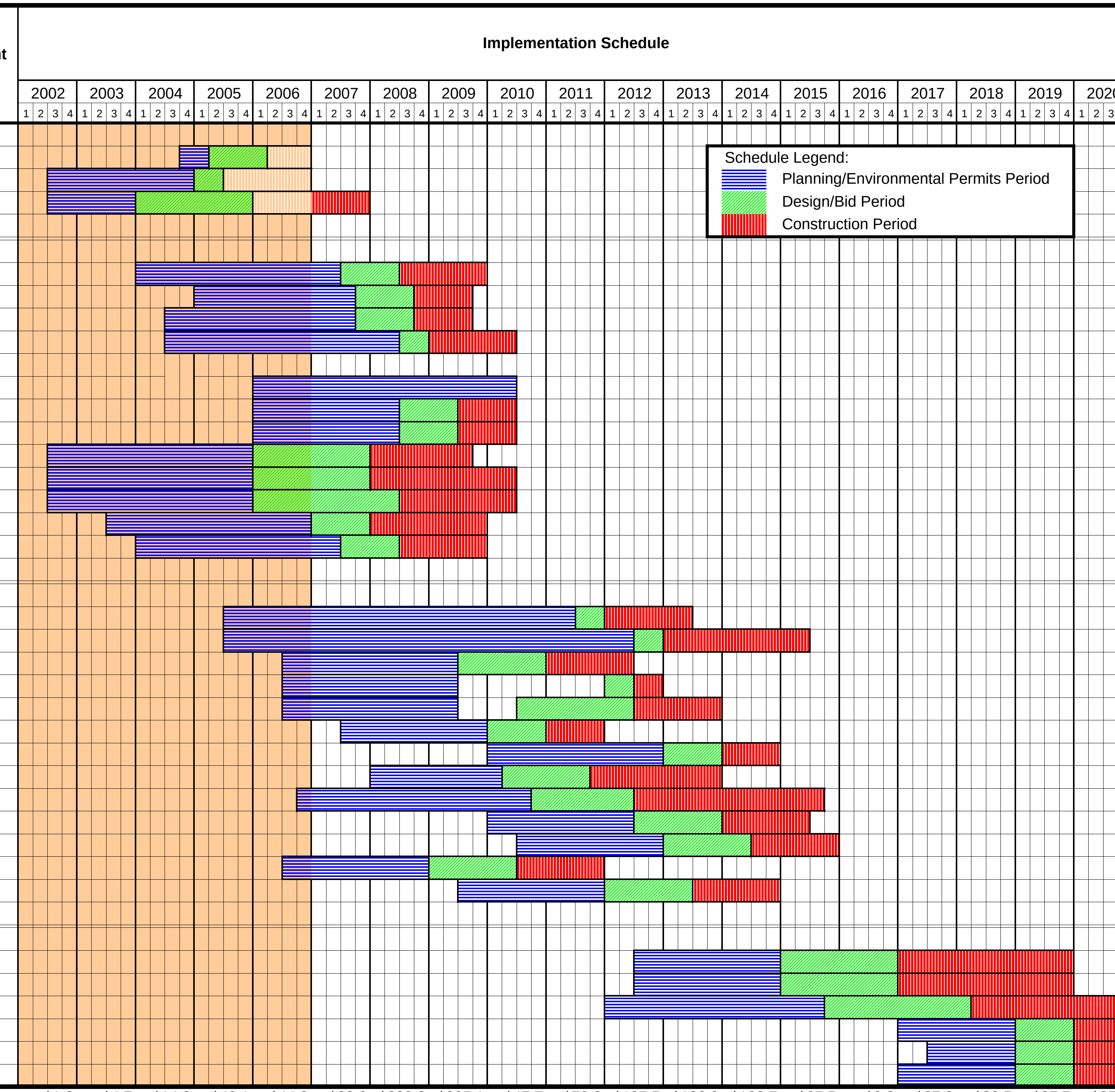


Figure 4 - Project Location Map

San Pedro Bay Ports
Potential Rail Enhancement Projects

	Capacity Improvement Project Description	On-Dock Projects	Infrastructure Projects	Sponsor	Development Costs ($ Millions)
	Phase I Short-term (by end of 2007)				
I. 1	Closure of Edison Avenue Grade Crossing		✓	POLB	0.3
I. 2	Expanded Control Points to POLB/POLA		✓	ACTA	4.9
I. 3	Thenard Track Connection at Alameda Street/K-Pac		✓	ACTA	4.6
	Phase II Near-term (by end of 2010)				
II. 1	Pier A On-Dock Rail Yard Expansion to Carrack	✓		POLB	19.6
II. 2	Terminal Island Wye Track Realignment		✓	POLB	3.6
II. 3	Pier S On-Dock Rail Yard	✓		POLB	34.3
II. 4	Pier B Street Realignment		✓	POLB	12.6
II. 5	New Near-Dock ICTF-South of Sepulveda	✓		POLA	
II. 6	Constrain Badger Bridge Lifts		✓	POLB/LA	1.0
II. 7	Track Realignment at Ocean Boulevard/ Harbor Scenic Drive		✓	POLB	20.0
II. 8	Pier F Support Yard		✓	POLB	3.4
II. 9	Pier G-New North Working Yard	✓		POLB	14.1
II. 10	Pier G-South Working Yard Rehabilitation	✓		POLB	40.7
II. 11	Double Track Access from Pier G to Pier J		✓	POLB	1.7
II. 12	West Basin Rail Access Improvements		✓	POLA	150.0
II. 13	West Basin East-New ICTF (Phase I)	✓		POLA	45.4
	Phase III Medium-term (by end of 2015)				
III. 1	Pier B Rail Yard Expansion (Phase I)		✓	POLB	85.4
III. 2	Pier B Rail Yard Expansion (Phase II)		✓	POLB	159.9
III. 3	Grade Separation for Reeves Crossing		✓	POLB/LA	60.0
III. 4	Closure of Reeves At-grade Crossing		✓	POLB/LA	1.0
III. 5	Navy Mole Road Storage Rail Yard	✓		POLB	10.0
III. 6	Pier 400 Second Lead Track		✓	POLA	7.7
III. 7	Reconfiguration at CP Mole		✓	POLB/LA	20.0
III. 8	Middle Harbor Terminal Rail Yard	✓		POLB	68.9
III. 9	Pier J On-Dock Rail Yard Reconfiguration	✓		POLB	100.0
III. 10	Pier 400 On-Dock Rail Yard Expansion (Phase I)	✓		POLA	33.4
III. 11	Pier 300 On-Dock Rail Yard Expansion	✓		POLA	23.4
III. 12	Terminal Island ICTF Rail Yard Expansion	✓		POLA	18.9
III. 13	West Basin ICTF Rail Yard Expansion (Phase I)	✓		POLA	6.2
	Phase IV Long-term (beyond 2015)				
IV. 1	Triple Track Badger Bridge		✓	ACTA	91.0
IV. 2	Triple Track South of Thenard Jct.		✓	ACTA	16.5
IV. 3	Pier A On-Dock Rail Yard East of Carrack	✓		POLB	31.4
IV. 4	Pier 400 On-Dock Rail Yard Expansion (Phase II)	✓		POLA	16.3
IV. 5	West Basin ICTF Rail Yard Expansion (Phase II)	✓		POLA	12.5
IV. 6	West Basin East-ICTF Expansion (Phase II)	✓		POLA	7.8



Total Annual Costs (millions) -->

2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
$1.2	$4.7	$14.3	$49.1	$44.2	$82.6	$220.3	$205.1	$47.7	$79.3	$135.5	$126.0	$108.7	$65.5	$9.8	$27.3	$32.5	$37.7	$35.0

	All Projects	On-dock Yards	Infrastructure
Subtotal ACTA Cost (millions)	$117.0	$0.0	$117.0
Subtotal POLA Cost (millions)	$321.6	$163.9	$157.7
Subtotal POLB Cost (millions)	$605.7	$318.9	$286.8
Subtotal Shared POLB/LA Cost (millions)	$82.0	$0.0	$82.0
Total Potential Rail Enhancement Program Cost (millions)	**$1,126.4**	**$482.8**	**$643.6**

Notes:

[1] Development costs are in 2005 dollars. Costs include administration, design/construction management, anticipated property acquisitions and construction. Construction costs include known buildings, facilities, utilities, sitework and hazmat remediations

[2] Construction costs are based on Class C estimates and include 25% contingency for unforseen requirements. Administrative costs are estimated at 15% of construction costs to cover agency administraction and environmental permitting. Design and CM are est

[3] Schedule estimate includes 6 months for project definition/conceptual engineering plus at least 24 months for EIR process, followed by property acquisition and hazmat remediation, as part of "Planning". Some design effort may occur during the "Planning"

Figure 5 - Rail Enhancement Program Chart **December 2006**

XI. Conclusions

Purpose

This Rail Study provides an update to the *Rail Master Planning Study* (POLB 2002) and *Rail Capacity Analysis* (POLA 2003). The Study identifies all rail related issues, including mainline track, storage capacities, operations and systems, and substantiates the actions required to provide acceptable levels of service for trains in 2005, 2010, 2015, 2020 and 2030. The study provides a Port Rail Enhancement Program (REP) that identifies necessary improvements and provides a phased implementation plan. This study was the first of the proposed 5 year updates, as recommended by the 2002 *Rail Master Planning Study* to incorporate revised cargo forecast, updated terminal plans and consider current operating conditions.

Benefits

As a measure of the benefits of on-dock rail, consider the hypothetical situation where all of the REP projects are built and operating today: the level of on-dock throughput would be nearly double that of existing and would remove nearly 6,000 trucks a day from the local roadways. As cargo volumes increase, the benefits of on-dock rail will increase as well. Given 2030 cargo forecasts and full development of the REP, on-dock rail would remove nearly 29,000 truck trips daily. Since there is currently no viable opportunity to accommodate the forecast cargo volumes elsewhere on the West Coast, the no action scenario would result in extensive truck trips over long distances seeking out available locations for intermodal capacity. This would add millions of truck-miles to our local freeway system each day.

Capacity & Demand

The San Pedro Bay Ports of Long Beach and Los Angeles will need to rely on their on-dock and near-dock facility plans to meet demand for intermodal capacity. Beginning in 2010, the current plans for on-dock rail yard expansion will not meet the projected demand. Additional capacity will be required and the Ports are evaluating other potential rail yard projects.

Potential near-dock expansion projects (e.g. SCIG or ICTF) appear to provide good opportunities for developing rail yard capacity to meet the projected demand. These facilities have ready rail access, efficient layout opportunities, good truck access and are committed to be "green." Other potential rail yard development projects on Terminal Island (beyond the REP projects) are shown by simulation to increase train delays on the entire Port rail network.

Off-dock rail yards that handle transload cargo (10 percent of total Port throughput) and domestic cargo will run out of capacity by the 2010-2015 timeframe, depending on domestic cargo growth rates (0% growth will leave capacity until 2015; 3% growth will take all capacity by 2010). To meet this latent demand, new off-dock rail yards will need to be developed, and the most likely location for the new facilities is in the Inland Empire or further inland. Another potential for accommodating some of the transload cargo is to expand near-dock facilities and allow these to handle larger containers from warehouses in the Port vicinity.

Rail Network Performance

Rail simulation modeling indicates that all rail infrastructure projects in the Rail Enhancement Program are needed to provide a rail network that performs without unacceptable train delays and gridlock. This investment will accommodate projected train traffic through 2030. These projects will require significant investment, but the benefit to cost ratio appears favorable.

It should be noted that if one Other Potential Project (a rail yard not included in the REP) is developed on Terminal Island, then simulation modeling indicates that the rail system performance will degrade to an unacceptable Level of Service. Based on simulation results, any additional Terminal Island development (beyond the one Other Potential Project) will cause such congestion and train delays as to cause the rail network system to fail.

Recent Operational Changes

Efforts of the *Truck Reduction Study* (including this Rail Study) and the Rail Action Planning Committee have identified key issues affecting goods movement and resulted in operational changes, including:

- Rail crews report at SPB
- Railroad dispatchers stationed at PHL
- Standardized rail data maintained between terminals/railroads
- Increased railroad work force and equipment
- Longer trains to/from SPB
- Train fueling within SPB
- New PHL agreement

The Rail Action Planning Committee was created in January 2006 with the goal of maximizing utilization of existing rail infrastructure. The Rail Action Planning Committee includes representation from POLB, POLA, marine terminal operators, shipping lines, railroads and ACTA. The following strategies are proposed to maximize on-dock rail utilization:

- Utilize LAXT tracks
- Maximize train lengths
- Improve switching efficiencies
- Improve locomotive availability
- Reduce marine terminal operational constraints
- Provide in-ground air system for trains
- Improve container stowage on ships
- Provide better system for planning and coordination
- Improve railcar utilization and Customs holds

The Rail Action Committee is also in the implementation stage of a project known as the San Pedro Bay Ports Rail Business Exchange. This project has the goal of improving Port rail operations by facilitating communications, maximizing intermodal cargo velocity, streamlining administrative processes and providing visibility about how cargo is moving and fits into other traffic.

The SPB Rail Business Exchange is an internet based communication/planning tool with features including:

- Input vessel rotations and train schedules for advanced planning
- Input vessel manifest/stowage plan 72 hrs prior to arrival for tactical planning
- Provide eastbound train lineup, pull times and departure slots
- Provide westbound train consist and estimated time of arrival for vessel planning
- Make Switch Job plans available to railroads and marine terminals
- Optimize daily conference call with each railroad customer
- Coordinate Plan to avoid asset and resource congestion
- Provide message board to post changes in status and otherwise document events

Non-traditional Rail Concepts

Non-traditional rail concepts involve uses of trains that are not currently employed. These include the following concepts.

Inland Shuttle Train: Defined as rail transport to an "inland port" for distribution of local cargo. The inland port concept may prove beneficial due to the level of highway congestion and the potential value of truck traffic reductions as a mitigation measure. However, this concept will increase the demand on Port rail yard capacity as well as mainline rail capacity.

Inland Block-Swap: The concept of an inland rail yard to sort trains can provide several rail operating improvements that coincide with the recommendations of this Study. Features of this concept and associated benefits are described as follows:

- Provide the ability to build multi-destination trains by blocks at each on-dock rail yard. Trains can then be block-swapped at the inland yard to create single destination trains. This will increase the potential volume of on-dock cargo by alleviating the challenges with building long destination trains.
- Provide the ability to block-swap westbound trains at the inland yard to create Port-terminal specific trains. This will reduce inter-terminal switching movements at the Port.
- Provide dedicated regional shuttle engines that handle the train movements between the inland yard and the Port. These locomotives will be fueled for round trip, readily manage crew changes, and have the ability to drop a westbound train and pick-up an eastbound train without turning the locomotive (have both ends functional so locomotive can simply be reversed). This will significantly reduce the light engine traffic moving around the Port by eliminating the need to turn engines, reach crew change points and transit to engine services facilities. This concept could also facilitate application of green technologies to locomotives in the sensitive Southern California Air Basin.

The Ports should work closely with the Railroads to define and pursue these non-traditional concepts as well as near-dock rail yard capacity enhancements. This relationship should be expanded to include other area government agencies for a critical evaluation of regional mainline capacity.

XII. Summary

The cargo that is forecast to arrive at the San Pedro Bay Ports will create the need for significant improvements in terminal throughput capabilities. The increased cargo volumes will also require careful evaluation of the landside transportation system. The 2001 *Port of Long Beach/Los Angeles Transportation Study* defined highway congestion that would result from the increased cargo volumes and recommended that at least 30 percent of the cargo should be moved by on-dock rail. This "Rail Study Update" defines the rail yard, mainline, systems and operations improvements necessary to achieve and exceed this goal.

The goal of this "Rail Study Update" is to maximize capacity and utilization of on-dock rail, and to evaluate the rail system performance and recommend enhancements to Port infrastructure that are necessary to meet forecast cargo demands. This Study incorporates recent market conditions, revised Port development plans, and modified cargo forecast based on the latest information available in 2005.

The key points of this Study are as follows:

- Rail yards are conceptualized for each of the proposed terminals at the San Pedro Bay Ports of Long Beach and Los Angeles (SPB). These rail yards have the combined throughput capacity to handle at least 30 percent of the Port cargo during the forecast period 2015 to 2030. Rail concepts will be refined through the environmental process, tenant negotiations and engineering design.
- Even after maximizing the potential on-dock rail yards proposed in the REP, the **demand for intermodal rail service creates a shortfall in rail yard capacity by at least 2010**.
- In addition to maximizing on-dock rail, it is recommended that rail yard capacity be developed at near-dock facilities in the vicinity of the Alameda Corridor and south of the I-405 freeway.
- If additional on-dock or near-dock capacity is proposed on Terminal Island (beyond that already recommended by the REP), this capacity should not exceed 1.5 million TEU to avoid potentially severe train delays or gridlock to the entire SPB Port rail network.
- The train volumes generated by on-dock rail yards are forecast to exceed 100 trains per day. Total train volumes on the Port rail network will exceed 250 trains per day and those on the Alameda Corridor will approach 200 trains per day by the year 2030. Alameda Corridor traffic is averaging 50 trains per day in 2005.
- Various mainline, system and operational improvements will be required within SPB to accommodate the projected train volumes. These required projects are compiled into a phased Rail Enhancement Program (REP). The total cost of this program is over one billion dollars split nearly equally between rail yard projects and rail network infrastructure.
- Even with REP infrastructure improvements, the rail network will suffer increasing train delays that will increase operating costs and potentially disrupt cargo flow.

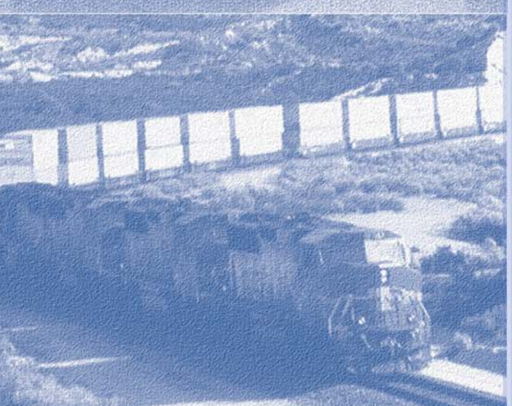
NOTABLE CONCLUSIONS

1. Implementation of the Rail Enhancement Plan (REP) is critical to support intermodal goods movement at the Port.

2. Planned rail yard expansions are not big enough to handle the cargo volumes that are forecast for 2010 and beyond. More rail yard capacity is needed and potential near-dock rail yards have beneficial features to complement the planned on-dock facilities.

3. Even with all planned rail network infrastructure improvements, cargo volumes forecast for 2020 and beyond will cause increased train delays and operating costs and could constrain intermodal throughput.

4. This Study evaluated the San Pedro Bay rail network and the Alameda Corridor to downtown Los Angeles. The Study did not evaluate the inland rail system beyond downtown Los Angeles, which could potentially present additional bottlenecks to Port intermodal throughput.



THE PORT OF LONG BEACH

THE PORT OF LOS ANGELES

PARSONS

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Intermodal Logistics & Ports of Los Angeles/Port of Long Beach Rail Infrastructure

Port of Los Angeles Public Rail Workshop

October 22, 2009

POLA Rail Workshop Introduction

Welcome

- **Welcome and Introductions**

- **Agenda**
  - Powerpoint Presentation: Rail Overview
    - Presented by Kerry Cartwright, *Director Goods Movement*
  - Q & A Discussion
    - Moderated by Ralph Appy, Ph.D., *Director Environmental Management*

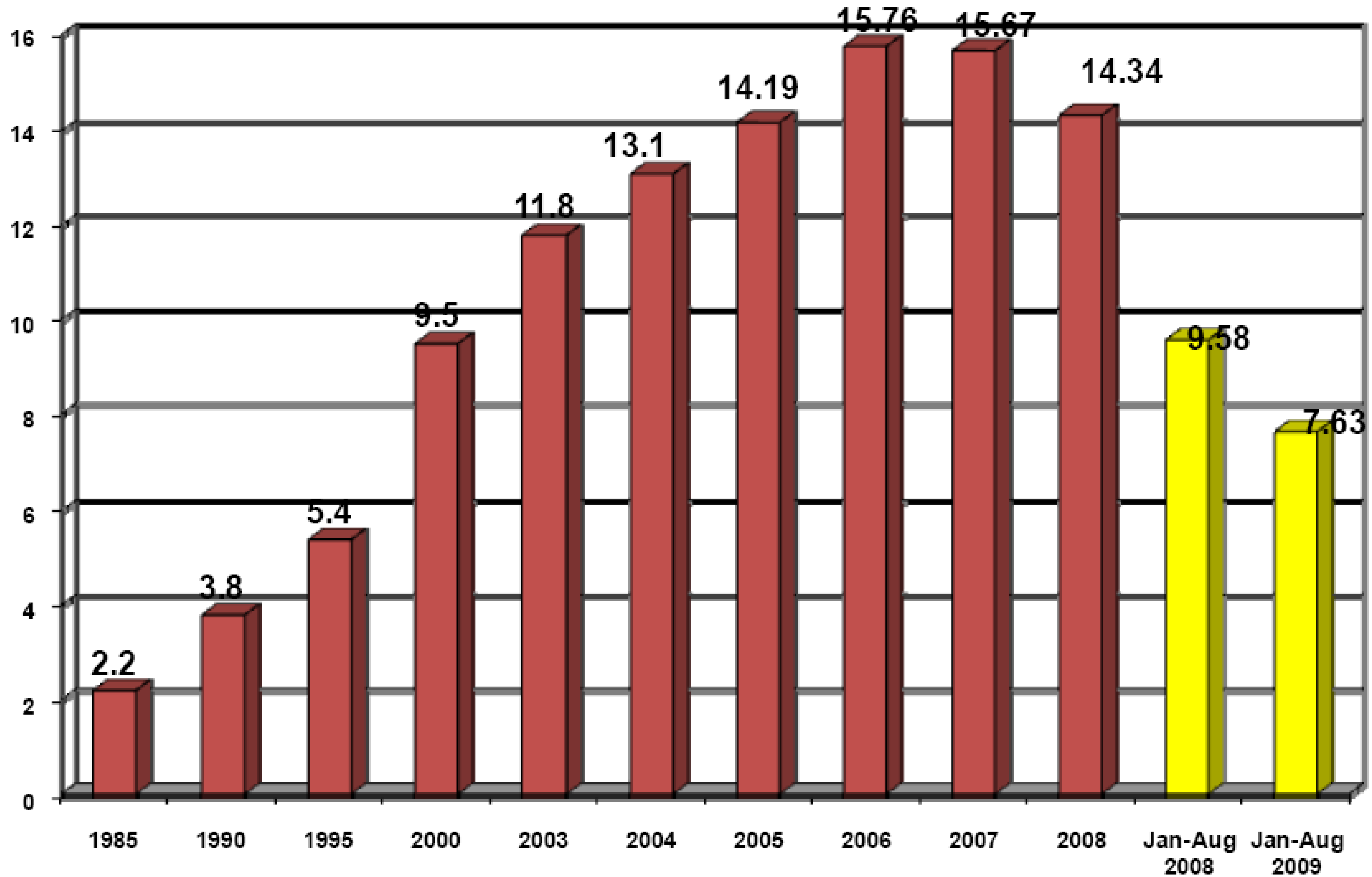
Introduction to Cargo and Rail Movement at the Ports

POLA Rail Workshop Introduction

San Pedro Bay Ports (SPBP) Complex

SPBP Cargo Throughput

POLA/POLB Container Volumes (millions TEUs)



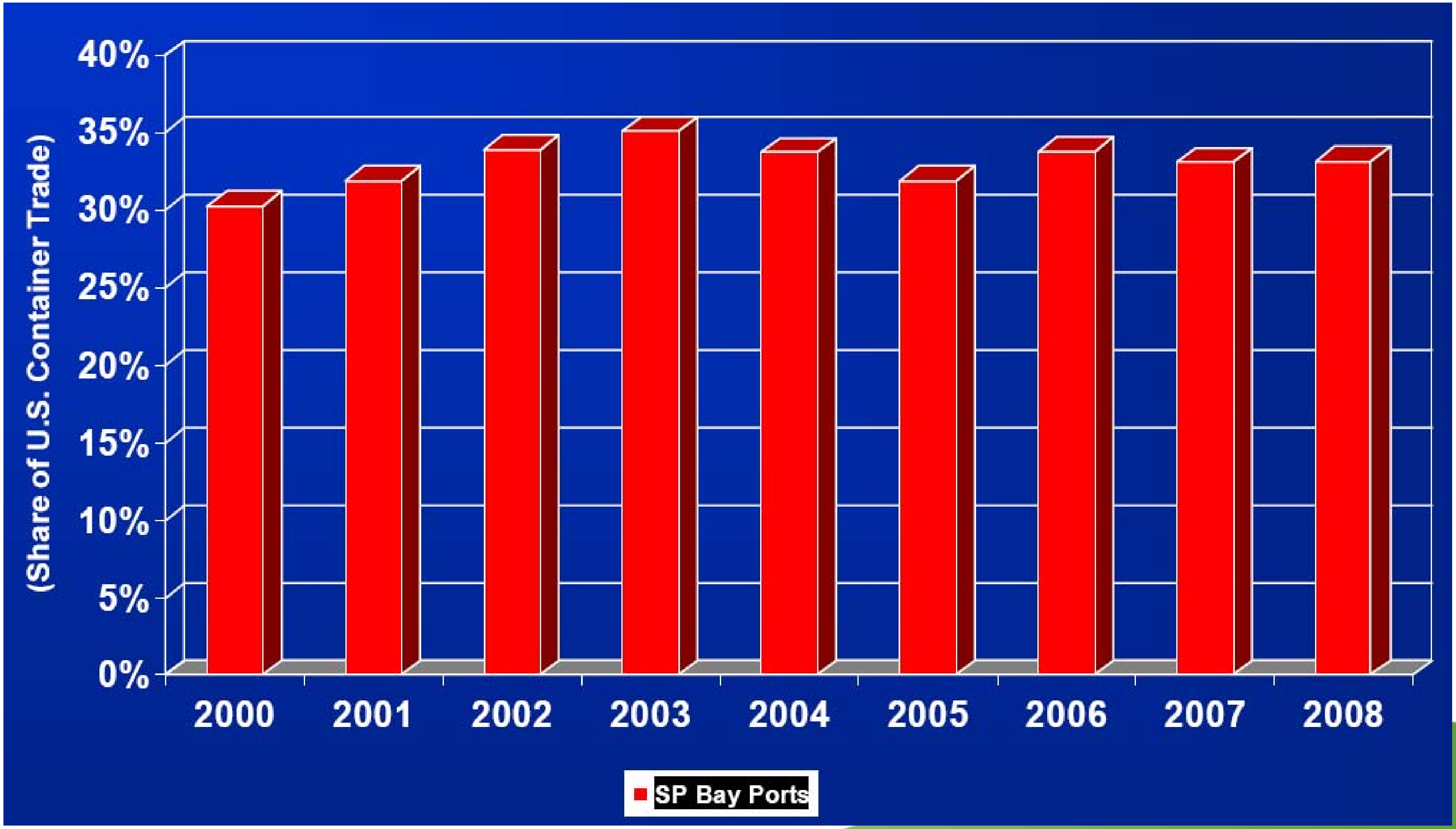
SPBP Cargo Throughput

U.S. West Coast Market Share

	2009 1st Quarter	2008 1st Quarter	Change
Los Angeles	35.45%	34.03%	+1.42%
Long Beach	25.33%	28.49%	-3.16%
Oakland	10.10%	9.74%	+0.35%
Vancouver	10.67%	10.04%	+0.63%
Tacoma	8.80%	8.17%	+0.63%
Seattle	7.64%	7.93%	-0.29%
Portland	1.06%	1.21%	-0.15%
Prince Rupert	0.95%	0.39%	+0.57%
Total	100.00%	100.00%	

SPBP Cargo Throughput

POLA/POLB Market Share



Cargo Movement

Rail 101: Definitions

- **Local Cargo:** cargo shipped in marine containers and trucked to local destination for consumption in so./mid CA area and parts of NV & AZ.

- **Intermodal Cargo:** Intermodal is the conveyance of freight by more than one carrier or mode of transportation in a single journey. Often meant to mean non-local cargo

  - ***Direct Intermodal*****:** cargo shipped in marine containers moved via on-dock & off-dock rail accounted for in cargo forecasts

  - ***Transloaded Intermodal***: cargo shipped in marine containers then transferred to domestic (53') containers at transload facilities, then trucked to railyard

- **Mode Split**: Breakdown of cargo moving by mode (rail or truck) and between On-dock vs. Off-dock (includes near-dock)

Cargo Movement

Rail 101: Definitions

- **Local Cargo** Moves by Truck only
- **Intermodal Cargo:** Moves by both truck and rail depending on destination and transloading
- **Drayage:** Commonly used to mean the transportation of containerized cargo by specialized trucking companies between ocean ports or rail ramps and shipping docks in Intermodal freight transport

Cargo Movement

Rail 101: Definitions

- **On-Dock Rail:** Railyards located within the marine cargo terminal at the Port. Containers are moved from the backlands to the railyard via terminal equipment without movement through the gate or on local roadways. Typically, trains consist of a single block of rail cars all headed for the same destination.

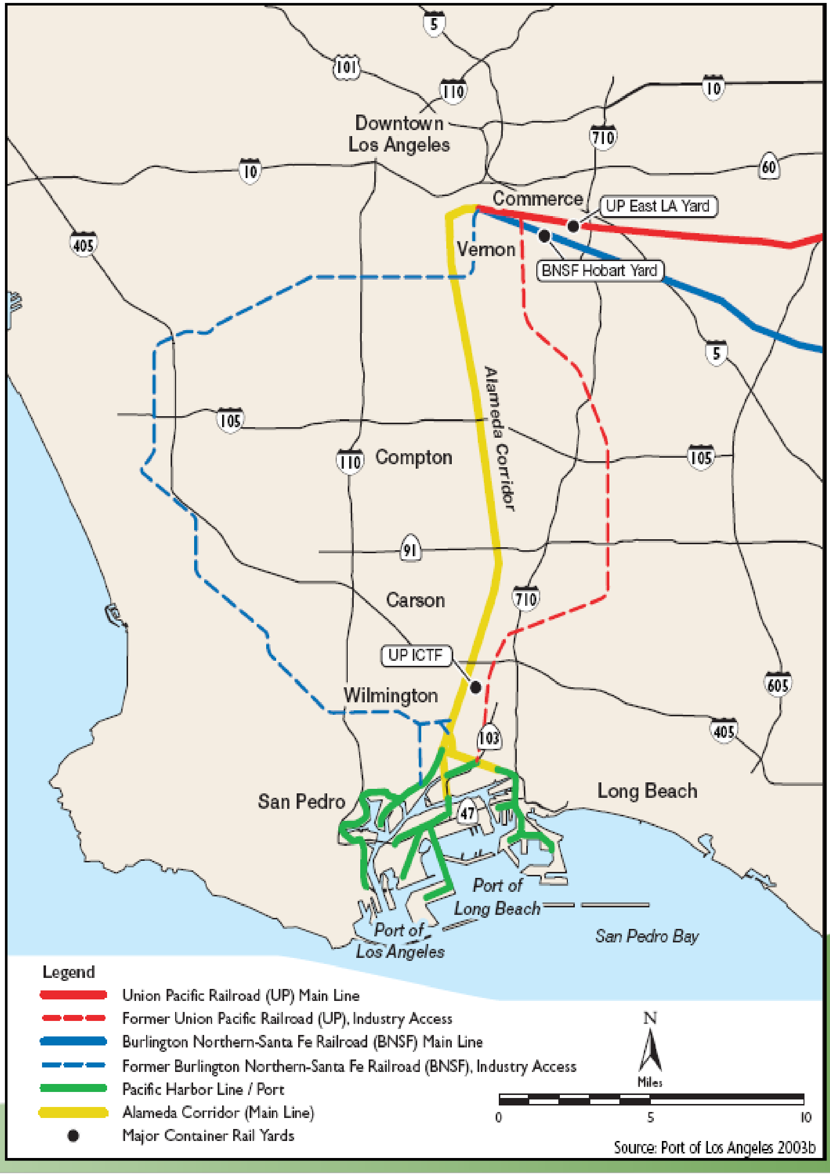
- **Off-Dock Rail: Railyards located outside the marine terminal sometimes split into the following 2 categories:**
  - **Near Dock:** railyard located less than 5 miles from the marine terminal requiring a truck trip from the terminal to the railyard via local streets. Currently, there is one near-dock railyard in the SPBPs: UP ICTF
  - **Off-Dock** railyard located greater than 5 miles from marine terminals. 2 off- dock railyards handle significant numbers of containers from the SPBPs, the BNSF Hobart Yard in Los Angeles/Commerce/Vernon and the Union Pacific East Los Angeles Yard.

Cargo Movement

SPBP On-Dock Railyards

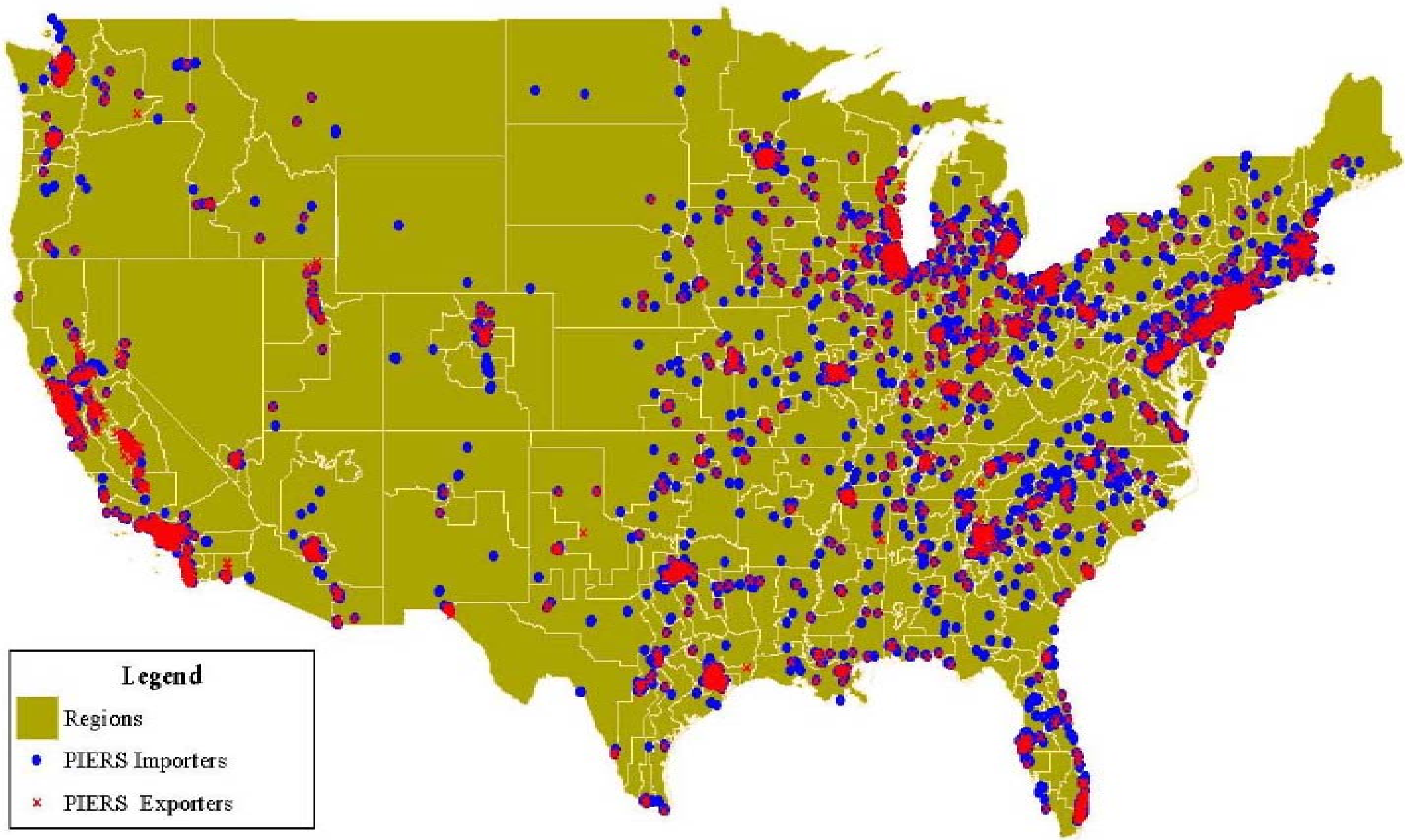
Cargo Movement

Southern CA Off-Dock Locations



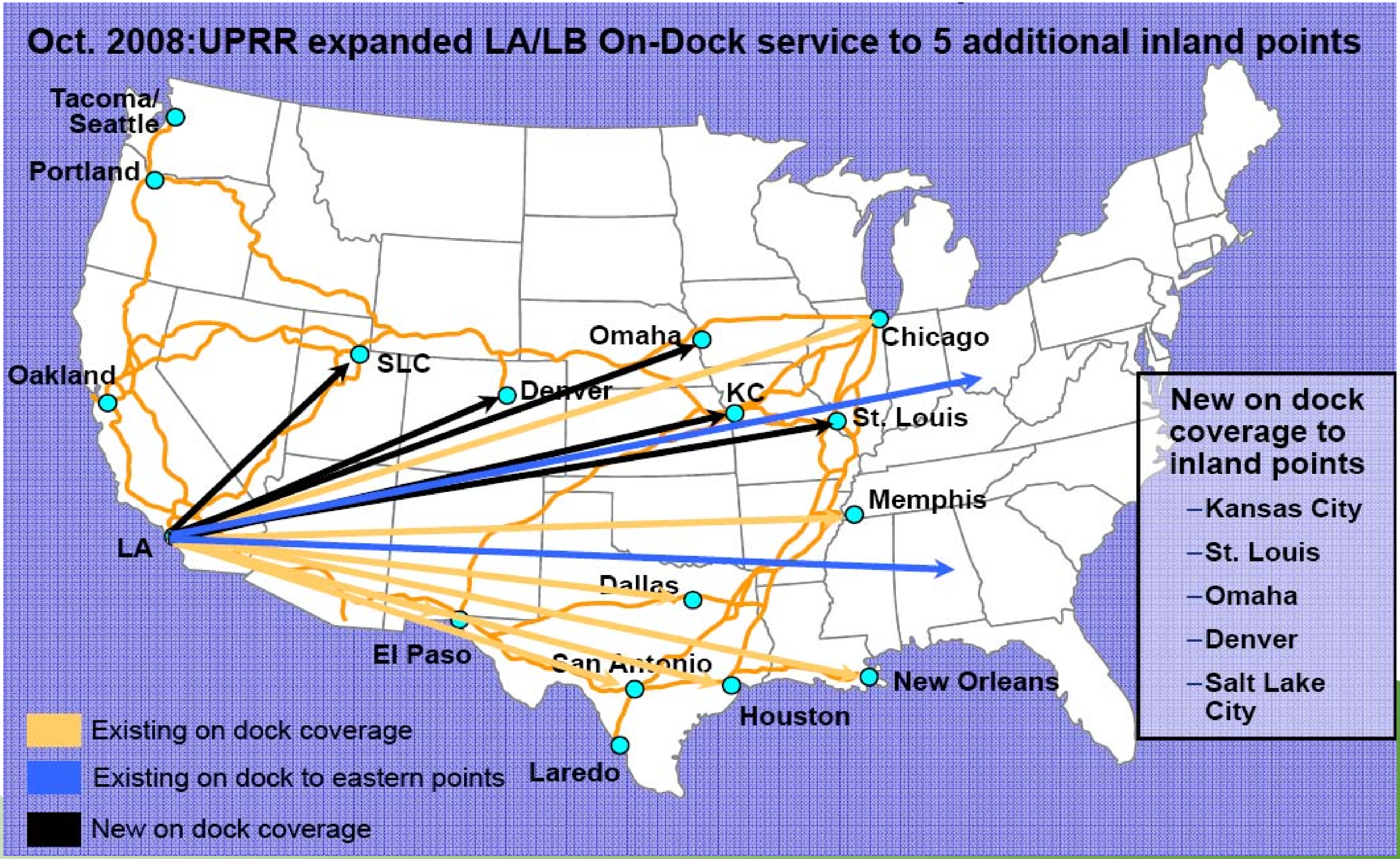
Intermodal Cargo Logistics

Locations of Importers & Exporters (trade w/SPBP)



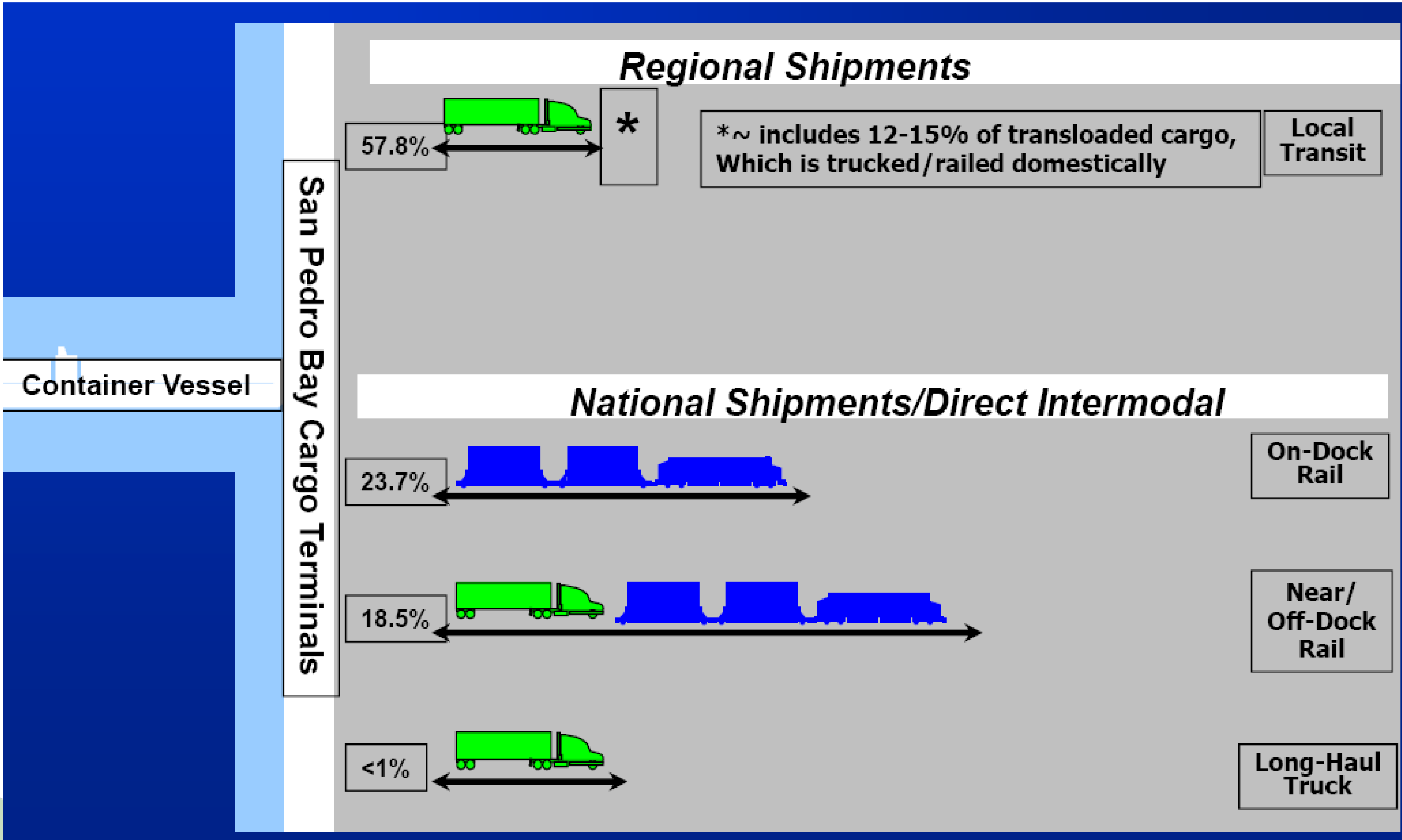
Intermodal Cargo Logistics:

Railroad Service



Intermodal Cargo Logistics

San Pedro Bay Ports Mode Splits



On-Dock Rail & Off-dock Rail Factors

On Dock vs. Off Dock Rail

Current SPBP On-Dock and Off-Dock Rates

	2003	2004	2005	2006	2007	2008
On-Dock						
BNSF	591,280	781,715	977,945	1,285,111	1,181,911	1,115,348
UPRR	456,299	534,870	652,527	827,051	821,070	774,218
Total On-dock	1,047,579	1,316,585	1,630,472	2,112,162	2,002,981	1,889,566
% of Total	15.9%	18.1%	20.7%	24.1%	23.0%	23.7%
Off-Dock (includes ICTF)						
BNSF	760,237	774,336	781,980	808,096	789,656	798,510
UPRR	777,534	771,562	757,598	826,802	812,502	673,854
Total Off-Dock	1,537,771	1,545,898	1,539,578	1,634,898	1,602,158	1,472,364
% of Total	23.4%	21.2%	19.5%	18.7%	18.4%	18.5%
Total On & Off-dock	2,585,350	2,862,483	3,170,050	3,747,060	3,605,139	3,361,930
% of Total	39.3%	39.3%	40.2%	42.8%	41.4%	42.2%
Total Port Volume	6,576,147	7,278,496	7,885,801	8,755,677	8,704,169	7,964,100

On Dock vs. Off Dock Rail

“To On-Dock or Not to On-Dock”

- **Unit vs. Partial Trains**
  - Ports have short-line switcher (PHL)
  - Destination block volumes
- **Vessel stowage, loading/unloading**
- **Capacity**
  - Terminal Container Yard vs. Intermodal Yard
  - Railyard capacity
- **Railroad schedules, operations, Railcar availability**
- **Transloading: on the rise in Southern California**
  - Major retailers transload high %
  - Shipper preferences (value added services, distribution network, intermodal system)
- **WB MTY repositioning**

On Dock vs. Off Dock Rail

Need for Off/Near Dock Rail

- Meet existing and future demand for off and near dock rail while maximizing on dock capacity
- Provide for the sorting of low-volume destination blocks to build complete unit trains (will always be req'd)
- Reduce truck trips and emissions with moving cargo to near dock rail close to the SPB Ports

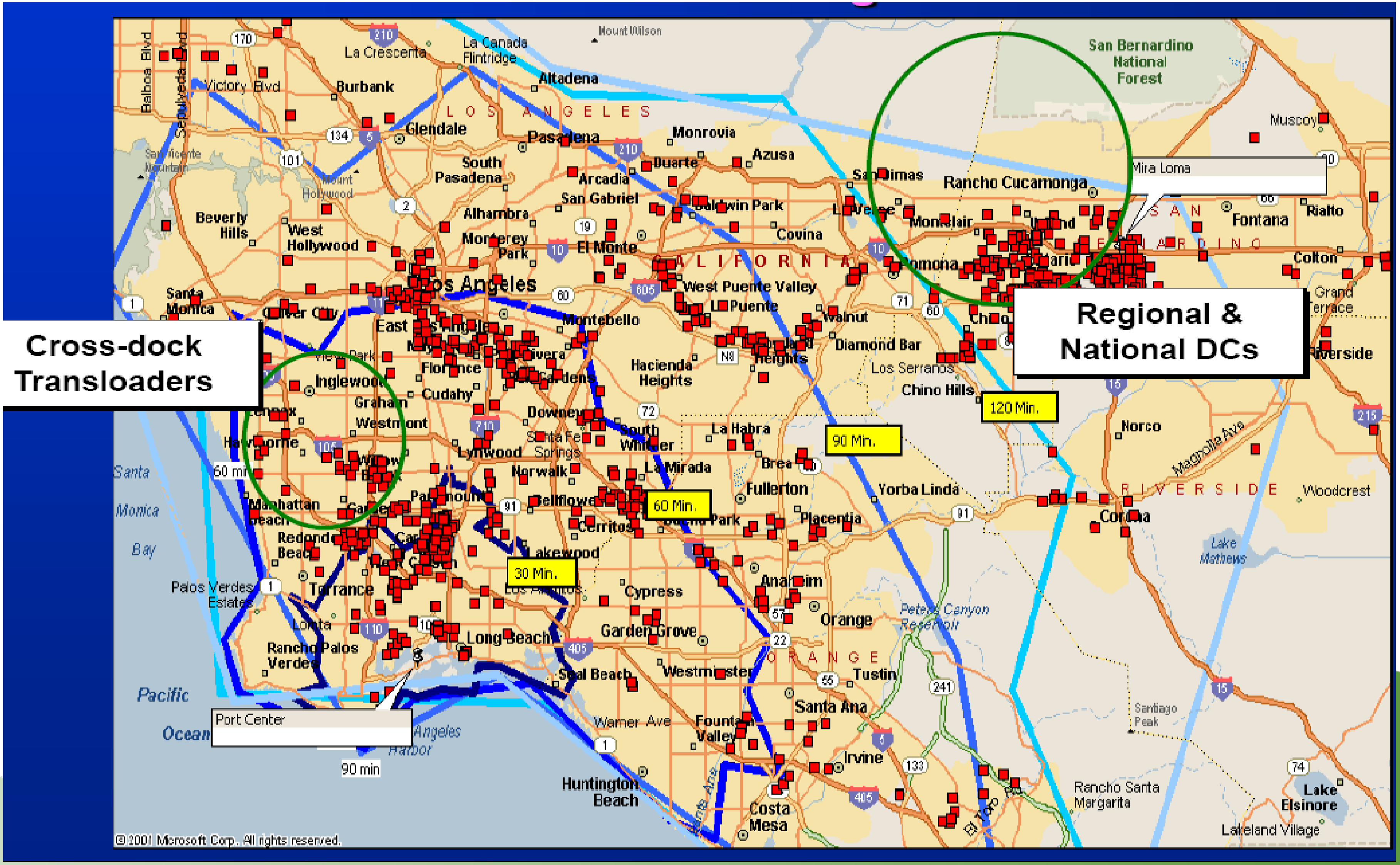
On Dock vs. Off Dock Rail

Recent Enhancements to Increase On-Dock %

- Railroad crews report at Port
- Railroad dispatchers stationed at PHL
- Standardize rail data between terminals & railroads
- Increased railroad work force
- More equipment
- Longer trains
- Train fueling facility at T. I. (Pier 300)
- New PHL Agreement

On Dock vs. Off Dock Rail

Transloading



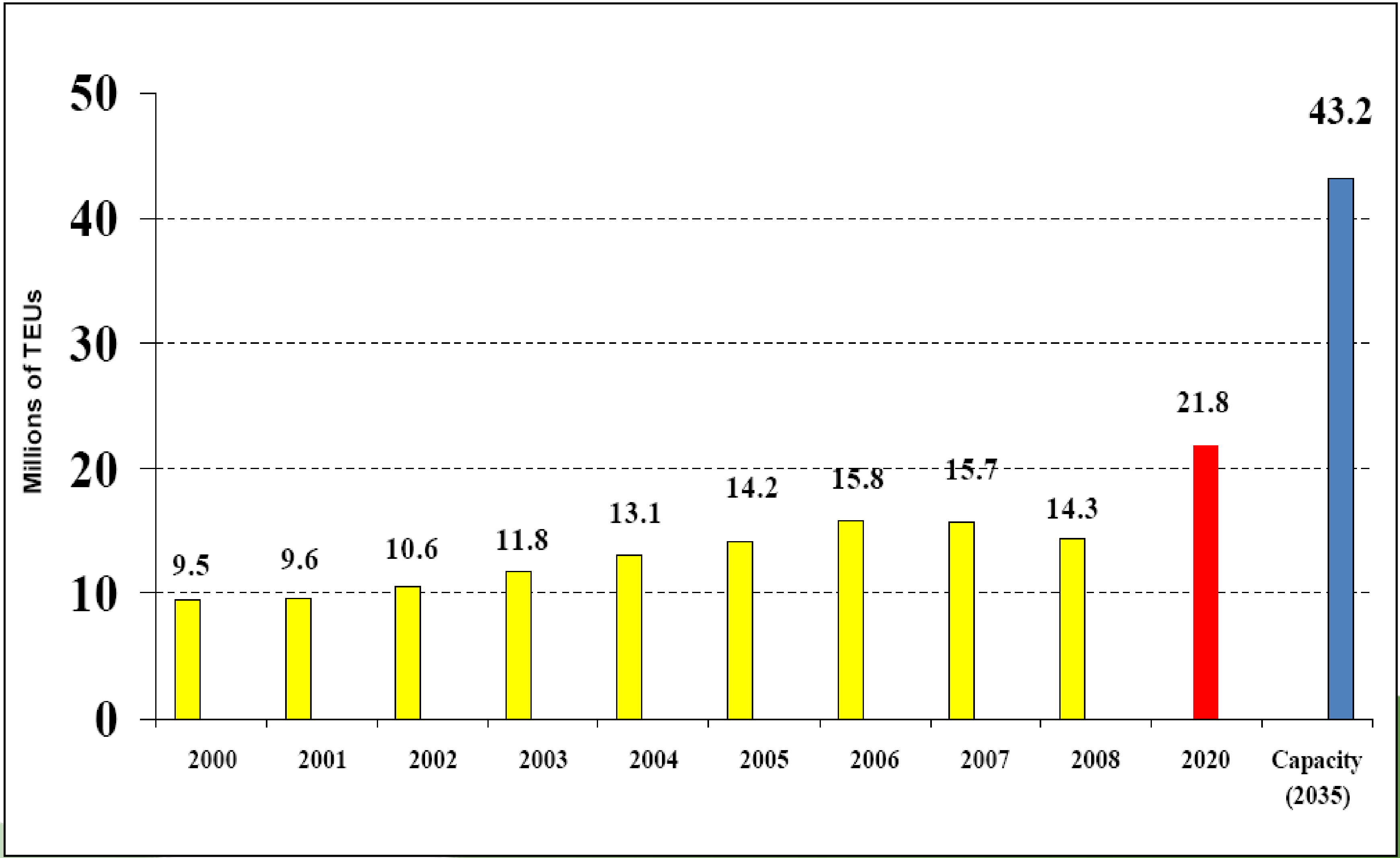
On Dock vs. Off Dock Rail

Cargo Forecast Trends/Parameters

- Coast DCs supplement West Coast DCs, not replace them
- All-water to East Coast only suitable for specific regional market segments and are price sensitive
- The level of transpacific imports (e.g. China) will continue to grow
- Neither BNSF nor UP will give up the Midwest market

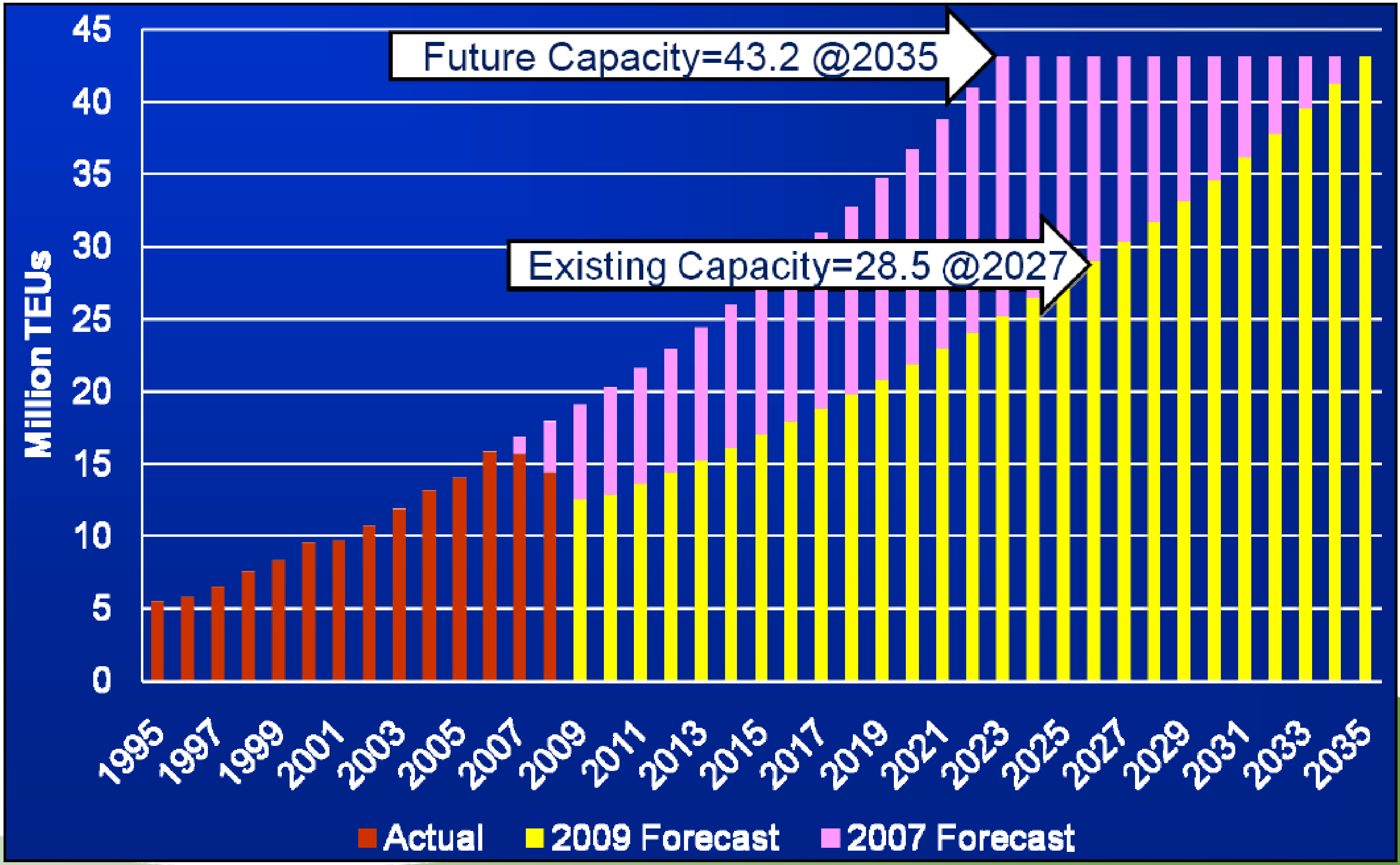
SPBP Cargo Forecasts

2009 Forecast



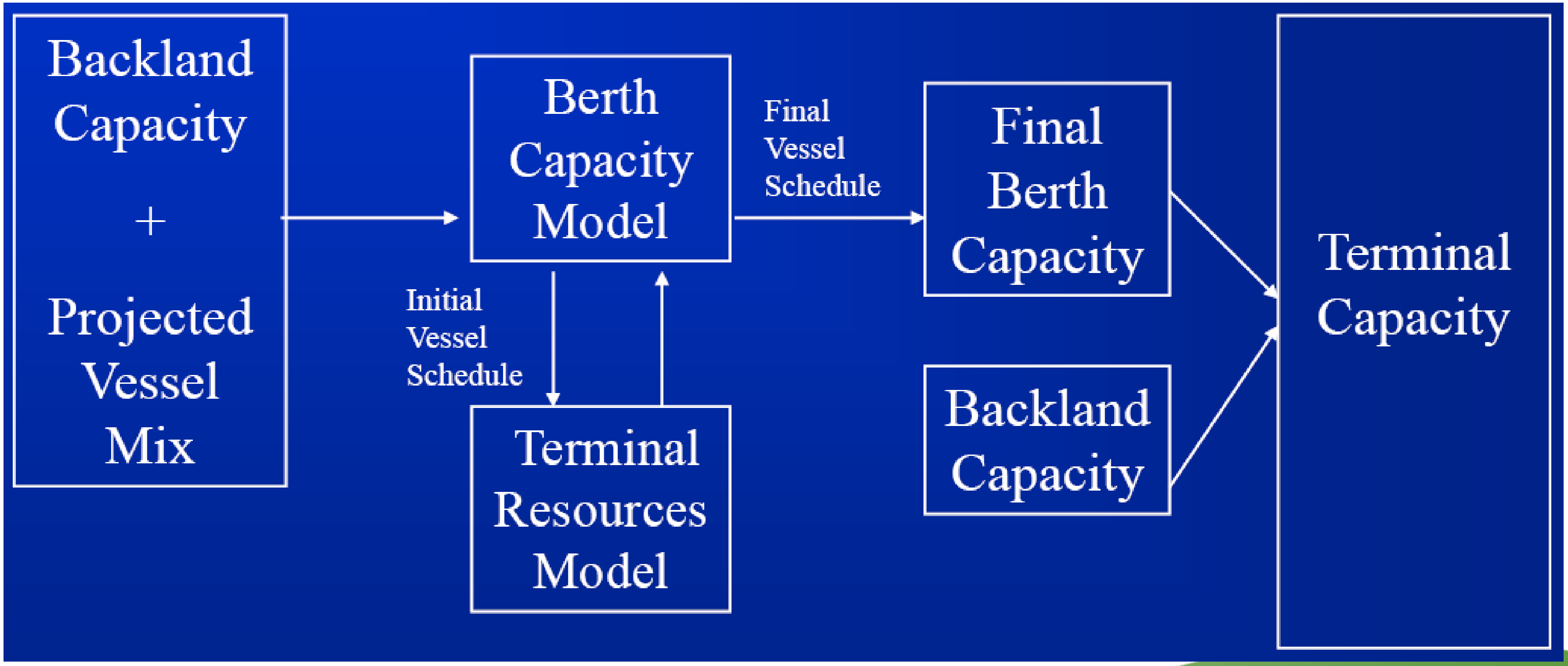
SPBP Cargo Forecasts

2009 vs. 2007 Forecasts



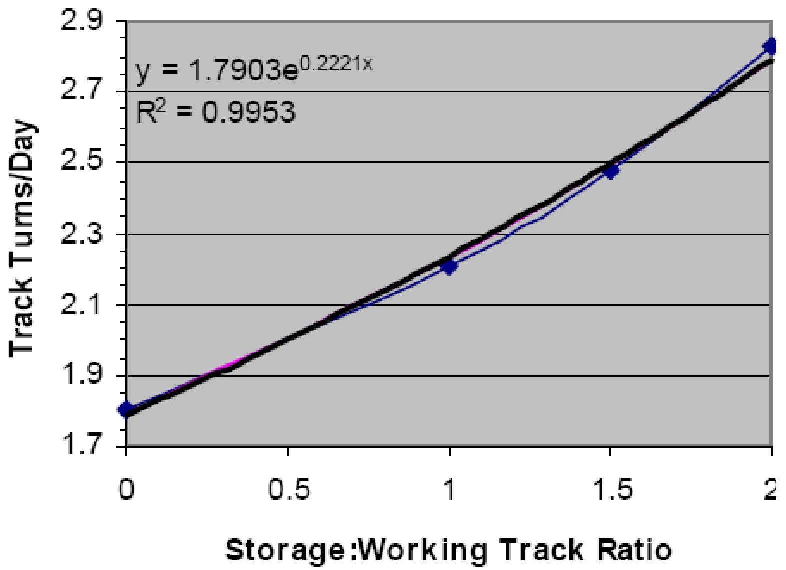
On Dock vs. Off Dock Rail

Container Terminal Capacity Modeling



On Dock vs. Off Dock Rail

Capacity On-dock Railyard Capacity Modeling



Peak Day Eastbound MPC =

*(Working Track Length in DS Cars)**
(Track Utilization Factor)(20 TEU/DS Car)**
(Railcar Utilization Factor)*
*(Track Turns/Day)**
(Switching Efficiency)

Monthly Eastbound MPC = Peak Day EB MPC *360 / 12* (Plant Utilization Factor) [includes shifts/day, labor rules]

Total Monthly MPC =(Monthly Eastbound MPC) * (2 for east + west)* (Export/Import Factor)

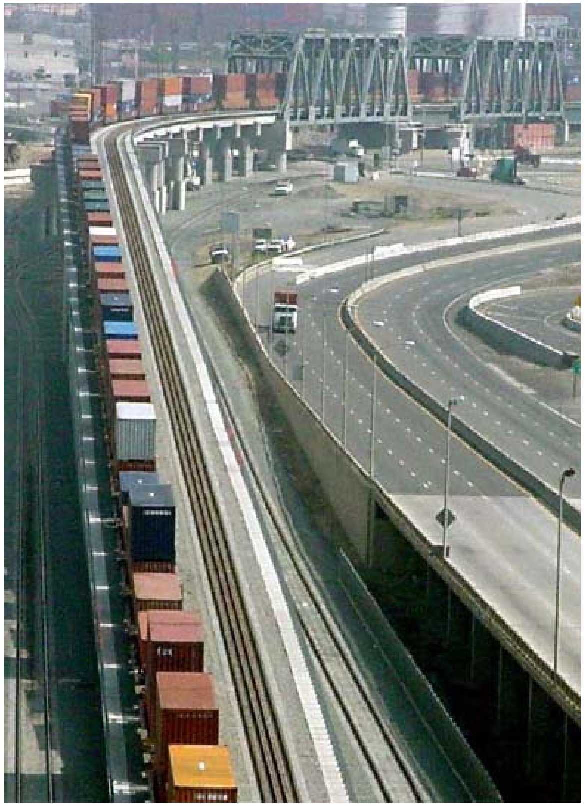
Total Annual MPC =(Total Monthly MPC)*12

On Dock vs. Off Dock Rail

Port Rail System Projects

Ports Rail System Projects ($1.096 B)
Essential For On-Dock Rail ($0.75 B)

- Pier B Railyard-$453.3m
- West Basin Railyard-$112.94m
- New Cerritos channel rail bridge-$155.6m
- South Wilmington Grade Separation -$73.06m
- Reeves grade separation -$108.8m
- Other in-port mainline -$192.5m



Benefits:

- Additional on-dock rail capacity
- Reduces train delays and emissions
- Reduces daily Vehicle Miles of Travel (VMT) for Port trucks by about 64,500 miles.
- Reduces daily VHT for Port trucks by about 2,300 hours

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On Dock vs. Off Dock Rail

Rail Simulation

On Dock vs. Off Dock Rail

POLB/POLA Intermodal Demand/Capacity

2007 Cargo Forecast Scenario

Year	2008 (1 shift)	2012 (3 shifts)	2016 (3 shifts)	2020 (3 shifts)	2023 (3 shifts)	2030 (3 shifts)	2035 (3 shifts)
Total	14,328,355	23,444,658	29,878,496	36,456,136	42,756,747	43,158,000	43,158,000
On-dock	3,401,219	5,490,000	7,910,000	10,340,000	11,710,000	12,860,000	12,860,000
	23.7%	23.4%	26.5%	28.4%	27.4%	29.8%	29.8%
Off/Near-dock	2,650,255	3,887,863	4,041,398	4,242,454	5,392,699	4,403,200	4,403,200
Total Intermodal	42.2%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%

2009 Cargo Forecast Scenario

Year	2008 (1 shift)	2012 (2 shifts)	2016 (3 shifts)	2020 (3 shifts)	2023 (3 shifts)	2030 (3 shifts)	2035 (3 shifts)
Total	14,328,355	14,334,116	17,836,885	21,827,000	25,176,816	34,563,000	43,158,000
On-dock	3,401,219	3,690,000	5,960,000	7,260,000	8,170,000	11,500,000	12,860,000
	23.7%	25.7%	33.4%	33.3%	32.5%	33.3%	29.8%
Off/Near-dock	2,650,255	2,043,647	1,174,754	1,470,800	1,900,726	2,325,200	4,403,200
Total Intermodal	42.2%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%
Transloaded	1,719,403	1,720,094	2,140,426	2,619,240	3,021,218	4,147,560	5,178,960

Zero Emission Container Movement Systems

Alternative Transport Systems

Zero Emission Container Movement Systems

- **Zero Emission Container Movement Systems (ZECMS)**
  - I-710 Corridor EIR/EIS: includes evaluation of alternative technologies for moving containers from ports to Hobart/East L.A. railyards
  - Ports Request for concepts initiative for potential demo project of moving containers from ports to near-dock railyards

Alternative Transport Systems

I-710 Corridor ZECMS Market Analysis

- **Assumptions**
  - An alternative technology could serve part of the projected 2035 near-dock and off-dock intermodal container markets
  - An alternative technology could also serve parts of other geographic markets
  - The on-dock market will continue to be served by rail
  - An alternative technology in the I-710 Corridor could be considered an initial segment of a regional network
  - No intermediate stops for the Automated Fixed Guideway system

Alternative Transport Systems

I-710 Corridor ZECMS Technologies: Trucks

- **Zero Emission Trucks: Are able to operate on a truckway and on a conventional highway**
  - Electric Motor / Wayside Power
  - Electric Motor / Battery Power
  - Electric Motor / Wayside and/or Battery Power
  - Hybrid Electric/Diesel
  - Hybrid Electric/LNG
  - Linear Induction / Diesel
  - Linear Induction / Electric Motor / Battery Power
  - Linear Induction / LNG Power

Alternative Transport Systems

I-710 Corridor ZECMS Technologies: Trucks

- Lowest Cost
- Maximum flexibility
- Utilizes a combination of existing technologies
- Utilizes existing roadway system
- Does not require additional intermodal yards
- Open to a range of propulsion technologies
  - Electrified motor
  - Linear induction
  - Hybrid

Alternative Transport Systems

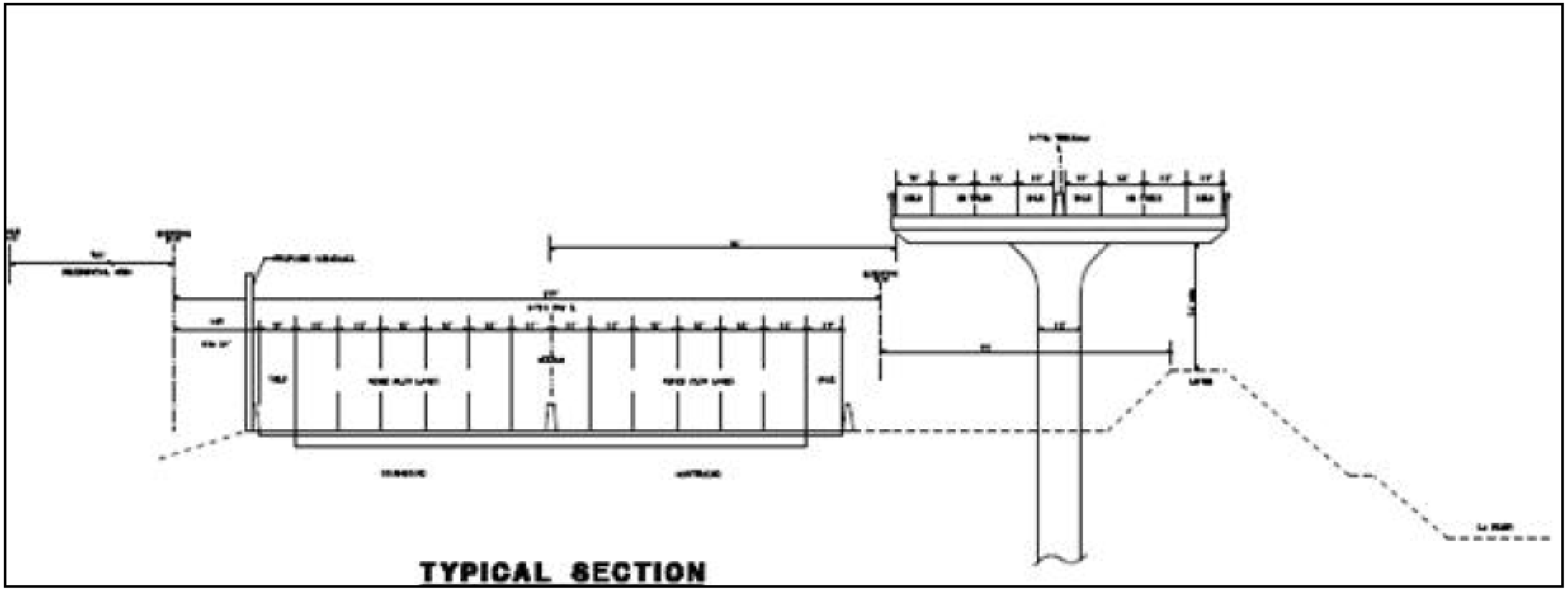
I-710 Corridor ZECMS Technologies: Trucks

- **Design/Construction Management:** $38-$39 million per mile
- **Capital:** $192 million to $196 million per mile
- **Operations:** $1.8 -$2.0 million per mile for the 1st year of operations based on a cost of $.20 per mile to operate electric/battery truck
- **Maintenance:** cannot be determined at this time
- **Estimate:**
  - $3.8 –$3.9 billion to construct
  - $36 -$41 million for the 1st year to operate

Alternative Transport Systems

I-710 Corridor ZECMS Technologies: Trucks

Conceptual Freight Corridor Cross Section



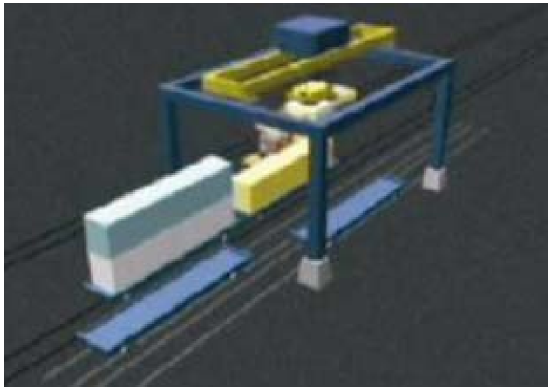
Fits within the available I-710 freeway right-of-way
Both at-grade and elevated

Alternative Transport Systems

I-710 Corridor ZECMS Technologies

Automated Fixed Guideway
Maglev

Electrified Conventional Rail
Exclusive Contact Guideway



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Alternative Transport Systems

Electric Cargo Conveyor System

Alternative Transport Systems

I-710 Corridor ZECMS Tech: Automated Fixed Guideways

- Many companies are promoting this technology family
  - Currently unproven
- Not flexible
  - Limited markets
- Requires expanded on-dock and near-dock intermodal yards
- Requires extensive network of collection and distribution guideways
- High cost
- May become feasible as the technology advances

Alternative Transport Systems

I-710 Corridor ZECMS Tech: Automated Fixed Guideways

- **Potential Fatal Flaws**
  - **Fixed Guideway Family Cost**
    - Serves limited market
    - Expansion limitations
    - Loading/unloading space requirements
    - Level of research and development required
  - **Zero Emission Truck Family**
    - Reliance on developing battery and/or hybrid technology

Alternative Transport Systems

I-710 Corridor ZECMS Implementation Phasing

1. Truck Lanes
2. Low Emission Diesel Trucks
3. Zero Emission Trucks
4. Fixed Guideway

QUESTIONS?

Roadmap for Moving Forward with Zero Emission Technologies at the Ports of Long Beach and Los Angeles

100 Centennial Celebration
Port of LONG BEACH
The Green Port

THE PORT OF LOS ANGELES

Technical Report

Updated August 2011

FINAL

Table of Contents

Acronyms and Abbreviations

ACTA	Alameda Corridor Transportation Authority
AQMD	South Coast Air Quality Management District
CAAP	San Pedro Bay Ports' Clean Air Action Plan
CalHEAT	California Hybrid Efficient and Advanced Truck
CARB	California Air Resources Board
CCDoTT	Center for Commercial Deployment of Transportation Technologies
CEC	California Energy Commission
CHE	cargo handling equipment
CO_2	carbon dioxide
DOE	United States Department of Energy
DPM	diesel particulate matter
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPA	United Stated Environmental Protection Agency
FRA	Federal Railroad Administration
GA	General Atomics
GCWR	gross combined weight rating
GHG	greenhouse gas
HC	harbor craft
HDV	heavy-duty vehicle
hp	horsepower
HSRT	high-speed, high-performance regional transportation system
HTUF	hybrid truck user's forum
ICTF	Intermodal Container Transfer Facility
LSM	linear synchronous motor
maglev	magnetic levitation
MCS	Major Corridor Study
Metro	Metropolitan Transportation Authority
MOU	memorandum of understanding
mph	miles per hour
NOx	nitrogen oxides
OCS	overhead catenary system
OGV	ocean-going vessel
PHL	Pacific Harbor Line
PM	particulate matter
ppm	parts per million
RFCS	Request for Concepts and Solutions
RFP	Request for Proposals
RL	railroad locomotive
RMG	rail-mounted gantry crane
ROW	right of way
RTG	rubber-tired gantry crane

Acronyms and Abbreviations (continued)

RTP	Regional Transportation Plan
SCAG	Southern California Association of Governments
SoCAB	South Coast Air Basin
SOx	sulfur oxides
TAC	technical advisory committee
TAP	San Pedro Bay Ports' Technology Advancement Program
TTC	Transportation Technology Center
UP	Union Pacific Railroad
USC	University of Southern California
ZECMS	Zero Emission Container Movement System

1. Introduction

For the last five years, the ports of Long Beach and Los Angeles have been evaluating zero emission goods movement technologies prompted by Boards of Harbor Commissioners that are keenly interested in leading the nation's two greenest ports into a cleaner future, by community demands for cleaner air, and by regulatory pressure to reduce the ports' "fair share" of air emissions. The purpose of this report is to provide a roadmap for moving forward with the identification, evaluation, and integration of zero emission technologies into ongoing port-related goods movement.

This report was jointly prepared by the staffs of the Port of Long Beach and Port of Los Angeles, with assistance from Starcrest Consulting Group, LLC. This report will:

- Define and clarify what is meant by "zero emission technologies" and how employing such technologies in the appropriate manner can assist the ports and the region in meeting their air quality and health risk reduction needs;
- Describe the technical and programmatic attributes of candidate zero emission technologies, including how they can be potentially integrated into goods movement;
- Explain the criteria and the process used to uniformly and impartially evaluate the technical and programmatic viability of zero emission technologies for drayage over short-haul distances and for in-terminal container handling equipment, and that will also be used for evaluation of additional technologies and other source categories in the future;
- Present the findings of the evaluation process for zero emission technologies, including constraints and opportunities related to near-term and longer-term options;
- Present recommendations for "next steps" in implementing zero emission technologies into port-related goods movement operations.

By the end of this paper, the reader should have a clear understanding of the roadmap for moving forward with zero emission technologies in port-related operations, based on the following key principles:

- The ports should pursue zero emission technologies for those segments of port operations where technically feasible and economically viable solutions are most likely to develop - on-road drayage, in-terminal container handling, and railroad locomotives.
- The ports must identify the technology options that are best suited for integration into port-related operations (e.g., duty cycle).

- The ports must preserve flexibility in their approach to allow future zero emission technology advancements to be integrated into port-related operations.
- The ports must consider the ability of any proposed zero emission strategy to scale out to the region in order to maximize port-related and regional air quality and health risk reductions.
- None of the zero emission technology options considered to date is ready for full-scale implementation. However, the ports will immediately move forward with demonstrations and collaborative efforts that advance promising technologies toward feasible real-world implementation.

Further, the ports must consider that, when evaluating the potential benefits and costs of the various zero emission technology options, resources will also be needed to help develop and implement control strategies for ocean-going vessels (OGVs) and harbor craft in order to achieve the San Pedro Bay Standards.

1.1. What are Zero Emission Technologies?

"Zero emission technologies" have been defined by the California Air Resources Board (CARB) as technologies that do not directly emit criteria pollutants, such as hydrocarbons, carbon monoxide, nitrogen oxides (NOx) or particulate matter (PM). Zero emission technologies may indirectly produce small amounts of emissions, for example, when an electric vehicle plugs into grid power to recharge the on-board batteries, therefore contributing in small part to emissions at the power plant source.

Since 2006, the ports have been evaluating opportunities for Zero Emission Container Movement Systems, or ZECMS, to move cargo through the ports and into the region using technologies that do not burn fossil fuels and therefore do not emit air pollutants "at the tailpipe".

The ZECMS title however gives the impression that there will be a "one-size-fits-all" zero emission option that will apply in all port-related operations. As will be discussed more fully below, such a concept is misleading and limiting, and does not fully address the needs of the various mobile sources involved in port-related operations. Accordingly, for the purposes of this paper and moving forward, with the exception of references to past activities, these technologies will be referred to by the more general and appropriate terminology of "zero emission technologies".

1.2. The Need for Zero Emission Technologies

The economic benefits of port-related activity are felt throughout the nation. However, the fact that the environmental impacts of trade are disproportionally felt in the local region led to the joint ports' landmark environmental initiative, the 2006 Clean Air Action Plan (CAAP). In the 2010 CAAP Update, the ports underscored their commitment to air quality improvement with the adoption of the San Pedro Bay Standards, which are comprised of two components: 1) reduction in health risk from port-related diesel particulate matter (DPM) emissions in residential areas surrounding the ports, and 2) "fair share" reduction of port-related air emissions to assist the region in achieving federal air quality standards. These components reflect the ports' stated goals of reducing health risks to local communities from port-related sources and reducing emissions to support the attainment of health-based ambient air quality standards on a regional level.

Specifically, the ports' Health Risk Reduction Standard is to reduce the population-weighted cancer risk of ports-related DPM emissions by 85% by 2020, relative to 2005 conditions, in highly impacted communities located near port sources and throughout the residential areas in the port region. The Emission Reduction Standards, relative to 2005 conditions are, by 2014, to reduce emissions by 22% for NOx, 93% for sulfur oxides (SOx), and 72% for DPM, and, by 2023, to reduce emissions by 59% for NOx, 93% for SOx and 77% for DPM.

While the ports have already made significant progress toward meeting these goals, as reflected in each port's annual emissions inventories, emissions forecasting indicate that the currently known emission reduction strategies will not be adequate to achieve the aggressive goals of the San Pedro Bay Standards. As a result, the ports must stay focused on identifying and reducing sources of port-related emissions. Staff believes that implementation of zero emission technology options could provide significant benefits to the ports, bringing them closer to achieving these goals, and in turn, assist the region in meeting national attainment standards.

Further, the South Coast Air Quality Management District (AQMD) has stated that in order to achieve the proposed federal ozone standards, the majority of land-based mobile sources will need to utilize zero emission technologies. The proposed U.S. Environmental Protection Agency (EPA) revised standards would reduce the 8-hour primary standard for ozone to a level between 0.070 and 0.060 parts per million (ppm), down from the 2008 standard of 0.075 ppm. The proposed rule also includes a separate cumulative "secondary" standard to protect the environment, especially plants and trees. If the proposed federal ozone standard is adopted, significant changes will be needed throughout all industries, as well as by private consumers, to meet these stringent air quality requirements for the region.

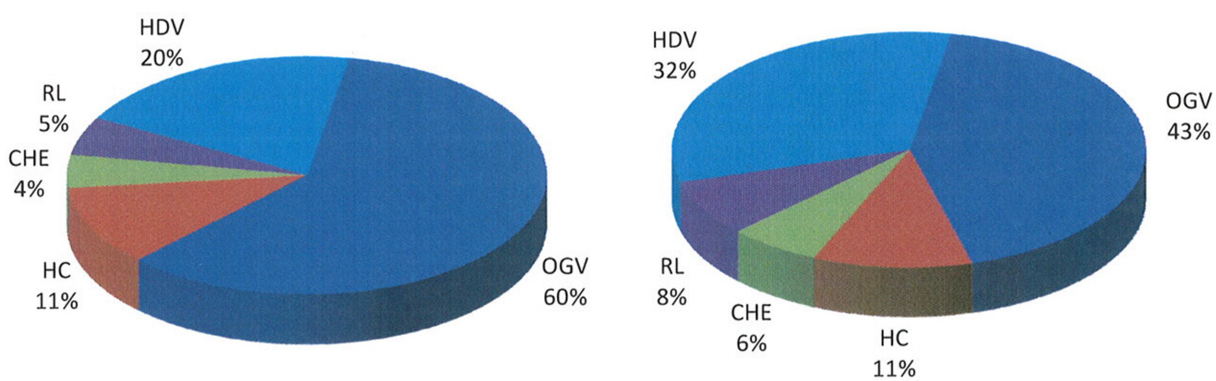
Additionally, utilization of zero emission technologies could be a significant strategy for reducing greenhouse gas (GHG) emissions. Each port, in cooperation with their respective City, has initiated a process to quantify, evaluate and implement strategies to reduce GHG emissions from their administrative operations as well as from port-related activities of their tenants and customers.

Finally, energy security (i.e., reducing dependence on foreign oil) is also a significant consideration as the ports transition into the future. Uncertainty about potential future supplies of oil and rising costs provide another reason for moving away from technologies that rely on fossil fuels to technologies that are powered by electricity ideally produced using renewable energy sources.

1.3. Potential Air Quality Benefits from Implementing Zero Emission Technologies at the Ports

The emissions source categories involved in port-related goods movement operations are OGVs, cargo handling equipment (CHE), drayage trucks (HDVs), rail locomotives (RL), and harbor craft (HC). Figure 1 is derived from each port's 2009 emission inventories and shows the relative contribution of emissions broken down by the source categories associated with such port-related sources.

Figure 1: 2009 DPM and NOx Emissions by Port Source Contribution



While the CAAP includes measures to mitigate air pollutant emissions from each of these major source categories, not all source categories are good candidates for transition to zero emission operation. For example, outside of at-berth operations (i.e., shorepower), it is not practical at this time to pursue zero emission operation of OGVs that call at the ports or harbor craft that operate within port waters due to technical and operational constraints.

The emissions standards being promulgated for OGVs and harbor craft by the regulatory agencies (International Maritime Organization, EPA, and CARB) do not require, nor even approach, zero emission levels. Secondly, and most importantly, zero emission technologies for commercial marine vessels do not currently exist and no practical zero emission technology solutions have been identified. While the goal of "zero emissions" is not appropriate for these source categories, technology options are being developed and implemented to mitigate emissions from OGVs and harbor craft, including the six OGV measures and one harbor craft measure included in the 2010 CAAP Update[1]. In fact, Foss Maritime operates the world's first hybrid-electric tugboat, demonstrating the opportunity for technology migration across applications. While not technically a zero emission tugboat, significant reductions in emissions and fuel consumption are being realized as a result of this advanced technology, which relies on earlier technology developments in the zero emission vehicle market.

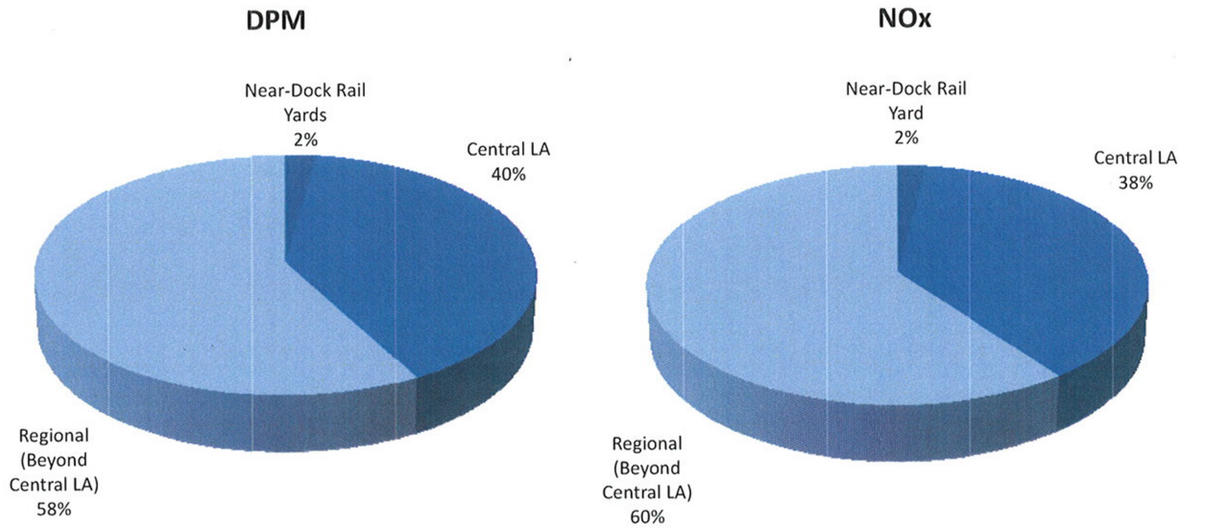
Additional emission reduction technologies for OGVs and harbor craft are being demonstrated under the ports' Technology Advancement Program (TAP). However, even with the successful implementation of these marine vessel emission reduction strategies, OGVs and harbor craft will remain the dominant source of port-generated emissions and the largest source contributor to community health risk for the foreseeable future. These two source categories represent 71% of total port DPM emissions and 54% of total port NOx emissions as documented in the 2009 emissions inventories. Therefore, while the ports must be diligent in their efforts to advance zero emission technologies, they must also be mindful that considerable resources will be needed to significantly reduce emissions from OGVs and harbor craft to achieve the San Pedro Bay Standards.

Technically feasible and economically viable zero emission options are most likely to develop for on-road container drayage conducted between the ports and destinations throughout the region, in-terminal container handling, and rail locomotives used in switching and line-haul operations.

In 2009, on-road drayage trucks produced 20% of total port-related DPM and 32% of total port-related NOx emissions. Of note, these percentages are anticipated to be reduced over the next few years with implementation of the Clean Trucks Programs at the ports. As shown in Figure 2, on-road drayage trucks emit the majority of their emissions during trips throughout the region. In 2009, *on-road truck emissions associated with the transport of cargo between port terminals and the Intermodal Container Transfer Facility (ICTF) represented 2% of total truck DPM emissions and 0.4% of total port DPM emissions.* On-road truck emissions associated with regional drayage represented 98% of total truck DPM emissions and 19% of total port DPM emissions in 2009. Therefore, while near-term efforts should move forward to develop technologies that can reduce emissions from on- and near-port drayage truck operations, ultimately, to provide the greatest benefits, zero emission technologies must be implemented on the regional scale.

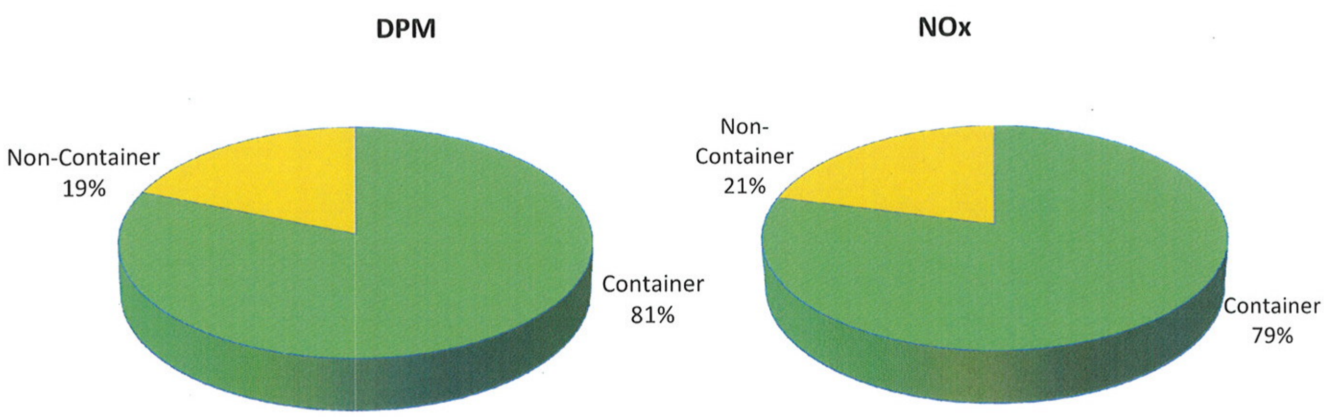
[1] 2010 CAAP Update includes the following OGV Measures: Vessel speed reduction (OGV1); At-berth emissions reductions (OGV 2); Low-sulfur fuels in OGV auxiliary engines and boilers (OGV 3) and in main engines (OGV4); Cleaner OGV Engines (OGV 5); and OGV Engine Emissions Reduction Technology Improvements (OGV 6). Harbor craft CAAP measure is HC1 – Performance Standards for Harbor Craft.

Figure 2: 2009 On-Road Drayage Truck DPM and NOx Emissions Contribution, by Mode



Cargo handling operations at marine terminals and intermodal facilities in close proximity to the ports generate 4% of total port-related DPM and 6% of total port-related NOx emissions. Figure 3 provides the breakdown of DPM and NOx emissions from CHE operations during 2009 at container versus non-container terminals. Since the majority of emissions from CHE are produced at container terminals, greater emissions benefits can be achieved by prioritizing implementation of zero emission technologies for CHE operations at container terminals.

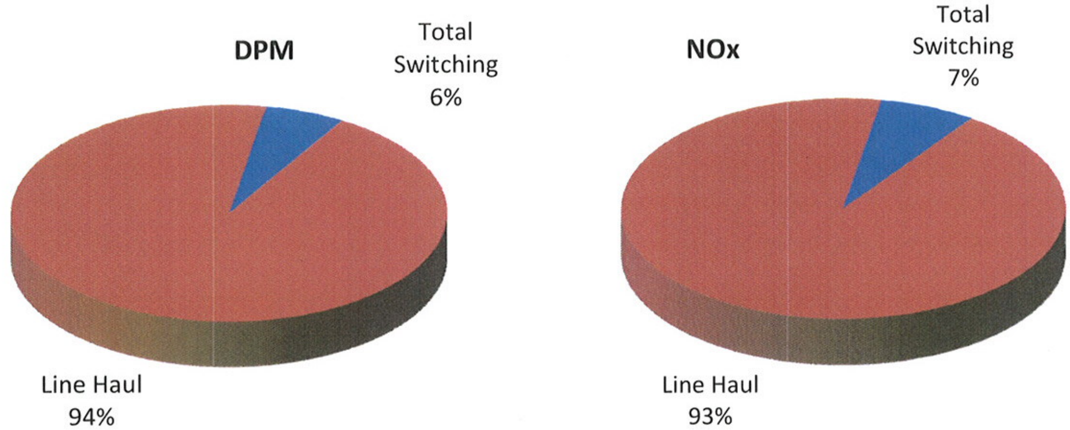
Figure 3: 2009 DPM and NOx Emissions Contribution from CHE by Terminal Type



Port-related rail operations generate 5% of total port DPM and 8% of total port NOx emissions. Rail locomotive emissions are primarily from line haul operations. As shown in Figure 4, 94% of DPM emissions and 93% of NOx emissions associated with port-related rail operations in 2009 were generated by the line-haul locomotives. Rail locomotive emissions are a regional source of air pollution;

thus, to maximize the emissions benefits, zero emission options targeting locomotive emissions should be pursued on a regional scale.

Figure 4: 2009 DPM and NOx Emissions Contribution by Rail Mode



The above analysis of port source emissions is the basis for seeking zero emission options for both port-scale and regional-scale goods movement. On the port scale, zero emission options will target emissions generated by short-haul container drayage and marine terminal operations. On the regional scale, zero emission options will target emission reductions from medium-haul drayage and rail.

Thus, for a zero emission technology to be an effective strategy in achieving the San Pedro Bay Standards, it must have scalability and connectivity throughout the region, and not applied only at discrete marine terminals or intermodal facilities within port boundaries. A zero emission option that connects only point "A" to point "B" within the ports, without the flexibility for expansion is not a viable zero emission solution for meeting the ports' goals.

1.4. The Ports' Role in Advancing Zero Emission Technologies

While the ports are principally interested in zero emission options to help them meet their health risk and "fair share" emission reduction commitments, the ports are also in a unique position to make additional, substantive contributions on a regional, national, and potentially global scale through developing, demonstrating, and supporting deployment of zero emission technologies.

Through the advancement of zero emission technology options, the ports are positioned to assume a lead role in the demonstration of zero emission transportation technologies and serve as a "regional test bed". Because port-related operations typically involve rigorous duty cycles, zero emission technologies that demonstrate the requisite levels of durability and reliability at the ports of Long Beach and Los Angeles can be replicated not only at other ports, but also in other non-marine applications.

Additionally, the pursuit of zero emission technologies provides an opportunity to serve as a "regional catalyst", stimulating both the pace of technology development as well as promoting economic development in Southern California. Currently, at least two zero emission vehicle manufacturers have established their businesses within the greater Los Angeles area, with the expressed intent of manufacturing zero emission on-road drayage trucks and off-road yard tractors for the port-related industry at commercial production rates. To ensure these technologies are carried beyond the ports, these efforts must be conducted with the support and collaboration of the regional planning agencies, including Metropolitan Transportation Authority (Metro), Southern California Association of Governments (SCAG), Gateway Cities Council of Governments, and AQMD.

2. Progress Toward Zero Emissions – Accomplishments to Date

Since 2006, the ports have advanced zero emission technologies through multiple pathways, investing over $4 million to date in this effort. The TAP has focused on numerous technologies, including zero emission options, which are ready for prototype demonstration in port-related applications. In addition, staff have also explored longer-term and larger-scale zero emission options through the ZECMS process.

2.1. Technology Demonstrations through the Ports' TAP

The mission statement for the ports' TAP is *"...to accelerate the verification or commercial availability of new, clean technologies, through evaluation and demonstration, to move towards an emissions-free port"*. The TAP is currently evaluating and demonstrating technologies that could eventually lead to deployment of zero emission technologies for sources in port-related operations. Some of those technologies represent interim or transitional technologies that help to significantly reduce air emissions, but are not yet emission free. Nonetheless, the deployment of these technologies in the near term will help the ports reduce air emissions and associated health risks while continuing to strive for full deployment of zero emission technologies in the appropriate areas of port-related goods movement for the future.

In 2007, the Port of Los Angeles and AQMD initiated a demonstration of the Balqon lead-acid battery electric truck. After initial testing, design upgrades were proposed for the battery management system, including an upgrade to a lithium-ion battery. In 2008, the Port of Los Angeles approved moving forward with phase 2, to purchase and test the upgraded systems for terminal applications, and phase 3, to purchase and test units made specifically for drayage. Phase 2 testing is currently underway. In addition, in an effort to further increase the range of the Balqon trucks, Port of Los Angeles is moving forward with combining the lithium-ion battery truck with Vision Motor Corporation's hydrogen fuel cell. Phase 3 of the system is anticipated to proceed in 3rd Quarter 2011. The tests for phases 2 and 3 will use upgraded lithium ion battery packs, which increase the energy capacity of the units.

The joint ports' TAP demonstrations for the Vision Motor Corporation's hydrogen fuel cell/plug-in electric on-road truck and terminal tractor began in late-2010, with testing of the two prototype vehicles anticipated to begin in 3rd Quarter 2011. The performance of these vehicles will be tested in various terminal and short-haul operations to evaluate their hauling capacity, range, speed, and reliability in the various duty cycles over an 18-month period.

The ports are also actively working with other technology developers as they prepare proposals for consideration through the TAP and anticipate additional zero emission technology demonstration projects to be brought forward for Board consideration later this year.

While these technology projects are underway, until they have successfully completed their prototype testing and are being produced for the commercial market, they are not yet considered viable options[2].

Further, through the TAP, the ports participated in regional and national efforts to develop advanced, lower emissions truck technologies including the national Hybrid Truck Users Forum (HTUF) and the California Hybrid Efficient and Advanced Truck (CalHEAT) research groups. Finally, the ports developed a port drayage truck duty cycle to provide technology developers with a detailed technical understanding of the performance requirements for a typical drayage truck.

2.2. The Ports' ZECMS Process

The concept of Zero Emission Container Movement Systems (ZECMS) has been under investigation for many years. The ports have been actively engaged or the lead agency in these evaluations.

In 2006, the ports evaluated various zero emission technologies through a Request for Proposals (RFP) process. The resulting evaluation report, issued in early 2008 by Cambridge Systematics, identified that

[2] TIAX LLC, *Technology Status Report – Zero Emission Drayage Trucks*, Prepared for the Port of Long Beach and Port of Los Angeles, June 2011.

none of the 13 technologies evaluated was deemed ready for deployment at that time. The process, however, provided valuable insight into the range of ZECMS approaches that could be pursued. As a follow-up to the RFP, and in response to unsolicited proposals by technology vendors, the Port of Long Beach (POLB) performed a right-of-way study to evaluate various routes for a potential fixed guideway system, identifying two potentially feasible routes between the ICTF and POLB's Pier A terminal. In mid-2009, the ports issued a Request for Concepts and Solutions (RFCS) which encouraged submissions of proposals to design, build, and operate a ZECMS between Pier A and the ICTF. The ports, aided by an independent team of technical experts from the Keston Institute for Public Finance and Infrastructure Policy at the University of Southern California (USC), reviewed seven proposals ranging from magnetic levitation (maglev), to linear-synchronous motor (LSM), to vacuum-propulsion technologies.

The USC Keston Institute presented their findings in mid-2010, concluding that none of the proposals were sufficiently mature to commit to a full-scale operational deployment or demonstrated they could deliver a reliable and financially sustainable system at this time. While the general level of proposed systems may have demonstrated experimental proof of concept in a laboratory environment, they all had shortcomings including immature technology, technology that was not proven or tested in port duty cycle applications, and/or technology that lacked a viable financial plan. Debrief interviews with several of the RFCS respondents indicated that additional research and development were needed on their proposed technology, as well as coordinated planning efforts with other regional stakeholders, including regulatory and transportation agencies.

2.3. Regional Zero Emissions Efforts

2.3.1 Metro's Freeway Major Corridor Study

In March 2005, following an extensive technical review and community outreach process, Metro completed the I-710 Freeway Major Corridor Study (MCS). The study analyzed existing and predicted congestion and mobility along the I-710 corridor in order to develop transportation solutions to preserve and enhance the quality of life of surrounding neighborhoods and communities. The study took into account projected increases in container volume at the ports of Long Beach and Los Angeles, the corresponding increase in container truck traffic volume along the I-710, as well as the physical condition of the I-710 freeway infrastructure. Priorities identified by stakeholders during the MCS process included:

- Improve air quality in communities adjacent to the I-710;
- Improve mobility, congestion and safety along the freeway corridor; and
- Assess alternative, "green" goods movement technologies.

The I-710 EIR/EIS studied 18 miles of the I-710 freeway between the Ports and the Pomona Freeway (SR-60). Four alternatives were analyzed in the EIR/EIS:

- No Build Alternative - As required by federal law, the "No Build Alternative" includes transportation improvement projects already programmed or committed to be constructed by the EIR/EIS planning horizon year of 2035;
- Ten Lane Facility - Widen the I-710 freeway to ten lanes for the length of the corridor;
- Ten Lanes and Four Separate Freight Lanes - Widen the freeway to ten general purpose lanes throughout the length of the corridor and add four separated freight movement lanes for exclusive use by conventional trucks;
- Freight Lanes Dedicated to Zero Emission Trucks - Includes all the improvements in the previous alternative, but requires use of zero emission technology to move goods in the freight lanes.

The results of the I-710 Corridor Project EIR/EIS were published in January 2009 in Metro's *Alternative Goods Movement Technology Analysis –Initial Feasibility Study Report*[3].

Two categories of zero emission technologies were assessed for potential I-710 application: automated fixed-guideway systems and battery electric trucks. The report characterized each category of alternative technology in terms of guideway requirements, propulsion, energy consumption, command and control, terminal interfaces, switching, sorting and storage, system operations, and system assurance.

In light of the apparent property requirements for deployment of an automated fixed-guideway technology at the ports and intermodal rail facilities, a new type of battery electric truck technology was considered that would interface with ports and rail terminals as conventional trucks do today, but would operate on a dedicated guideway subject to controls that safely optimize capacity. The report concluded that such a technology does not exist as a commercial product today, but would incorporate characteristics of existing freight and passenger technologies. It was also conceived that drayage trucks powered by electric motors could draw wayside electric power along the corridor and operate on battery power at the ports and intermodal rail facilities.

2.3.2 SCAG's Goods Movement Plan

The SCAG's Regional Transportation Plan (RTP) represents the "long-term investment framework for addressing the region's transportation and related challenges"[4]. An important effort under the 2008

[3] Final Report: Alternative Goods Movement Technology Analysis –Initial Feasibility Study Report, WBS ID:160.10.60, Los Angeles County Metropolitan Transportation Authority, January 6, 2009.

[4] 2008 Regional Transportation Plan, *http://www.scag.ca.gov/rtp2008/pdfs/finalrtp/f2008RTP_ExecSum.pdf*

RTP is development of SCAG's Comprehensive Regional Goods Movement Plan and Implementation Strategy which seeks to optimize the region's transportation system with the application of new technologies. This plan will include evaluation of all freight modes relative to economic efficiency, congestion mitigation, air quality improvements, and system security enhancements. The regional goods movement system defined through this plan will "feed" the upcoming 2012 RTP, which is also under development.

Specifically, SCAG's vision includes the introduction of a high-speed, high-performance regional transport system (HSRT). An HSRT system could potentially include new alternative, zero emission, technology-based systems that can provide enhanced throughput and reliability from the ports of Long Beach and Los Angeles to an inland port facility. The system would capitalize on the synergy of multiple uses on a single infrastructure by operating on shared alignments with a HSRT passenger system. Significant additional evaluation is required, especially with regard to the location of an inland port facility and the associated costs. In the 2008 RTP, SCAG estimated the cost to connect the ports to the HSRT to be $18 billion, with an implementation target of 2020.

3. Recommended Direction – A Roadmap to Zero Emissions

3.1. Candidate Source Categories

As described in Section 1, the ports identified the source categories where zero emission technologies best apply – specifically, container drayage conducted between the ports and destinations throughout the region, container handling at marine terminals, and locomotives used in switching and line-haul operations.

For the purpose of this discussion, container drayage is grouped into two modes:

- Short-Haul Drayage - This operation involves very short container moves from two to six miles in length. Cargo moves between the port terminals and the ICTF, which functions as the Union Pacific (UP) near-dock rail terminal, or nearby container yards are included within this category;
- Medium-Haul Drayage
  - Local Drayage - A high concentration of warehouses and truck terminals, as well as a major rail yard (Hobart), exist within 20 miles of the ports. These terminals include distribution centers in downtown Los Angeles, Compton, and Rancho Dominguez. For the purposes of this report, local operation is defined as cargo moves originating or terminating at the ports and having the other end point between six and twenty miles distance from the ports. According to drayage truck origin and destination surveys, approximately 50 - 60% of port drayage truck activity is captured in this range;

- Regional Drayage - At distances greater than twenty miles from the ports but within the South Coast Air Basin (SoCAB), large warehouse facilities are common and may be used to transfer goods for interstate delivery.

Container handling within a marine terminal involves a wide range of specialized CHE, each type of equipment performing a specific function. This equipment includes vehicles such as yard tractors, top handlers, side picks, and rubber tired gantry cranes. A review of the combined ports' emissions inventories indicates that 50% of CHE operating at the San Pedro Bay Ports consists of yard tractors that move containers within the marine terminals and intermodal facilities.

Locomotive activities include switching activities to build trains, occurring primarily within the port boundaries and intermodal yards, and line-haul activities, transporting trains along the rail corridors, typically to destinations outside of the SoCAB.

These four container movement modes – short-haul drayage, medium-haul drayage, cargo handling equipment, and rail locomotives – represent the four highest priority pathways on the road to zero emissions. The sections that follow will discuss the identification and evaluation of candidate zero emission technology options relative to these four priority container movement modes, culminating in recommended next steps in the zero emission roadmap.

3.2. Process to Identify Zero Emission Technology Options

As described in Section 2, the ports employed a structured process to develop the recommended roadmap to zero emissions, first identifying and screening, then evaluating the applicability, compatibility, feasibility, and economic viability of zero emission options at each step in a container's movement through the ports and into the region. Consistent with the principles identified in Section 1, this process included the following key components:

- Development of Operational and Performance Requirements – Characterization of the operations and performance of each segment of container movement, both in-port and on a regional level. This assessment included conducting detailed analytical studies of container drayage and yard tractor duty cycles to define performance requirements.
- Identification of Zero Emission Technologies - A compilation of technical and programmatic information relative to candidate zero emission technologies, including near term technologies undergoing development and demonstration through the TAP, as well as longer-term technologies identified during the ports' ZECMS RFCS process. In addition to technical and programmatic information provided by technology providers, the ports conducted independent

research and evaluation[5] of zero emission options to better understand their level of technical maturity, feasibility, and potential for near term commercialization.

- Evaluation of Candidate Zero Emission Technologies - For the candidate zero emission technologies identified as potentially applicable and compatible within a segment of port-related container movement, a detailed evaluation was performed using the evaluation criteria presented in Section 3.3 below.
- Recommendations – Recommendations relative to specific zero emission technologies that should be advanced by the ports at this time, including next steps.

Through this process, it became clear that due to differences in operational requirements and implementation issues encountered in various segments of goods movement, *there is no single zero emission technology solution that currently exists or is anticipated to become available that satisfies all of the stated principles and evaluation criteria.* A zero emission option for marine terminals will be different from a zero emission technology applied to container movement on a regional scale. This is because the operational requirements of container movement within a marine terminal environment are very different than those associated in moving containers along rail corridors to the edge of the SoCAB boundary or along public roadways from the terminal to the ICTF, downtown Los Angeles, or the Inland Empire. Unfortunately, there are no zero emission technology "silver bullets" that will provide a single solution that serves all stakeholder interests or requirements.

That being said, the port staff identified opportunities in which a zero emission technology that is not included in the near term zero emission roadmap could have a potential role in the longer term. Zero emission technologies being advanced in the near-term will preserve flexibility for future innovations. There are also paths along the roadmap that identify the incremental expansion of zero emission technologies across multiple goods movement segments and multiple source categories. Thus, while no single solution exists for a near term solution, technologies that are not fully developed today may have a more defined role in the future.

It is important to recognize that the identification and evaluation of zero emission options is a dynamic and ongoing process. The roadmap does not identify a specific end point or future state of technology – it is intended to identify steps in the ports' transition to zero emissions that can be supported today with the understanding that advancements in technology readiness and availability will continue to evolve and must be continually assessed. Thus, it is essential that the ports establish and work within a process framework that allows for technology assessment and reassessment, and fosters collaboration with port tenant, customer, regional, and regulatory stakeholders. The ports' TAP is the key element in this ongoing, dynamic process. Through the TAP, the ports will accelerate the verification or commercial

[5] Technology Status Report - Zero Emission Drayage Trucks, Draft Report, TIAX LLC, May 2011.

availability of zero emission technologies across all applicable source categories, through identification, evaluation, and demonstrations. *However, the principal objective of the zero emission roadmap is to identify next steps and get started now.*

3.3. Criteria for Evaluating and Prioritizing Zero Emission Options

In order to evaluate and prioritize candidate technologies and options for inclusion in the ports' roadmap for zero emissions, the ports defined seven decision criteria. These criteria were used to assess competing technologies for short-haul drayage and in-terminal container handling equipment. The evaluation criteria were developed under the guidance of the ports' principles and also derived from criteria used for the TAP to be consistent with the San Pedro Bay Standards. The criteria also favor options that could bring more immediate benefits and that faced fewer technical, operational, economic and implementation obstacles. Finally, the criteria will be used to uniformly evaluate additional technologies and other source categories in the future.

In developing recommendations, the port staff employed the following criteria:

- **Emissions Reduction and Health Risk Benefits** – the zero emission option's anticipated port-related emission and health risk reductions and contribution toward achieving the San Pedro Bay Standards. The magnitude of benefits derived from the zero emission solution should be commensurate with the investment required, i.e., evaluated on a "cost/benefit" basis with preference given to technologies with higher ratios of benefits to cost;
- **Constructability** – including infrastructure and utility requirements, availability of required space, and Right of Way (ROW) acquisition requirements with preference given to projects that can be integrated into the existing infrastructure or those with fewer barriers to construction;
- **Technology Readiness** – the level of technical maturity and feasibility, demonstrated reliability/durability, and commercial availability with preference given to more mature technologies so as to speed the pace of implementation;
- **Operations Compatibility** – the capability of candidate zero emission technologies to be integrated into ongoing port operations and duty cycles, as well as compatibility with existing operations with preference given to technologies that can more easily be integrated into existing operations;
- **Regional Scalability** – the ability of a port-scale zero emission solution to be incrementally expanded to a regional scale (i.e., in-port, port to ICTF, and expansion along corridors like I-710 between ports and downtown Los Angeles and beyond to the Inland Empire) favoring technologies that can be readily expanded to the regional scale;

- **Cost and Economic Sustainability** – the capital, operational, and life cycle cost, need for incentives or subsidies, and the potential to become economically competitive and sustainable relative to conventional container movement operations with preference given to cost-competitive projects;
- **Timeline** – the expected timeframe for zero emission technology demonstration, commercialization, regional expansion, etc. While the timeline is not used as a criterion to approve or reject technologies, it is used to prioritize actions. For the purpose of the zero emission roadmap, discrete timeframes were defined as follows:
  - Near Term timeframe: Within 3 years
  - Longer Term timeframe: Beyond 3 years

3.4. Zero Emission Options for Short-Haul Container Drayage

Two distinct options emerged from the ports' efforts to identify candidate zero emission options to replace or augment short-haul container drayage currently performed by trucks:

1. Deployment of on-road zero emission trucks, including but not limited to battery-electric trucks, zero emission hybrid-electric trucks, electric trucks powered by an overhead catenary system, or electric trucks using wayside power or LSM embedded in existing roadways or dedicated truck lanes;
2. Construction of an automated fixed guideway system incorporating technologies such as maglev or the adaptation of LSM to existing railroad tracks.

These options are described below, specifically the performance requirements and technology status for each, in addition to a recommended approach for moving forward.

3.4.1. Performance Requirements for Short-Haul Drayage Trucks

To successfully develop advanced zero emission trucks for short-haul drayage, vehicle manufacturers must understand the duty cycle requirements of port drayage trucks. To characterize port drayage duty cycle requirements in analytical terms, the ports developed and published detailed duty cycles for drayage trucks serving both the Port of Long Beach and Port of Los Angeles[6] using data obtained from instrumented trucks in actual container drayage service.

[6] Characterization of Drayage Truck Duty Cycles at the Port of Long Beach and Port of Los Angeles; Final Report, TIAX LLC, February 2011.

A typical short-haul drayage duty cycle includes three distinct driving modes:

Creep → Low Speed Transient → Short High Speed Transient

In analytical terms, the requirements of a typical short-haul container dray can be represented as follows:

- Average Duration of Short-Haul Container Dray: 39 minutes
- Average Truck Speed: 7.7 mph
- Maximum Truck Speed During Haul: 42.2 mph
- Average Short-Haul Distance from Port: 5 miles
- Number of Stops During Dray: 31 stops (traffic control, etc.)
- Percentage of Time Spent Idling: 44%

The short-haul duty cycle requirements were then used to define the minimum performance requirements for zero emission drayage truck:

- 80,000 lbs. gross combined weight rating (GCWR)
- 50+ mph top speed with full load
- 20% or greater gradeability at vehicle launch
- 6% gradeability[7] at 40+ mph and 80,000 lbs. GCWR
- Operating time between refueling or recharging must allow for one complete shift (approximately 8 hours) or have comparable fill times as diesel trucks.

Note that the gradeability at 40+ mph is based on the characteristics of the three major bridges in the port area (Gerald Desmond Bridge, Vincent Thomas Bridge, and Commodore Schuyler F. Heim Bridge). It is possible to use other routes to avoid the steep grades on the bridge, possibly lowering the specified grade requirements.

3.4.2 Development Status of Zero Emission Short-Haul Trucks

Vehicles employing partially electrified drive trains have seen dramatic growth in the light-duty market over the last ten years with the commercialization of various hybrid-electric passenger cars. The medium- and heavy-duty markets have also shown recent trends toward electrification of drive trains in

[7] Based on Gerald Desmond Bridge approach grade, Gerald Desmond Bridge Replacement Project Traffic Impact Study, October 2009

both on-road and off-road applications. Several manufacturers are pursuing commercialization of heavy-duty electric trucks that have the potential to meet the basic operational requirements for short-haul drayage trucks.

As identified earlier, two electric truck manufacturers, Balqon and Vision Industries, are currently working with the ports to test prototype on-road electric trucks that meet the CARB definition for zero emission. The Balqon and Vision Industries prototype technologies are being used as examples to characterize the current state of development for zero emission trucks that are potentially suitable for short-haul drayage service at port terminals.

- Balqon Corporation Battery-Electric Drayage Truck - In 2007, the Port of Los Angeles and AQMD entered into a contract with Balqon Corporation to develop and demonstrate a battery-electric truck that could operate within and outside terminal facilities in both on-road and off-road applications. The initial prototype truck, the Nautilus E-30, was completed and tested in early 2008, primarily as an off-road yard tractor. Based on an assessment of the prototype truck's performance by port and AQMD staff, it was determined that an upgraded version of the E-30 had the potential to meet the performance requirements for an on-road short-haul drayage truck. In June of 2008, the Port of Los Angeles approved Resolution Number 08-6571[8], thereby entering into a multi-phased test program with Balqon that ultimately includes the purchase and delivery of five E-30 battery electric on-road drayage trucks that could be used for short-haul operations. This multi-phased test program has been underway primarily focusing on enhancements to the batteries and battery management system. Initial tests have been conducted on yard tractors. Because yard tractors and short haul drayage trucks have similar electric drive system components and duty cycles, many of the lessons learned and potential enhancements, including those made to the batteries and BMS, would assist in the development of the on-road units. Balqon is currently in production of the first on-road unit for short-haul operations, which will be delivered in the third quarter of 2011.

- Vision Industries Hybrid-Electric – The Vision Industries Tyrano™ on-road truck is a special type of zero emission hybrid-electric vehicle that uses battery power for propulsion and an on-board hydrogen fuel cell system to recharge the vehicle's batteries. The vehicles being tested under the ports' TAP include a plug-in option for recharging the batteries; however Vision has stated that the fuel cell can be relied upon to recharge the batteries in lieu of plugging into the electrical grid. The vehicle's performance characteristics, including horsepower, torque, gradeability, etc., are substantially similar to the Balqon E 30 described above. Based on Vision's preliminary vehicle specifications, the Tyrano™ hybrid drive system has the potential to provide adequate horsepower and torque to meet the needs of drayage service. Vision engineers report

[8] *http://www.portoflosangeles.org/Board/2008/June/061908_Special_Meeting_Item1_trans.pdf*

that the Tyrano™ will have a rated gradeability of 13% when fully loaded at 80,000 GCWR; this should enable it to meet all grades that will be encountered in short-haul drayage trucking. One potential performance-related issue is that the Tyrano™ day cab tractor weighs approximately 17,500 pounds; this is approximately 2,000 pounds heavier than a comparable diesel tractor. However, Vision engineers point out that the Tyrano™ tractor's weight distribution has been optimized to help prevent overloading of the front axle when heavy loads are moved. In July 2011, Vision delivered the demonstration unit and the 18 month in-use demonstration was initiated.

Battery and zero emission hybrid electric trucks are expected to initially cost more than double that of a conventional diesel Class 8 on-road drayage truck. The majority of the incremental cost is associated with the battery storage system. Most heavy-duty electric truck manufacturers specify advanced lithium chemistry batteries. These batteries offer the benefits of high levels of electrical energy storage capacity, long life, and lower weight as compared to other battery types. However, at today's production rates, lithium chemistry automotive batteries are the single most expensive component of the electric drive system. As additional hybrid electric and battery electric passenger cars enter the marketplace, it is anticipated that increased production rates, production automation, and competitive market forces will result in economies of scale that ultimately lower the cost of electric vehicle batteries. This is already being seen as it pertains to lithium-ion batteries entering the marketplace.

The reliability and durability of heavy-duty electric trucks in a short-haul port duty cycle have yet to be proven. While the prototype electric trucks are anticipated to be capable of meeting the combination of payload and grade performance requirements necessary for local drayage operation, testing of the initial Balqon units have shown inadequate speed at grade while under load and limited range, indicating further design improvements are needed. To assess the technical capability of the Balqon and Vision Tyrano, a test program is being developed for the TAP demonstration that employs the truck over an extended period of time in actual, fully loaded container drayage service on typical routes.

While Balqon and Vision are used as examples in this report because they are currently being evaluated by the ports, they are not the only Class 8 zero emission truck options in development. The AQMD is currently funding the development of Class 8 battery electric trucks, and manufacturers of Class 5 - 7 battery electric trucks have expressed confidence that existing electric drive systems are scalable to meet Class 8 container drayage operational requirements. Thus, it should not be construed that staff is recommending any specific vendor or vehicle – the reference to electric trucks in the zero emission roadmap includes all electric trucks that meet port requirements and is not limited to these two options.

With respect to electric trucks designed to operate using an off-board electric power source, such as electric trucks powered by an overhead catenary system (OCS) or wayside power, these technologies are not being dismissed as options. These off-board power systems may offer the potential to extend the range of the zero emission trucks beyond what can be provided by the on-board battery system, and can be developed based on the successes and/or lessons learned from the current electric or hydrogen-electric hybrid projects. However, it is important to recognize that commercially available linear induction/linear synchronous motor technologies do not currently exist. While OCS has been widely used in on-road transit bus applications, the need for and benefits of OCS as compared to electric trucks using on-board energy storage (i.e., batteries) for *short-haul drayage* have yet to be identified or evaluated for operation at the San Pedro Bay ports. It is recommended that the ports view the zero emission option of electric drayage trucks as inclusive of all electric power technologies, recognizing that the implementation timeline of each technology will vary, and that some currently infeasible technologies may become viable in the longer term or for range extension, as long as there is flexibility in the implementation to allow for future advancements.

3.4.3. Performance Requirements for Fixed Guideway Systems

The construction of a *fixed guideway* to connect marine terminals with near-dock intermodal facilities as an alternative to zero emission trucks was the predominant theme in the responses received under the ports' RFCS. Technologies proposed for operation on a fixed guideway include maglev propulsion systems, linear induction motor technology (without levitation), vacuum propulsion systems, and OCS. While the details of each propulsion technology vary, the common attribute is that containers are conveyed along a dedicated guideway that requires construction of new port infrastructure.

Because a fixed guideway represents new infrastructure and provides dedicated connectivity between the port terminals and near-dock rail facilities, the typical duty-cycle requirements corresponding to short-haul drayage operations do not necessarily apply. Instead, container movement requirements for a fixed guideway can be specified in terms of connectivity and throughput. To replace short-haul drayage service currently performed by drayage trucks, a fixed guideway option will need to have the following attributes:

- Connect the 13 existing marine container terminals spread throughout both ports to multiple near-dock intermodal facilities;
- Not impede existing on-dock rail or other operations at port terminals or operations at near-dock intermodal facilities;
- Be cost competitive in a reasonable timeframe with existing short-haul drayage services;
- Offer container throughput capacity that equals or exceeds marine terminal drayage requirements.

3.4.4. Development Status of Fixed Guideway Systems

During the ports' RFCS process, an evaluation team comprised of staff from each port, the Alameda Corridor Transportation Authority (ACTA), and a panel of experts selected by the Keston Institute of USC concluded:

- None of the systems proposed are sufficiently mature to commit to a full-scale operational deployment at this time;
- Additional testing that simulates the port environment is needed;
- A full understanding of port duty cycles was absent from all responses;
- None of the submissions adequately addressed the risks of insufficient market demand; and
- Technology and financial risk cannot be fully evaluated until the robustness and reliability of the systems have been demonstrated.

It is possible, and even likely, that issues involving insufficient technology maturity can be resolved through additional research and development. However, constraints imposed by ongoing operations at port terminals present integration issues that may render a fixed guideway solution impractical compared to trucks for short-haul.

To effectively replace current container movement operations, a fixed guideway would need to provide connectivity to at least 13 marine terminals and several near dock intermodal facilities which would require a virtual "web" of dedicated guideways. The method to deliver containers to the guideway, load containers onto the guideway at the marine terminals, and unload containers at the near-dock intermodal facility is currently undefined and must be resolved so as to not adversely impact port terminal and rail yard operations. In addition, construction of a fixed guideway, including elevated guideways, would require acquisition of terminal right-of-way and potentially acquisition of private right-or-way which may be impractical and prohibitively expensive.

Further and very importantly, a fixed guideway solution does not provide regional scalability and connectivity. In order to significantly reduce emissions and make progress toward meeting the ports' goals identified in the San Pedro Bay Standards, a zero emission option must have scalability and connectivity throughout the region, and not be applied only to discrete marine terminals or intermodal facilities near the ports. A zero emission option that is only able to capture operations between the marine terminals and intermodal facilities will, at best, only be able to reduce 0.4% of port-related DPM emissions; whereas if the zero emission option is scalable to the region, it could be capable of reducing 19% of port-related DPM emissions.

From an economic feasibility perspective, a fixed guideway option must compete with current drayage services performed using trucks. If the cost to use the fixed guideway option is greater than the drayage truck rates, then it will not be able to compete in the market, and will therefore not be financially viable. Fixed guideway concepts are the most expensive zero emission options, requiring significant capital investment for construction costs, acquisition of right of way, and loss of revenue for physical land area dedicated to the loading stations. Some of the respondents to the RFCS understated these costs. Hence, the RFCS review team concluded that the commercial financing assumed by some of the respondents may not prove to be readily available at terms that would enable a financially sustainable technology deployment. The conclusion of the port evaluation team was that, under best case assumptions regarding growth in container volume and share of container drayage market capture and absent environmental regulation or significant subsidies, a fixed guideway option will have difficulty competing economically with conventional truck drayage.

A variation on the fixed guideway concept is to adapt LSM to be integrated into existing rail tracks connecting marine terminal on-dock rail facilities with near-dock intermodal rail facilities. This concept offers the potential benefits of lower capital development costs and eliminates right-of-way acquisition issues. LSM technology will be further discussed in Section 3.7 – Zero Emission Options for Regional Rail Locomotives.

3.4.5 Evaluation of Zero Emission for Short-Haul Drayage

The two zero emission options for short-haul drayage, electric trucks and fixed guideway system, were evaluated using the evaluation criteria defined in Section 3.3. The result of this evaluation is provided in Table 1 and discussed below.

Table 1: Assessment of Zero Emission Options for Short-Haul Drayage

Evaluation Criterion	Electric Trucks	Fixed Guideway
Emissions and Health Risk Reduction	Excellent	Excellent
Constructability	Excellent	Poor
Technology Readiness	Satisfactory	Poor
Operations Compatibility	Good	Unacceptable
Regional Scalability	Satisfactory	Unacceptable
Cost and Economic Sustainability	Good	Unacceptable
Timeline for Implementation	Satisfactory	Poor

Excellent Good Satisfactory Poor Unacceptable

Each evaluation criterion is discussed below relative to the two general options:

- Emissions and Health Risk Reduction – both an electric truck and fixed guideway system offer zero emission container transport. It should be noted, however, that a fixed guideway system implementation timeline is significantly longer than the deployment of electric trucks; thus, emission and health risk reductions will be realized sooner under the electric truck option, contributing to achievement of the San Pedro Bay Standards;
- Constructability – Battery electric trucks operate on existing roadways and require no additional right of way or significant infrastructure development. Electric trucks using an OCS or wayside power would require construction of additional infrastructure; however, this is a potential longer term option for short-haul drayage if needed to extend the range beyond what can be provided by the on-board battery system. A new fixed guideway requires acquisition of right of way both within and outside of port boundaries as well as construction of the actual guideway which must connect to all 13 container terminals, the near-dock rail yard and possibly other near-port destinations;

- Technology Readiness – battery electric trucks are being demonstrated today with the goal of moving towards commercialization. Fixed guideway technologies, such as maglev and LSM are in the initial research and development stage of technical readiness;
- Operations Compatibility – Electric trucks, especially those powered by an on-board energy source such as batteries, can be seamlessly integrated into ongoing short-haul drayage operations assuming they have adequate range to perform the work and can be recharged in an acceptable amount of time. A fixed guideway solution would require significant changes to container handling practices within a marine terminal environment, including but not limited to container loading and unloading from the fixed guideway;
- Regional Scalability – Electric trucks, when operational, may be deployed throughout the SoCAB, and development of technology to extend the operational range of electric trucks is ongoing. A fixed guideway would be isolated to the specific locations where it is connected, and therefore does not offer the same level of flexibility and regional scalability;
- Cost and Economic Sustainability – Electric trucks currently carry a price premium and successful deployment of large numbers of zero emission trucks will most likely require funding incentives on an interim basis. It is assumed that such incentives will be made available, as they have been in the past for alternative fuel vehicles. Economies of scale, especially in high cost components such as batteries, will reduce the incremental cost of an electric truck as compared to a conventional diesel vehicle. A fixed guideway system requires significant capital development expenditure and must compete with drayage trucks performing short-haul drayage. The results of the ports' RFCS evaluation suggest a fixed guideway system is not economically competitive for short-haul drayage and not financially sustainable barring significant on-going cost subsidies;
- Timeline for Implementation – Electric trucks are undergoing demonstration in port duty cycles now and more zero emission truck concepts are expected to be demonstrated in the near future. A fixed guideway solution will require many additional years of research and development, design, environmental planning, and construction.

3.4.6 Recommendations for Short-Haul Drayage

The first critical piece in the zero emission roadmap is to continue the demonstration and refinement of zero emission, battery electric trucks for short-haul drayage operations by conducting technical evaluations and testing under the TAP. The goal of these efforts is to ensure the technologies can meet the demands of the port duty cycle, provide the technology developers with a test bed to refine their system designs, and ultimately to accelerate commercialization of zero emission trucks for port operations. *Demonstration and commercialization of zero emission trucks is the #1 priority as it relates to implementing zero emission technologies for short-haul drayage.*

Electric trucks offer:

- Seamless integration into ongoing port operations and offer the highest level of operational flexibility;
- Can be incrementally integrated into port drayage operations;
- Offer flexibility for scaling up to meet the regional needs;
- Do not require construction of new infrastructure or acquisition of right-of-way; and
- Appear economically viable with a high likelihood of self-sustainability as anticipated economies of scale and market forces lower vehicle acquisition costs.

In the near term, the demonstrations of zero emission trucks that are currently underway through the TAP are designed to address the need for zero emission, battery electric technologies for short-haul drayage. The Vision Tyrano truck was delivered in July 2011 and the Balqon truck will be delivered by 3rd Quarter 2011. Both trucks will undergo an 18-month demonstration period in accordance with an approved Demonstration and Test Plan. In addition, the ports will continue to evaluate new technology options by proposers through the TAP. Industry representatives will participate in these projects as demonstration partners and in an advisory capacity, along with the TAP Technical Advisory Committee (TAC), which includes the ports, EPA, CARB and AQMD.

In the longer term, the ports could:

- Continue to move forward with TAP demonstrations of advanced zero emission technologies for short-haul drayage, including conducting broader operational and durability testing, as needed;
- Promote improvements in battery technologies through the TAP;
- Identify funding support for additional demonstration tests;
- Work with industry to evaluate operational compatibility of larger-scale zero emission truck deployment;
- Assist with identifying funding support for purchases of zero emission trucks;
- Assess the need for battery charging and hydrogen fueling infrastructure with larger-scale zero emission truck deployment, and assist as needed and appropriate; and
- Evaluate overhead catenary or other wayside power systems for short-haul drayage, considering at a minimum, the benefits that could be offered beyond the capabilities of a zero emission truck with an on-board battery system, the cost, and the operational constraints.

3.5. Zero Emission Options for Medium-Haul Container Drayage

Medium-haul drayage has been defined as having two subcategories: local drayage, within 20 miles of the ports, and regional drayage, to destinations 20 miles beyond the ports but within the SoCAB.

The implementation of zero emission options beyond the ports' boundaries presents an array of challenges far greater than those associated with short-haul container movement. Outside the ports, issues such as right of way, jurisdictional authority, infrastructure requirements, and particularly cost become primary issues that must be resolved before any specific zero emission option can be deemed fully viable. The implementation of zero emission options beyond the ports' boundaries will require the coordinated efforts of multiple regional stakeholders, including but not limited to Metro, SCAG, Gateway Cities, and AQMD. Therefore, staff recommends that collaboration with regional stakeholders be the first step in a zero emission roadmap for medium-haul container drayage.

3.5.1 Performance Requirements for Medium-Haul Drayage

Medium-haul drayage consists primarily of the movement of cargo along local and regional freight corridors. Typically, medium-haul drayage includes container moves originating or terminating at the ports and having the other end point of the move between six (6) and 60 miles in length - this range effectively covers drayage operations between the ports and distribution centers in the Inland Empire.

While short-haul drayage can be typically characterized by a single duty cycle, medium-haul drayage, from an operational and performance requirements standpoint, is comprised of two duty cycles, represented as follows:

Local Dray (6 to 20 miles) - Creep → Low Speed Transient → Long High Speed Transient

Regional Dray (20+ miles) - Creep → Low Speed Transient → High Speed Cruise

The primary difference between the local and regional cycles is the duration of the high speed portion of the duty cycle. However, as shown below, the average length of a regional medium-haul dray is *five times* that of a local haul:

	Local Haul	Regional Haul
• Average Duration of Container Dray:	64 minutes	118 minutes
• Average Truck Speed:	10.2 mph	27.3 mph
• Maximum Truck Speed During Haul:	48.7 mph	57.6 mph
• Average Medium-Haul Distance from Port:	11 miles	54 miles
• Number of Stops During Dray:	46 stops	33 stops
• Percentage of Time Spent Idling:	41%	25%

The duty cycle requirements for medium-haul drayage, especially those conducted along regional corridors, are significantly more demanding on a truck compared to the short-haul duty cycle discussed in the preceding section. Medium-haul increases the range requirements of a zero emission technology by an order of magnitude compared to short-haul, and in the case of electric trucks, pushes the limits on range that can reasonably be expected from today's state-of-the-art battery-electric drive systems.

Also, drayage truck operations on a local or regional scale are conducted with greater periods of sustained, high speed operation. High speeds under heavy loads quickly consume energy stored within a vehicle's battery pack, dramatically reducing the electric truck's overall range.

3.5.2. Technology Development Status for Medium-Haul Drayage

To expand the capabilities of zero emission drayage trucks beyond the short-haul duty cycle, the introduction of additional zero emission technologies that substantially increase the vehicle's range will be required. Candidate zero emission technologies to extend the range of an electric truck include:

- Extended range battery packs through advanced battery technology, additional storage, or maximizing battery efficiency;
- Augmentation of on-board battery storage, such as hydrogen fuel cells; and
- Use of wayside power, including OCS and incorporation of linear inductive motors or LSM embedded in the roadway pavement.

Current battery technologies do not provide adequate range at a reasonable cost. While efforts are being made to improve battery technologies, no cost-effective options are expected to become available for the Class 8 truck application in the near term. Using an on-board fuel cell as a range extender will be tested by the ports Vision Tyrano truck project starting later this year and continuing for an 18-month demonstration period, however reliability in the short-haul application must first be proven before proceeding with a longer range test. OCS has been used for buses that travel along fixed routes. While the technology is potentially applicable to zero emission Class 8 trucks, further testing would be necessary to determine how such a system could be integrated into existing operations given the wide variety of routes and destinations for drayage trucks throughout the region. Further, an electric truck would be needed to connect to the system, and as stated previously, no such truck is commercially available at this time. A demonstration of this technology could be a logical follow-on after the short-haul drayage truck demonstrations have been conducted. Finally, application of wayside power embedded in the roadway to power electric trucks has never been tested for this type of operation. Development of a system would require significant research and development work before it could be implemented on a large scale.

3.5.3 Evaluation of Zero Emission Options for Medium-Haul Drayage

The criteria established by the ports to evaluate candidate technology options could be used to evaluate technologies for medium-haul drayage. As identified above however, medium-haul drayage is not just a port issue and criteria development and technology evaluation must be conducted in collaboration with regional stakeholders such as Metro, SCAG, Gateway Cities, and AQMD. The ports will seek to work with these and other stakeholders to develop collective criteria to evaluate regional zero emission technology options.

3.5.4 Recommendations for Medium-Haul Drayage

Zero emissions options addressing medium-haul drayage must be compatible with other solutions being developed for the region. Therefore, development of strategies will require a broad-based partnership to make zero emission options a reality.

In the near term, the ports should focus their efforts on the following:

- Establish a regional partnership including Metro, SCAG, Gateway Cities, AQMD, and others and work together to define regional zero emission freight transport needs and develop criteria for evaluating options for moving forward with zero emission technology on a regional scale;
- Build on and leverage the technology platform demonstrated for short-haul drayage;
- Work collaboratively with the regional partners to identify and evaluate specific range extension options for zero emission truck technologies, including hybridization, in-road LSM and OCS; and
- Work with the regional partnership to identify potential funding sources.

In the longer-term, the ports should work with the regional partnership to implement the agreed upon regional strategy, which could include:

- Work on regional zero emission freight strategy implementation, including demonstrating transitional technologies and technologies to extend zero emission truck range;
- Assist with zero emission truck deployment by identifying funding opportunities and assisting with charging, wayside power or hydrogen fueling infrastructure as appropriate; and
- Collaboration on further improvements in battery technologies.

3.6. Zero Emission Options for Cargo Handling at Marine and Intermodal Terminals

Container movement through a marine or intermodal terminal is currently performed by various types of CHE. CHE includes all vehicles and equipment that move cargo, containers, and bulk materials to and from marine vessels, railcars, and on-road drayage trucks.

At existing marine or intermodal terminals, the pathway to zero emission operations is likely to occur through the incremental transition of existing types of CHE and vehicles to zero emission operation, similar to the path recommended for electric short-haul drayage trucks. It is also probable that a terminal that transitions its fleet of conventional CHE to electric operation would at some point consider electrifying the terminal and/or converting some portion of their terminal to a semi-automated container movement system.

3.6.1 Zero Emission Cargo Handling Equipment

Due to the diversity of cargo handling requirements within a marine or intermodal terminal, there is a wide range of specialized CHE, each type of equipment performing a specific function. The majority of the CHE can be classified into one of the following equipment types:

- Forklift
- Rubber Tired Gantry (RTG) crane
- Side Pick
- Other equipment[9]
- Sweeper
- Top Handler
- Yard Tractor

A breakdown of CHE operating at the San Pedro Bay Ports is shown in Table 2[10]:

Table 2: CHE Composition at the San Pedro Bay Ports

CHE Type	POLB		POLA		Combined Ports	
	# of units	% of CHE Fleet	# of units	% of CHE Fleet	# of units	% of CHE Fleet
Forklift	252	19%	538	27%	790	24%
RTG	89	7%	108	5%	197	6%
Side Pick	34	2%	40	2%	74	2%
Sweeper	22	2%	15	1%	37	1%
Top Handler	154	11%	154	8%	308	9%
Yard Tractor	713	52%	962	48%	1,675	50%
Other	94	7%	183	9%	277	8%
Total	1,358	100%	2,000	100%	3,358	100%

[9] Other equipment includes but is not limited to construction-related equipment, non-container moving cranes, miscellaneous warehouse equipment, and utility and support vehicles.

[10] Source: 2009 POLA and POLB Emissions Inventories

The relative contribution of each type of CHE to the emissions at the combined ports is shown in Table 3. Yard tractors that comprise 50% of the CHE fleet account for 51% of total CHE DPM and 42% of total CHE NOx emissions. Top handlers, which comprise only 9% of the total CHE fleet, account for 22% of total CHE DPM and 27% of total CHE NOx emissions. In contrast, forklifts which account for 24% of all CHE represent only 5% of total CHE DPM and 8% of total CHE NOx emissions.

Table 3: Relative Emission Levels of CHE Types at the Combined Ports

CHE Type	DPM (tpy)	% DPM of Total CHE Fleet	NOx (tpy)	% NOx of Total CHE Fleet
Forklift	2	5%	102	8%
RTG	4	9%	142	11%
Side Pick	1	2%	41	3%
Sweeper	0	1%	8	1%
Top Handler	9	22%	350	27%
Yard Tractor	22	51%	560	42%
Other	4	10%	115	9%
Total	42	100%	1,318	100%

3.6.2 Performance Requirements for Cargo Handling Equipment

A challenge with implementing zero emission technologies for CHE is the diversity of CHE duty cycle requirements, which vary by type of equipment. Performance requirements for specific types of CHE are shown below in Table 4:

Table 4: Typical Performance Requirements for Port Cargo Handling Equipment

			POLA			POLB		
CHE Type	Typical Duty Cycle	CHE Operations Description	Engine Size (avg. HP)	Load Factor	Average Hours per Year	Engine Size (avg. HP)	Load Factor	Average Hours per Year
Forklift	Operate two 6.5-hour shifts per day, 5-6 days per week.	Used to move cargo, truck chassis, or other equipment short distances for placement on or removal from stacks	105	0.3	848	106	0.3	426
RTG	Operate two 7-hours shifts, 4 days per week.	Used to stack containers, or move containers on and off yard trucks	543	0.2	1,155	682	0.2	970
Side Pick	Operate two 6.5-hour shifts per day, 5-6 days per week.	Used to stack containers, move containers from one area of the terminal to another, or move containers on and off yard trucks	208	0.59	1,055	181	0.59	602
Sweeper	Operate two 8-hour shifts per day, 5-6 days per week.	Used to clean paved areas in the yard	128	0.68	293	118	0.68	397
Top Handler	Operate two 6.5-hour shifts per day, 5-6 days per week.	Used to stack containers, move containers from one area of the terminal to another, or move containers on and off yard trucks	290	0.59	1,534	294	0.59	1,450
Yard Tractor	Operate two 8-hour shifts per day, 5-6 days per week.	Used to move containers to and from ships or rail, move containers within the terminal, and move containers to and from RTG cranes for placement on or removal from stacks	215	0.39	1,699	189	0.39	1,301
Other	Various special purpose duties	Includes a variety of equipment types including aerial lifts, rail-car movers, and heavy duty off-highway trucks	37 - 401	0.43 - 0.55		37 - 401	0.43 - 0.55	

It is noteworthy that the duty cycle requirements for yard tractors have some similarities to the near-dock/short-haul duty-cycle for on-road drayage trucks discussed in preceding sections. This similarity in operational requirements suggests that zero emission technology solutions that are feasible for short-haul drayage have a high probability of being applicable to yard tractors within a marine terminal.

3.6.3 Technology Status for Zero Emission Cargo Handling Equipment

All of the ship-to-shore gantry cranes in both ports are powered by electricity. In addition, the ports have aggressively advanced technologies that reduce or eliminate emissions from other CHE operating within the terminals. This includes demonstration of bridge technologies on the path towards zero emissions, such as diesel-electric hybrid. These technologies not only provide incremental emission reduction benefits in the near-term, they can provide useful information to benefit the development and demonstration of future advanced technologies. Low emission technology CHE projects undergoing demonstration through TAP are summarized below in Table 5:

Table 5: Interim Technologies Toward Zero Emissions Demonstrated Through TAP

Technology Category	Project	Anticipated Emission Reductions
Hybrid Technologies	Vycon REGEN System for RTGs	25% DPM; 30% NOx; 30% CO2
	Capacity Plug-In Hybrid Yard Tractor	60% CO2
	Diesel-Electric Hybrid Yard Tractor	93% DPM; 5% NOx
	Railpower EcoCrane RTG	75% DPM and NOx
Alternative Fuel Technologies	LNG Yard Tractors (2005 Model Year)	100% DPM; +21% NOx; 18% CO2
	APT Emulsified Biodiesel	40% DPM
Retrofit and Exhaust After-treatment Technologies	Rypos Active Diesel Particulate Filter	85% DPM

In addition, the ports are also conducting demonstrations of zero emission technologies, as identified below:

- Balqon Lead-Acid Battery Yard Tractor;
- Balqon Lithium-Ion Battery Yard Tractor;
- Balqon Lithium-Ion Battery Yard Tractor integrated with a Vision Motor Hydrogen Fuel Cell; and
- Vision Motor Hydrogen Fuel Cell/Plug-In Electric Yard Tractor.

As discussed in Section 3.4.2, the Port of Los Angeles and AQMD contracted with Balqon to develop and demonstrate a battery-electric truck. The Port of Los Angeles has ordered Nautilus E-20 units with lead acid batteries and is currently releasing them in a demonstration program at non-container terminals where the duty cycle is less demanding. The next generation E-20 units are equipped with lithium ion batteries, some with range extending hydrogen fuel cells for on-board charging. These next generation E-20 units will be released for demonstration at a trucking company-based container facility with plans to demonstrate them at marine container terminals thereafter. Vision Motor's Hydrogen Fuel Cell/Plug-In Electric Yard Tractor is currently being produced and is expected to be tested at a trucking company-based container facility in 2011.

Manufacturers of conventional diesel yard tractors have also expressed interest in offering electric versions of their existing product line; thus, it is anticipated that additional manufacturers will enter the electric yard tractor marketplace in the future.

For RTGs, electric conversion kits are commercially available and have been used in other countries. RTGs can be electrified by retrofitting the units with a kit (cable reel, transformer and interface) to allow the RTG to utilize grid electricity. The Port of Los Angeles is currently pursuing an electric RTG crane project with one terminal operator; two terminal operators in Port of Long Beach had initially pursued RTG crane electrification projects and were awarded $2.5 million grants from the port in 2007, however both projects were cancelled due to financial constraints and/or a decision by the terminal operator to wait until the project would better fit into future terminal plans.

Similar to electric RTGs, rail mounted gantry cranes or RMGs, are also powered by electric grid power. RMGs travel forward and backward along a fixed rail. RMGs are currently in use in rail yard operations at ICTF and terminal operations at APL in Port of Los Angeles.

3.6.4 Evaluation of Zero Emission Technologies for Cargo Handling at Marine Terminals

The evaluation criteria introduced in Section 3.3 were applied to individual CHE types at the "vehicle level" to identify and prioritize zero emission CHE opportunities for existing marine and intermodal terminal operations. Note that the evaluation included only those equipment types for which staff had information at this time on electrification or zero emission technology options. As part of recommended next steps, zero emission technologies will be identified and advanced for all CHE types. Note that the "regional scalability" evaluation criterion does not apply when evaluating zero emission options for CHE, since these vehicles are a captive fleet at a terminal. The evaluation results are provided below in Table 6.

Table 6: Evaluation of Marine and Intermodal Terminal Cargo Handling Options

	Zero Emission Cargo Handling Equipment			
Evaluation Criteria	**Yard Tractor**	**RTG**	**RMG**	**Forklift**
Emissions and Health Risk Reduction	Excellent	Excellent	Excellent	Good
Constructability	Excellent	Good	Good	Excellent
Technology Readiness	Satisfactory	Excellent	Excellent	Satisfactory
Operations Compatibility	Good	Good	Satisfactory	Good
Regional Scalability	N/A	N/A	N/A	N/A
Cost and Economic Sustainability	Good	Good	Good	Good
Timeline for Implementation	Satisfactory	Good	Good	Satisfactory

Excellent   Good   Satisfactory   Poor   Unacceptable

A discussion regarding CHE relative to each criterion is provided below:

- Emissions and Health Risk Reduction – All of the zero emission CHE offer significant emissions reduction. It should be noted, however, that many of the forklifts already operate on propane, and a few of the smaller forklifts are battery powered. Therefore, the emissions reduction potential for forklifts is slightly less than for the other diesel equipment.

- Constructability – Zero emission yard tractors and forklifts would operate on the existing terminals and would only require installation of electric battery charging capabilities, if necessary. Electric RTGs and RMGs would require construction of electrical infrastructure, potentially guard rail systems to protect the infrastructure and, in the case of RMGs, construction of rail tracks.

- Technology Readiness – Zero emission yard tractors are in the development stage, as battery-electric and zero emission hybrid-electric yard tractor prototypes are undergoing development and demonstration in port-related operations. Zero emission forklifts are commercially available for the smaller horsepower range (~100 hp), but development work is needed to apply zero emission technology to heavy-duty forklifts in port container terminal operations. Electric RTG retrofits, electric RMGs and forklifts are commercially available and have been used in port-related operations.

- Operations Compatibility - Electric yard tractors and forklifts offer a high level of compatibility with ongoing terminal operations and can be seamlessly integrated into a marine or intermodal terminal incrementally. Accommodation will need to be made for recharging, as needed; however a goal of the TAP demonstrations will be to evaluate any impacts on operations from recharging. When integrating electric RTGs and RMGs into operations, some of the current flexibility offered by traditional diesel-powered RTGs will be lost. In particular, the installation of electric infrastructure and rail tracks for RMGs requires that the electric RMGs be fixed to a specific location which will limit the ability to make adjustments to yard configurations. Some terminal operators have stated that this inflexibility is incompatible with their current operations, and therefore further evaluation on how this technology could be integrated into existing operations may be needed in some cases. Converting an RTG to electric requires electrical infrastructure, but it is only semi-fixed and therefore provides greater flexibility for future yard re-configuration. In addition, as an interim measure, the ports are continuing demonstration of low-emission technologies for RTGs that are not converted to a zero emission configuration.

- Cost and Economic Sustainability – In the near term, electric CHE will most likely require incentives to partially offset the higher capital acquisition costs of battery electric vehicles and equipment. From a life cycle cost perspective, it is anticipated that the terminal operators will realize lower operating costs tied to lower fuel costs and lower equipment maintenance costs.

  Electric yard tractors also share common technology and components with electric short-haul drayage trucks; this commonality leverages prior investments and should generate manufacturing economies of scale, reducing future costs for vehicle acquisition. It is also expected that electric drive system designs and components developed for yard tractors can and will be adapted to other types of CHE, such as top handlers and side picks. This transferability will further leverage zero emission technology investments.

- Timeline for Implementation – Electric yard tractors are undergoing demonstration in port duty cycles now and more concepts are anticipated to be demonstrated in the near future. Electric RTGs, RMGs and smaller forklifts are commercially available. Electric RTGs or RMGs are currently being implemented in new or redeveloped terminal projects.

3.6.5 Recommendations for Cargo Handling Equipment

The ports recommend the following near-term course of action:

- Continue to sponsor the demonstration of electric CHE by port tenants in cargo handling operations. Electric yard tractor prototypes are currently under development through the TAP program, and the priority of port staff is to demonstrate the capabilities of electric yard tractor technologies in meeting port duty cycle requirements. These demonstration tests will also need to determine overall integration into operations, including battery charging/fueling requirements. The advanced lithium-ion battery Balqon yard tractor is undergoing preliminary testing and will be delivered for testing in container terminal operations by 3rd quarter 2011. The prototype Vision Motors zero emission yard tractor is also anticipated to be delivered for testing by 3rd quarter 2011. Both units will immediately begin an 18-month demonstration period in accordance with an approved Demonstration and Test Plan. The goal is to have zero emission yard tractors fully developed, tested, and commercially available within the next 2 -3 years.

  The top priority is to bring electric yard tractor technologies successfully through the development and demonstration phase, including operational integration, resulting in the commercial availability of zero emission yard tractors in the near term.

  Advanced yard tractor technologies, such as diesel hybrid electric, have also been successfully demonstrated under the TAP. These technologies have the potential to achieve near-term emission reductions from diesel-fueled yard tractors and can serve as bridge technologies until electric yard tractors are fully commercialized.

  Because battery electric yard tractors are anticipated to carry a cost premium compared to conventional diesel yard tractors, the availability of financial incentives to buy down a portion of the incremental capital cost of the electric technology may be necessary in the near term. Dedicated electric yard tractor recharging infrastructure may also be required and will add additional cost. Costs for equipment maintenance however are expected to be reduced from conventional equipment. To fully or partially offset the incremental cost for zero emission technologies that reduce emissions above and beyond the CARB Cargo Handling Equipment rule, the ports should encourage agencies such as the Department of Energy (DOE), California Energy Commission (CEC), EPA, CARB and AQMD to make financial incentives available.

- Continue to work with terminals operators to select additional zero emission CHE technologies for demonstration through the TAP process, with oversight by the TAC.

- Working with a terminal operator in the Port of Long Beach, the ports commissioned the development of performance specifications for yard tractors. The final specification information, which was completed in 2009, is posted on the ports' CAAP website. The ports continue to work with terminal operators to develop performance specifications for additional equipment types, operational requirements, and integration strategies for zero emission cargo handling equipment.

- Continue to facilitate the electrification of RTGs. Kits that convert diesel generator powered RTG cranes to grid electricity are commercially available. The ports should continue to facilitate implementation of this technology for port terminals, where feasible, through ensuring adequate electrical capacity and infrastructure at the terminals. The ports should also encourage the agencies, such as DOE, CEC, EPA, CARB, and AQMD, to make financial incentives available to offset incremental costs. The ports can also apply for grants from government agencies on behalf of port terminal operators as needed.

- Expansion of RMGs into terminal operations, as feasible and appropriate, should also be encouraged. Typically, because RMGs require installation of rail tracks, implementation of RMGs will be more appropriate during new terminal construction or renovation of existing terminals. The ports are currently requiring electric RTGs or RMGs in new or redeveloped terminal projects.

- As needed, the ports can also apply for grant funding assistance on behalf of terminal operators to support zero emission CHE demonstration and deployment at marine and intermodal terminals. Each port has previously provided this type of support to their terminal operators for equipment retrofit, replacement and repower projects by applying to grant programs that are only available to government entities.

In the longer term, the ports could also:

- Continue to move forward with TAP demonstrations of advanced zero emission technologies for all CHE, including broader operational and durability testing. The ports should pursue the demonstration of electric technology applied to other types of CHE, specifically container top-handlers that comprise 9% of the ports' CHE equipment inventory but account for 22% of total CHE DPM emissions and 27% of total CHE NOx emissions;

- Continue to facilitate electrification of RTGs and RMGs, and work with marine and intermodal terminals to identify additional opportunities for integrating and implementing zero emission terminal operations;

- Promote ongoing improvements in battery technologies through the TAP;

- Assess the need for battery charging or hydrogen fueling station infrastructure with larger-scale zero emission CHE deployment, and assist as needed and appropriate;

- Assist with identifying funding support for purchases of zero emission equipment and/or terminal electrification, which may include applying for grants on behalf of terminal operators.

3.7. Zero Emission Options for Regional Rail Locomotives

The ports understand that locomotive emissions impact communities near the port complex and along goods movement rail corridors within the SoCAB. Thus, there is a compelling need to address locomotive emissions both at the in-port and regional levels. While the challenges presented in adapting zero emission technologies to rail locomotive operations are considerable, they are by no means insurmountable.

The ports, in partnership with rail stakeholders from both government and industry, must develop a recommended course of action to substantially reduce emissions from rail locomotives at both the in-port and regional levels. It is essential that any zero emission rail concept identified for possible implementation be developed and demonstrated with the cooperation and concurrence of several key stakeholders, particularly the U.S Department of Transportation Federal Railroad Administration (FRA) and the Class 1 railroads that serve the ports, BNSF Railway and UP Railroad. Further, it must be understood that due to the complexities associated with zero emission rail technologies, the timeframe for zero emission integration with rail operations is substantially longer compared to technology options for other sources discussed in this report. Therefore, the ports must continue to pursue the CAAP strategies in the interim for reducing rail emissions, even as they work to identify viable and feasible zero emissions options for the long term that could be integrated into railroad operations.

The application of zero emission technologies to rail locomotive operations within and beyond port boundaries is a far more complex task than for short-haul drayage and CHE. First, the technical and programmatic assessments conducted by the ports relative to port-related rail operations revealed that implementation challenges will exist related to right of way entitlements and future track capacity to accommodate optimized or high frequency container moves by rail between marine terminals and near-dock intermodal facilities. Second, the ports' authority as it pertains to rail operations is limited, specifically on the Alameda Corridor and particularly beyond port boundaries. However, despite these challenges, the long-term implementation of zero emission technologies for rail operations must be pursued in cooperation with all stakeholders to address in-port and regional locomotive emissions.

3.7.1 An Overview of Rail Operations at the San Pedro Bay Ports

Port rail emissions represent 5% of the combined ports' total emissions inventory for DPM and 8% of the NOx emissions. Port efforts to further reduce port-related rail emissions remain a main concern. In fact, the effort to utilize best available control technologies to mitigate locomotive emissions is a priority of the ports' TAP.

Railroad operations at the ports are typically described in terms of two different types of operation, line-haul and switching. Line-haul refers to the movement of cargo over long distances (e.g., cross-country) and occurs within the port as the initiation or termination of a line-haul trip, as cargo is either picked up for transport to destinations across the country or is dropped off for shipment overseas. Switching refers to short movements of rail cars, such as in the assembling and disassembling of trains at various locations in and around the ports, sorting of cars of inbound cargo trains for subsequent delivery to marine terminals, and short distance hauling of rail cargo within the port complex.

The ports are served by three rail companies:

- BNSF Railway
- UP Railroad
- Pacific Harbor Line (PHL)

BNSF and UP are designated Class 1 railroads[11] and operate both within and outside of the port boundaries. Both operate national fleets under the regulations and scrutiny imposed by the FRA. PHL is the switcher locomotive operator within the port boundaries, controlled under operating agreements with both ports. Locomotives used for line-haul operations are typically equipped with large, powerful engines of 4,000 horsepower (hp) or more, with each railroad operating a variety of different locomotive models. Switcher locomotives are smaller, typically having one or more engines totaling 1,200 to 3,000 hp.

3.7.2 Ongoing Efforts to Reduce Locomotive Emissions

The 2010 CAAP Update includes measures targeting continued reductions in locomotive emissions. Specifically, CAAP Measure RL3 ("New and Redeveloped Near-Dock Rail Yards") outlines the strategy to achieve significant reductions in locomotive emissions through the accelerated turnover of the existing locomotive fleet, replacing existing locomotives with newer, lower emitting models. The goal of this measure is to have the Class 1 railroads incorporate the cleanest locomotive, CHE, and HDV technologies into near-dock operations. Measure RL3 establishes the goal that the Class 1 locomotive fleet associated with new and redeveloped near-dock rail yards meets a minimum performance requirement of an emissions equivalent of at least 50% Tier 4 line-haul locomotives and 40% Tier 3 line-haul locomotives when operating at the port properties by 2023, to support CARB's published goal of 95% Tier 4 line-haul locomotives serving the ports by 2020. In addition, RL3 will implement idling restrictions, the use of cleaner fuels and evaluation of cleaner locomotive technologies.

[11] The Surface Transportation Board defines a Class I railroad in the United States as "having annual carrier operating revenues of $250 million or more" after adjusting for inflation using a Railroad Freight Price Index developed by the Bureau of Labor Statistics.

Additionally, the ports amended PHL's operating agreements in 2006 to provide funding assistance for the replacement of PHL's existing locomotives with new locomotives meeting Tier 2 emission standards. The locomotives purchased under the amended agreements were delivered during 2007 and 2008; and immediately thereafter, PHL retired the last of the pre-Tier 2 locomotives. Since 2009, PHL's fleet has consisted of 16 Tier 2 locomotives and six "multi-engine genset switcher" locomotives that are powered by three relatively small diesel engines rather than one large engine. These multi-engine genset switcher locomotives use Tier 3 engine technologies. Further, under subsequent amendments to the operating agreements in 2010, PHL is now moving forward with repowering the 16 Tier 2 locomotives with engines that meet even cleaner Tier 3 + standards prior to the end of 2011.

Finally, the ports and UP are participating in an emerging technology demonstration of a Johnson Matthey diesel particulate filter retrofit device for locomotives, anticipated to reduce DPM emissions by over 85%. The project is being funded by a combination of a grant from CARB secured by the ports and TAP funding.

3.7.3 Jurisdictional Authority

The vast majority of line-haul trains bound for destinations outside the port utilize the Alameda Corridor, a 20-mile dedicated rail line running between the San Pedro Bay area and downtown Los Angeles. The ports' ability to impose zero emission requirements on Class 1 locomotives that use the Corridor is substantially limited by the 1988 Alameda Corridor Use and Operating Agreement between the Cities of Los Angeles and Long Beach, ACTA, BNSF and UP.

Beyond the Alameda Corridor Use and Operating Agreement, the ports also have long-term agreements with BNSF and UP that guide track use. These "Use of Tracks" agreements contain long-term conditions that cannot be changed via lease or tariff.

Further, Class 1 locomotives and rail transportation are regulated on a federal level by the EPA, FRA and STB. The EPA adopts emission standards for new and re-manufactured locomotive engines and approves state implementation plans under the Clean Air Act. CARB has entered into voluntary Memorandums of Understanding (MOUs) with the Class 1 railroads to achieve emission and health risk reductions through accelerated turnover of older locomotives with newer, cleaner locomotives and through measures to reduce impacts from railyard operations.

Given the existing agreements and jurisdictional limitations, development and demonstration of zero emission technologies and measures to implement these technologies are most effectively accomplished through a cooperative partnership with the railroads and participating railroad authorities.

3.7.4 Status of Zero Emission Technologies Applicable to Rail Locomotives

As discussed in Section 1, 94% of DPM emissions and 93% of NOx emissions associated with port-related rail operations in 2009 were generated by line haul locomotives. Port-related locomotive emissions are a regional source of air pollution; thus, zero emission options targeting locomotive emissions should be primarily pursued on a regional scale, with the prospect that these options may potentially be applicable to in-port operations.

All zero emission options identified for regional rail use electricity. Rail electrification options that may need to be explored include, but are not limited to:

- Incorporation of LSM technologies into existing rail beds;
- OCS to power electric or dual-mode locomotives; and
- Battery electric tender car.

There are significant operational issues that must be addressed when contemplating the use of rail-related zero emission technologies on a regional scale within the SoCAB, specifically availability of electrification infrastructure and use of dedicated electric-powered locomotives. For example, it must be determined how a dedicated electric-powered locomotive will continue to operate beyond the end of the SoCAB's geographic boundary, if its power source does not continue beyond the SoCAB. The railroads have expressed concerns about any zero emission option that requires a change out of locomotives upon entering or leaving the SoCAB. This presents a serious operational constraint to advancing dedicated electric-powered locomotives as a viable option.

When considering these operational constraints, LSM technology has several potential advantages that warrant further consideration:

- LSM can be adapted to existing rail beds, but does not require electrification of the rails themselves. This propulsion system consists of concrete-encased motor winding modules mounted between rails that provide a magnetic field. Permanent magnets are attached to the bottom of a standard rail car carrying a fully loaded single or double-stacked container. This all-electric approach is free of any exposed high-voltage third rails or OCS wires. Power is provided only to the area of track around each vehicle by using solid-state electronic switches. There is no conflict with conventional diesel locomotives using tracks retrofitted with LSM.

- Conventional rail cars can be used on LSM-equipped track with minimum modifications. A standard rail car is equipped with two wheel "bogies" (the truck that secures the steel wheels and suspension components). Each rail car bogie is modified with the installation of a magnet module containing arrays of permanent magnets. These magnet arrays interact with the magnetic field induced in the LSM motor modules and provide the thrust to move and stop the rail car. The system as conceived will be capable of propelling very large loads, including multiple double-stacked railcars. The width of the LSM modules and the length of the magnet arrays will be based on the specifics of the application, but hold the potential to propel complete trains. No modifications are required on the locomotives themselves.

- LSM can be integrated into existing rail beds incrementally. On LSM-equipped track, the locomotive can operate in a zero emission mode; then at the end of the LSM line, the diesel locomotive engine can be started and continue in a conventional operations mode;

- LSM is an option that is ready for prototype development and demonstration. A demonstration will provide valuable data to better understand how LSM could apply to regional, and potentially in-port, rail operations.

There are some challenges with LSM however that must also be addressed during any evaluation, especially if the technology will be considered for application between the port terminals and the near-dock rail yards. For example, incorporating automation, or self-propelled rail cars, into an LSM option is currently prohibited by the United States Department of Transportation and the FRA, and no LSM technology has been safety certified by the FRA. Further, the existing rail system within the port complex may not have sufficient capacity to accommodate optimized container routing in either an automated or crewed operation mode. Detailed rail simulation and on-dock railyard capacity analysis, based upon current rail planning, indicated that by 2020, there will be insufficient capacity to handle additional LSM rail car moves to and from near-dock railyards beyond normal movement on on-dock trains and other switching movements. Therefore, a thorough understanding of these issues, and the opportunities to overcome them, is an important aspect of the LSM evaluation.

It is also important to note that consistent with the zero emission technology "process approach" and a commitment to preserve flexibility to allow for integration of future advancements, in addition to LSM, other zero emission rail options will continue to be actively identified, evaluated and demonstrated. The TAP will be utilized for this purpose.

3.7.5 Recommendations for Rail Locomotives

The ports' technical and programmatic screening assessment of zero emission technologies for existing rail operations did not identify any solutions that can reasonably be implemented within the near-term (three years). Thus, implementation of CAAP Measure RL3 discussed in Section 3.7.2 is the recommended primary near-term option to address rail locomotive emissions. *Therefore, for near-term in-port and near-dock rail emission reductions, the ports should continue efforts to reduce switch and line-haul locomotive DPM and NOx emissions through implementation of CAAP Measure RL3.*

Both BNSF Railway and UP Railroad have proposed projects forthcoming that will require new or re-negotiated leases. The ports have adopted policies that their leases shall be compliant with the CAAP, and the Boards of Harbor Commissioners have discretion at the time of lease approval to include among the negotiated lease conditions, CAAP Measure RL3 as a lease condition. The Boards have discretion to include other lease conditions, such as a provision that the Class 1 railroads work with the ports to jointly advance zero emission technology demonstrations, and evaluate new feasible technologies for implementation e.g. every seven years (lease reopener). Concurrent with technology demonstrations, collaboration with the railroads and other regional transportation stakeholders should be initiated to identify and better define issues and challenges to implementing zero emission technologies along regional rail corridors from in-port to the edge of the SoCAB.

As regards rail-related zero emission technologies, there is considerable interest to assess the technical feasibility and programmatic viability of applying LSM technology to existing rail infrastructure. AQMD is currently developing a proposal with General Atomics (GA) for demonstration of LSM technology on conventional rail tracks with a single rail car at GA's test facility located in San Diego. The proposed Phase 1 demonstration, or Proof of Concept, is expected to be initiated by 4th Quarter 2011 and would be conducted over an 18-month period. Other partners in this demonstration project could include the Lawrence Livermore National Laboratory and the Center for Commercial Deployment of Transportation Technologies (CCDoTT).

It is envisioned that this first phase Proof of Concept demonstration would be followed by a second phase, 18-month demonstration, with multiple railcars at a rail research and development testing site that can provide FRA certification. The FRA and American Association of Railroads jointly sponsored Transportation Technology Center (TTC) in Pueblo, Colorado offers such a testing site and the Ports, AQMD, and CCDOTT have had exploratory discussions with TTC. To provide technical input and consistency, TTC may participate as a technical observer/advisor in the Phase 1 test at the GA facility.

Staff recommends that discussions continue with all involved parties regarding a near term Proof of Concept demonstration of LSM technology at an offsite test facility. As the proposed demonstration project matures, a staff recommendation for participating in the project as a stakeholder will be brought forward to each port's Board of Harbor Commissioners for consideration, which may include financial participation. It is anticipated that this recommendation will be brought forward to the Boards within the next few months.

Further, if the Phase 1 testing proves that the LSM technology is promising, the ports could participate in the Phase 2 demonstration of the LSM technology applied to multiple rail cars, as appropriate.

The ports should also collaborate with the rail companies and other stakeholders to further evaluate additional zero emission rail technologies, including LSM, OCS, and a battery electric tender car.

In the longer term, beyond three years, the ports should continue to participate, with a stakeholder collaborative, in existing or proposed zero emission rail demonstration projects, as appropriate; continue to collaborate with rail companies and other stakeholders to evaluate strategies for integrating and implementing zero emission technologies into port-related rail operations on a voluntary basis; and work with stakeholders at the local, state and federal levels to secure funding for zero emission rail technologies.

4. Conclusions and Recommendations

As emphasized throughout this report, there is no single off-the-shelf technology or stand-alone strategy to achieve zero emissions at the ports. Instead, attaining zero emission port-related operations will require multiple pathways of action, strong collaborations and regional partnerships, and support – technical, operational and financial – to advance technological innovation and evolution. It is also a dynamic and ongoing process, a framework approach to transition to zero emissions starting with options that can be supported today.

The roadmap defined in this paper is ambitious. It requires near-term commitments and longer term actions from a broad cross-section of stakeholders. Most of all, this roadmap requires flexibility to accommodate new technologies and approaches alongside a commitment to the end goal – achieving the San Pedro Bay Standards – while addressing and overcoming the myriad challenges identified in this report. If successful, however, this roadmap has the potential to dramatically improve air quality for local communities and throughout the region.

The recommendations proposed here – targeting short- and medium-haul drayage trucks, cargo-handling equipment, and rail – adhere to the key principles identified in Section 1.

Recommended near-term and longer term actions are summarized in Table 7.

Table 7: Recommendations for Zero Emission Technology Implementation

Timeline	Source Category	Actions
Near Term **(within 3 years)**	On-Road Drayage	Conduct Technology Advancement Program (TAP) demonstrations of Vision Motors hybrid electric/hydrogen fuel cell and Balqon lithium-ion battery zero emission drayage truck technologies in short-haul port-related operations following approved testing protocols and within specified timelines. Both manufacturers will deliver trucks for testing by 3rd Quarter 2011. Industry representatives will participate in these demonstrations in an advisory capacity, along with the TAP Technical Advisory Committee (TAC), which includes the ports, Environmental Protection Agency (EPA), California Air Resources Board (CARB) and South Coast Air Quality Management District (AQMD); Select additional zero emission truck technologies for demonstration through the TAP process, with input from industry and the TAP TAC; Seek grant funding assistance and industry partnerships to support zero emission truck demonstration and deployment, as needed; Establish regional partnership with the Los Angeles Metropolitan Transportation Authority, Southern California Association of Governments, Gateway Cities, South Coast Air Quality Management District (AQMD), and others. Work together to define regional zero emission freight transport needs and develop criteria for evaluating options for moving forward with zero emission truck technologies on a regional scale; Working with the regional partnership, identify and evaluate specific range extension options for zero emission truck technologies, including hybridization, in-road LSM, and overhead catenary; Work with the regional collaborative to identify potential funding sources.

Timeline	Source Category	Actions
Near Term **(within 3 years)**	Cargo Handling Equipment	Conduct TAP demonstrations of Vision Motors hybrid electric/hydrogen fuel cell and Balqon lithium-ion battery zero emission yard tractor technologies in port-related operations following approved testing protocols and within specified timelines. Both manufacturers will deliver yard tractors for testing by 3rd Quarter 2011; Working with terminal operators, select additional zero emission cargo handling equipment technologies for demonstration through the TAP process, with TAC oversight; Working with terminal operators, develop performance specifications, operational requirements, and integration strategies for zero emission cargo handling equipment; Continue to facilitate electrification of RTGs and RMGs by ensuring adequate electrical capacity is available at marine terminals and require their use in new and redeveloped terminal projects; Apply for grant funding assistance to support zero emission cargo handling equipment demonstration and deployment at marine terminals, as needed.
	Rail Locomotives	Participate (with AQMD, the Center for Commercial Deployment of Transportation Technologies, and other stakeholders) in a proposed Proof of Concept demonstration of LSM technology applied to a single rail car test at the General Atomics facility in San Diego. The project is anticipated to be initiated by 4th Quarter 2011; Collaborate with rail companies and other stakeholders to further evaluate zero emission rail technologies, including LSM, overhead catenary, and battery electric tender car; As appropriate, participate in a Phase 2 demonstration of LSM technology applied to multiple rail cars. The phase 2 test would be conducted at a testing center equipped to provide Federal Railroad Administration certification, such as the Transportation Technology Center rail test site in Pueblo, Colorado.

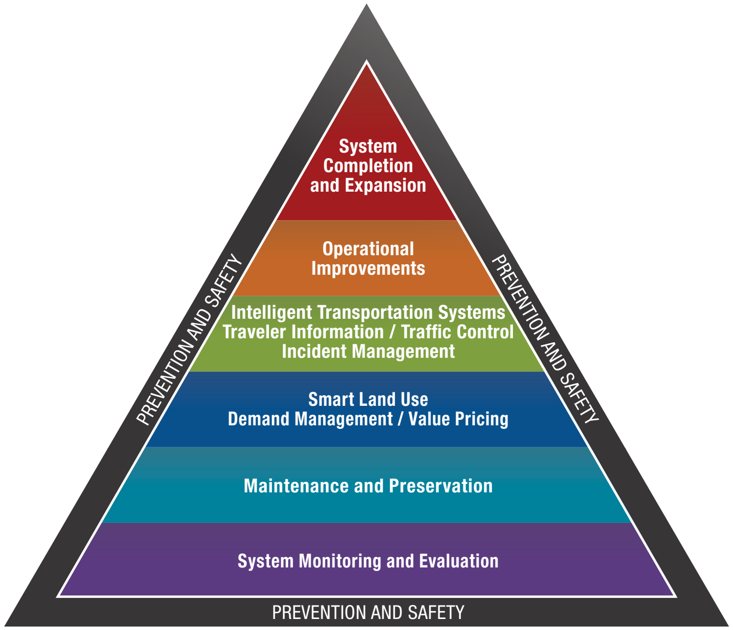
Timeline	Source Category	Actions
Longer Term (>3 years)	On-Road Drayage	Conduct broader operational and durability demonstration testing of advanced zero emission drayage truck technologies in short-haul port-related operations, as needed; Working with industry, evaluate operational compatibility of larger-scale zero emission truck deployment; Work with regional partnership on regional zero emission freight strategy implementation, and on demonstration projects for transitional technologies and technologies to extend zero emission truck range, including hybridization, in-road LSM, and overhead catenary; Assist with zero emission truck deployment by identifying funding opportunities and assisting with charging, wayside power or hydrogen fueling infrastructure as appropriate; Promote on-going improvements in battery technologies through TAP.
	Cargo Handling Equipment	Conduct broader operational and durability demonstration testing of advanced zero emission technologies for all cargo handling equipment, as needed; Assist with zero emission equipment deployment by identifying funding opportunities and assisting with charging or hydrogen fueling infrastructure as appropriate; Promote on-going improvements in battery technologies through TAP; Continue to facilitate electrification of RTGs and RMGs, and work with marine terminals to identify additional opportunities for integrating and implementing zero emission terminal operations.
	Rail Locomotives	Continue to participate, with a stakeholder collaborative, in existing or proposed zero emission rail demonstration projects, as appropriate; Continue to collaborate with rail companies and other stakeholders to evaluate strategies for integrating and implementing zero emission technologies into port-related rail operations; Work with stakeholders to secure funding for zero emission rail technologies.

02 TRANSPORTATION INVESTMENTS

Introduction

SCAG has consistently advocated a system management approach that aims to protect, maximize the productivity of, and strategically expand our region's transportation system. This approach recognizes that we can no longer afford to rely on system expansion alone to address our mobility needs. Rather, an integrated approach is needed, based upon comprehensive system monitoring and evaluation and the use of performance measures to ensure that the best-performing projects and strategies are included in the RTP. This approach is depicted as the mobility pyramid shown in **FIGURE 2.1**.

FIGURE 2.1 Mobility Pyramid



Over the course of developing the plan, we have heard from our stakeholders that we need to make sure we are investing our scarce transportation dollars more efficiently and effectively before we expect our taxpayers to pay more. Making sure that every dollar available is spent wisely is at the heart of this philosophy. At the bottom of this pyramid is System Monitoring and Evaluation. In order to be effective system managers, we must have an in-depth understanding of how our system performs and why it performs the way it does. Only by understanding these causes can we identify the optimal mix of strategies and projects that yield the highest returns on our investments. Next, we must take care of what we have, and make sure that what we have is performing at the most efficient level possible. So, the basic idea as you move up the 'mobility pyramid' is to implement less capital intensive strategies or less invasive strategies before we consider implementing more drastic measures to deal with our challenges. At the same time, we must be realistic about our ability to address our challenges with 'soft solutions' alone in the face of tremendous growth that we anticipate over the next 25 years. Therefore, at the top of the pyramid are the capital improvement projects that will allow us to expand our system strategically to accommodate such future growth and maintain and improve our economic prosperity.

Following the system management philosophy, this chapter sets forth the investments and strategies that constitute the 2012 RTP/SCS. First, transportation investments should seek to optimize the performance of the existing system, and this includes system maintenance and preservation, integrated land use, operational improvements, transportation demand management, and transportation systems management strategies. Second, investments should seek to complete the system by addressing gaps. Finally, our investments should expand the system strategically. As a result, Southern Californians will enjoy more and better travel choices via an efficient multimodal transportation system with improved access to the vast opportunities this region has to offer.

Getting the Most Out of Our System

Over the past half-century, the SCAG region has invested billions of dollars into building and expanding the multi-modal transportation system that we have and rely on today. This investment must be protected. Under the system management approach, priority should be given to maintaining and preserving this system, as well as ensuring that it is being operated as safely, efficiently and effectively as possible. Protecting our previous investments in developing the region's transportation system and getting the most out of every one of its components is the highest priority for this RTP/SCS.

Safety and Security First

SCAG recognizes how important the safety and security of our transportation system is to our residents. The good news is we have made significant progress in improving safety, particularly highway safety, which accounts for the majority of transportation related accidents, around the State and in our region. But, we can do more. SCAG continues to support the implementation of the State Highway Safety Plan (SHSP) and work in partnership with Caltrans and the CTCs around the region to improve Safety and Security of our transportation system.

Safety improvements are intricately woven into the RTP/SCS at all levels. Many of the strategy and investment categories in this RTP/SCS aim to improve the safety of our multi-modal transportation system. For instance, enhancing maintenance and preservation of the region's buses, rail track, bridges, and roadway pavements will contribute towards reduced accidents and improved safety. Similarly, expanding the network of bike lanes and sidewalks, and bringing them into ADA (American with Disabilities Act) compliance will reduce accidents directly related to these modes. Furthermore, deploying technology such as advanced ramp metering to manage traffic flow also reduces collisions at on-ramps and critical freeway-to-freeway interchanges. In short, almost every category of investments discussed in this chapter leads to safety benefits.

SCAG has two main safety and security goals:

- Ensure transportation safety, security, and reliability for all people and goods in the region.
- Prevent, protect, respond to, and recover from major human-caused or natural events in order to minimize the threat and impact to lives, property, the transportation network, and the regional economy.

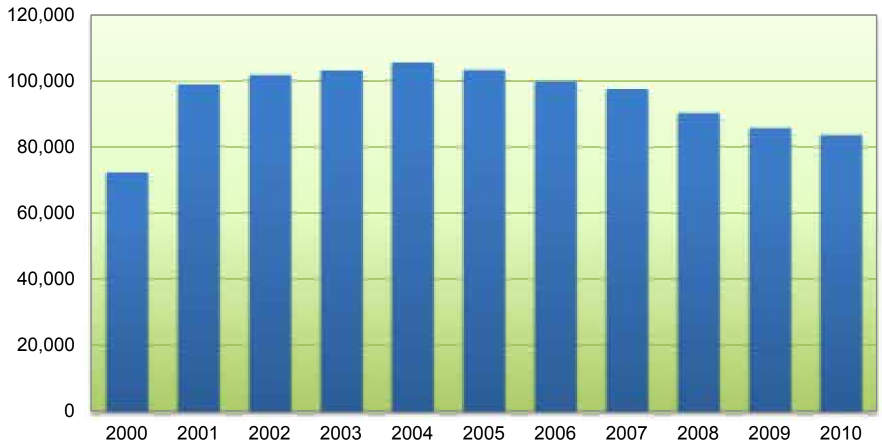
SAFETY

The rate of fatal and injury collisions on California's highways has declined dramatically since the California Highway patrol began keeping such data in the 1930's. California has led the nation in roadway safety for much of the past 20 years. Only recently have roadways nationally become as safe as those in California. **FIGURE 2.2** shows the improvement in roadway accidents in the SCAG region over the last 10 years.

While the trend indicates a long-term decline in fatalities compared to VMT, it remains an unacceptable personal burden to those involved. In 2008, over 1,500 people died on roadways in the SCAG region, and just under 125,000 were injured. The average costs for each traffic death, traffic injury, or property damage crash were (in 2005):

- Death – $1,150,000
- Nonfatal Disabling Injury – $52,900
- Property Damage, including non-disabling injuries – $7,500

FIGURE 2.2 Annual Collisions on the State Highway System in the SCAG Region



SAFETEA-LU required states to develop Strategic Highway Safety Plans (SHSPs). The California Department of Transportation (Caltrans) responded by developing its SHSP through a participatory process with over 300 stakeholders throughout California. The overarching goal was to reduce the California roadway fatality rate to less than 1.0 fatality per 100 million vehicle miles traveled (VMT) by 2010. The efforts culminated with 17 challenge areas and over 150 actions designed to reduce fatalities in each challenge area. The State achieved its goal in 2009, and is now focusing on reducing transportation fatalities further with a new SHSP in development.

SECURITY

Currently, there are numerous agencies that participate in the response to incidents and assist with hazard preparedness for individual jurisdictions. Collaboration occurs between many of these agencies. The Federal Emergency Management Agency (FEMA) oversees coordination. However, FEMA defines metropolitan areas and coordination differently than the U.S. Department of Transportation, limiting SCAG's ability to participate at an agency level. SCAG seeks to utilize its strengths and organization to assist planners, first responders and recovery teams in a supporting role.

There are three areas in which SCAG can assist both before a major emergency and during the recovery period:

- Provide a policy forum to help develop regional consensus and education on security policies and emergency response
- Assist in expediting the planning and programming of transportation infrastructure repairs from major disasters
- Encourage integration of transportation security measures into transportation projects early in the project development process by leveraging SCAG's relevant plans, programs and processes, including regional ITS architecture

Beginning in 2008, SCAG participated in the development of the draft Southern California Catastrophic Earthquake Preparedness Plan. The Plan was based on the 2007 Operation Golden Guardian scenario, which SCAG also assisted in developing, and envisioned a 7.8 earthquake starting in the Salton Sea area and travelling across the SCAG region to the Grapevine area where I-5 meets SR-138.

The Plan examines the initial impacts, inventory of resources, care for the wounded and homeless, and developed a long-term recovery process. The process of Long-Term Regional Recovery (LTRR) provides a mechanism for coordinating federal support to state, tribal, regional, and local governments, nongovernmental organizations (NGOs), and the private sector to enable recovery from the long-term consequences of extraordinary disasters. The LTRR process accomplishes this by identifying and facilitating availability and use of sources of recovery funding, and providing technical assistance (such as impact analyses) for recovery and recovery planning support. "Long-Term" refers to the need to re-establish a healthy, functioning region that will sustain itself over time.

Long-term recovery is NOT debris removal and restoration of utilities, which are considered immediate or short-term recovery actions.

Once a disaster has been proclaimed, the LTRR process may be activated for incidents that require a coordinated federal, state, tribal, regional, and local government response to address significant long-term impacts (e.g., impacts on housing, government operations, agriculture, businesses, employment, regional infrastructure, the environment, human health, and social services) to foster sustainable recovery. The three main focus areas of LTRR are:

- Housing,
- Infrastructure, and
- Economic Development.

When a disaster occurs, the initial operational focus is centered on response activities. This effort may last from a few hours to an extended period of time (several days or longer) depending on the situation. As response activities begin to taper off and non-life safety issues begin to be addressed, the operational focus begins to shift from response to recovery. Federal and state support will be heaviest during the beginning phase of the recovery effort when:

- Long-term impact analyses are performed,
- Necessary technical support to establish local long-term recovery strategies and/or plans is provided, and
- Coordination of long-term recovery resources needed by the region to launch its recovery efforts are complete.

Federal and state support lessens by the later stages of the LTRR process once the region has sufficient capacity to implement its long-term recovery plan.

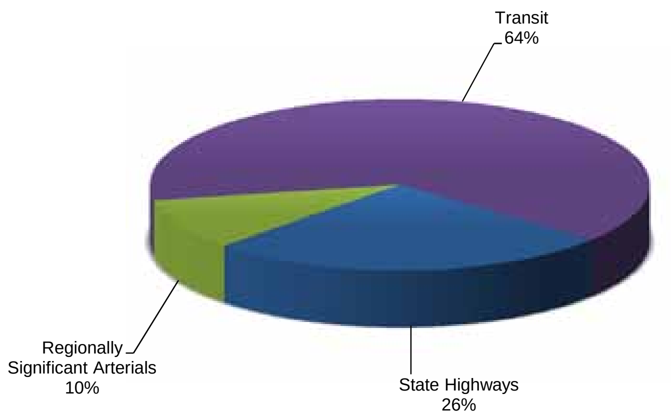
System Preservation

Recognizing that deferring the maintenance of our transportation system will only result in much costlier repairs in the future, preserving our assets now is a critical priority of this RTP/SCS. Approximately $217 billion, or almost half of all of its proposed expenditures through 2035, is allocated to system preservation and maintenance. As indicated in Chapter 1, to a great extent, this high cost is a result of three decades of preservation

underinvestment. Deficient road conditions are all too familiar to the region's drivers, and without a renewed commitment to improving the condition of our transportation infrastructure, costs will increase even more dramatically. Therefore, SCAG will continue to work with its stakeholders, particularly county transportation commissions and Caltrans, to prioritize funding for preservation and maintenance.

FIGURE 2.3 presents the allocation of these expenditures among the transit system, the state highway system, and arterials of regional significance within the 2012 RTP. Note that the allocation for the state highway system includes bridges and the allocation for transit includes funding to both preserve and operate the transit system.

FIGURE 2.3 Preservation and Operations Funding



Smart Land Use

Since initiating one of the nation's first large-scale regional growth visioning efforts in 2000, SCAG has sought to integrate land use and transportation by working with subregions and local communities to increase development densities and improve the jobs/housing balance. Implementing such smart land use strategies encourages walking, biking, and transit use, and therefore reduces vehicular demand. This saves travel time, reduces pollution, and leads to improved health. The SCS (in Chapter 2) describes the successes of the previous and smart land use efforts in the region, and lays the foundation for significant further improvements moving forward.

Transportation Demand Management

Transportation Demand Management (TDM) strategies reduce vehicular demand and thereby congestion, particularly during peak periods. Successful TDM combines two complementary strategies: "soft" or "pull" strategies—such as vanpool subsidies and preferential parking for carpools, with "hard" or "push" strategies—such as congestion pricing.

The first encourages or incentivizes travelers to reduce automobile use by making alternatives more desirable. The second discourages travelers from using automobiles by increasing out-of-pocket travel costs.

The RTP financial plan (Chapter 3) identifies reasonably available revenue sources that provide much needed funding for infrastructure preservation and critical regional projects. Increasing driving costs over the RTP time frame will also encourage some to look for more cost-effective travel options. In total, the RTP/SCS allocates $4 billion to TDM strategies to target such drivers and others and incentivize them in three ways:

- **Increase carpooling and vanpooling.**
  Carpooling is supported by a host of strategies. High Occupancy Vehicle (HOV) lanes and convenient Park-and-Ride Lots increase carpool usage. Other strategies include vanpool services for larger employers and rideshare matching services. Los Angeles, Orange, Riverside and San Bernardino Counties jointly sponsor a regional "Guaranteed Ride Home Program," which provides transportation for carpoolers and transit users in emergency situations.
- **Increase the use of transit, bicycling, and walking.**
  The RTP/SCS extends the reach of transit by focusing on "first mile/last mile" solutions. One of the biggest challenges in attracting new riders to transit is providing a reasonable and practical means of accessing transit at the origin and destination. "First mile/last mile" strategies are TDM strategies that offer reasonable and practical solutions to this problem, resulting in higher ridership for our transit services. Specific first mile/


Image courtesy of the Riverside Transit Agency

last mile strategies include development of mobility hubs around major transit stations to provide easier access to destinations. Other strategies include integrating bicycling and transit through folding bikes on buses programs, triple racks on buses, and dedicated racks on light and heavy rail vehicles. A study by the Los Angeles County Metropolitan Authority (Metro) indicates that 1.3 percent of all annual Metro Rail riders access transit stations via bicycle. The percentage of bicyclists accessing transit is likely to increase as investments are made.

The RTP/SCS also commits $6 billion to active transportation, which will expand bikeways, improve local streets, and address ADA requirements. Additional strategies include traffic calming and Complete Streets strategies, particularly near transit stations and schools, so as to further reduce vehicle trips by improving safety and desirability of active transportation.

- **Redistribute vehicle trips from peak demand periods to non-peak periods by shifting work times/days/locations.**
  The TDM investments also aim to reduce peak-hour congestion by promoting flexible work schedules and telecommuting, where applicable. Flexible work schedules allow employees to work fewer days in exchange for longer hours on the days they do work. For example, many employers offer a 9/80 schedule, where employees work 9 hours each day and have one day off every two weeks.

Telecommuting has increased dramatically over the past decade. Nearly 2.6 percent of all workers in the SCAG region telecommute most of the time, and an even greater number telecommute at least one day per month. Strategic investments that would remove barriers associated with telecommuting are expected to increase the number of full-time (equivalent) telecommuters to 5 percent in 2020, and 10 percent in 2035.

Congestion Management Process

The federal requirement for a Congestion Management Process (CMP) was initially enacted in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, and continued in the Transportation Equity Act for the 21st Century (TEA-21) in 1998 and subsequently in SAFETEA-LU. CMP requires monitoring, performance measures, and, in certain cases, mitigation measures. Above all, CMP requires and ensures that highway capacity projects that significantly increase the capacity for single occupancy vehicles (SOV) be developed in a comprehensive context that considers all possible alternatives, including transit, TDM and TSM strategies. Furthermore, if alternative strategies are demonstrably neither practical nor feasible, appropriate mitigation strategies must be considered in conjunction with significant roadway capacity improvement projects that would increase SOV capacity.

Each county transportation commission (CTC) in the SCAG region, with the exception of Imperial County, is also designated Congestion Management Agency (CMA) and are required to develop Congestion Management Plans (CMPs) pursuant to California Government Code Section 65089, and update it every two years. Imperial County, the least populated county in the region, has not reached the population threshold that would require them to opt in or out of the state CMP process at present. Nevertheless, Imperial County has embraced the spirit of CMP and is actively seeking to incorporate its key elements into their next long range transportation plan update. So, effectively SCAG's CMP is comprised of the CMPs developed by each of the CTCs integrated into the RTP and FTIP process as a unified response to reducing congestion in our region.

SCAG is proposing two critical improvements to our current CMP process, partly in response to the federal certification review that was concluded in the Spring of 2010. First, SCAG will incorporate a requirement in the FTIP Guidelines that calls for submittal of documentation by the sponsoring agencies associated with significant roadway capacity projects (greater than $50 million) to ensure documentation of all the alternatives considered in defining the project as well as identifying appropriate mitigations that would be implemented in conjunction with the project.

Second, this RTP/SCS recognizes the importance of addressing non-recurring congestion (collisions, stalled cars, severe weather). Non-recurring congestion accounts for almost 50 percent of all congestion on our roadway system. So, for the first time, this RTP identifies non-recurring congestion delay on the state highway system, both for general purpose lanes and carpool lanes, as a key performance metric that will be monitored and reported over time to ensure we are making progress towards addressing this critical issue.

A more complete discussion of our regional CMP is provided in a separate technical report.

Transportation Systems Management

Transportation Systems Management (TSM) increases the productivity of the existing multi-modal transportation system, thereby reducing the need for costly system expansion. TSM relies in part on intelligent transportation system (ITS) technologies to increase traffic flow and reduce congestion. This RTP/SCS dedicates up to $6.8 billion to TSM. Examples of TSM categories and their associated benefits are described in **TABLE 2.1**.

TABLE 2.1 TSM Categories and Benefits

Category	Benefit
Enhanced Incident Management	Reduces incident related congestion which is estimated to represent half of the total congestion in urban areas
Advanced Ramp Metering	Alleviates congestion and reduces accidents at on-ramps and freeway to freeway interchanges
Traffic Signal Synchronization	Minimizes wait times at traffic signals and therefore reduces travel time
Advanced Traveler Information	Provides real-time traffic conditions, alternative routing, and transportation choices to the public
Improved Data Collection	Allows agencies to monitor system performance and optimize the impact of transportation investments
Universal Transit Fare Cards (Smart Cards)	Reduces time required to purchase transit tickets and allows inter-operability among transit providers
Transit Automatic Vehicle Location (AVL)	Enables monitoring of transit vehicles and ensuring on-time performance

TSM will also play an increasingly larger role in regional goods movement improvements. The Ports of Los Angeles and Long Beach have identified ITS technologies, specifically automated vehicle location (AVL), as a major component in their proposed air quality mitigation strategies. Advanced monitoring will assist in achieving system efficiencies in ports and intermodal operations, reducing delays and wait times at gates and destinations, and allowing for more flexible dispatching, all of which reduce emissions. Weigh-in motion systems and enhanced detection will allow for better enforcement of commercial vehicles rules, reducing pavement damage, and identifying critical paths for goods movement planning in the future.

Corridor System Management Plans

With the passage of Proposition 1B by California voters in November 2006, a program of funding called the Corridor Mobility Improvement Account (CMIA) was created to improve mobility on the state highway system. The California Transportation Commission adopted guidelines for the CMIA program that required the development of Corridor System Management Plans (CSMPs) for those projects receiving CMIA funding, to ensure that mobility improvements would be maintained over time. In the SCAG region, CSMPs were developed by Caltrans for the following corridors:

- I-5 and I-405 in Los Angeles County;
- SR-57, SR-91, and SR-22/I-405/I-605 in Orange County;
- SR-91 and I-215 in Riverside County;
- I-10 and I-215 in San Bernardino County; and
- US-101 in Ventura County.

The CSMPs include several key components: a comprehensive corridor description and understanding; a performance assessment and bottleneck identification; identification of operational and minor infrastructure improvements to relieve congestion; and development of simulation models to estimate improvements from those projects and strategies. The recommended improvements include TSM investments such as ramp metering and enhanced incident management. The recommendations also include small infrastructure improvements such as auxiliary lanes and ramp and interchange improvements. The RTP/SCS includes $840 million of funding for the CSMP-recommended improvements.

Completing Our System

Southern California's highways and arterials extend for almost 22,000 center-line miles and 67,000 lane-miles and serve 53 million travelers each weekday. However, there are still critical gaps in the network that hinder access to certain parts of the region. Closing these gaps to complete the system will allow our residents to enjoy improved access to opportunities such as jobs, education, healthcare, and recreation.

Highways and Local Arterials

The expansion of highways and local arterials has slowed down over the last decade. This has occurred in part due to increasing costs and environmental concerns. However, there are still critical gaps in the network that hinder access to certain parts of the region. Locally-developed county transportation plans have identified projects to close these gaps and complete the system, and they are included in the RTP. **TABLE 2.2** highlights some of these highway completion projects. The full list of RTP projects is provided in the Project List technical appendix.

TABLE 2.2 Major Highway Completion Projects

County	Project	Completion Year*
Imperial	SR-115 Limited Access Expressway	2018
Los Angeles	SR-710 Gap Closure	2030
Los Angeles, San Bernardino	High Desert Corridor	2020
Orange	SR-241 Improvements	2020–2030
Orange, Riverside	CETAP Intercounty Corridor A	2035
Ventura	US-101 and SR-118 Improvements	2018

*Represents the Plan network year for which the project was analyzed for the RTP modeling and regional emissions analysis


Image courtesy of the Orange County Transportation Authority

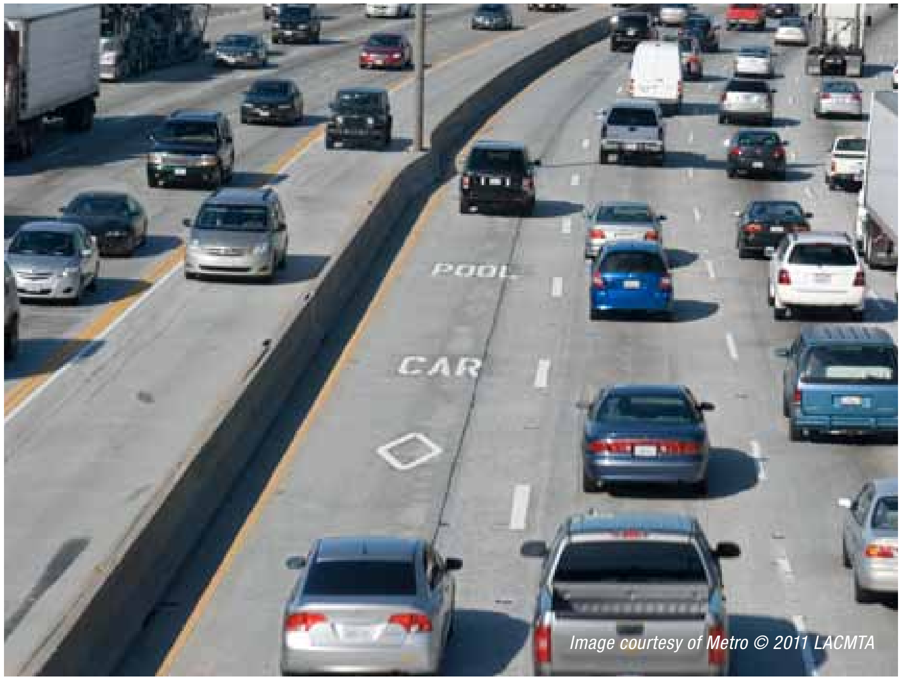


Image courtesy of Metro © 2011 LACMTA

Southern California's heavy investment in high-occupancy vehicle (HOV) lanes has given it one of the nation's most comprehensive HOV networks and highest rideshare rates. The Plan proposes strategic HOV gap closures and freeway-to-freeway direct HOV connectors to complete the system. The HOV lane network will serve as the backbone of the regional HOT lane system proposed in the "HOT Lanes Network" section later in this chapter. Another key HOV strategy in the Plan is the conversion of certain HOV lanes in the region to allow for continuous access. Orange County has taken a leadership role on this over the past few years, and their recent studies have concluded that continuous-access HOV lanes do not perform any worse than limited-access HOV lanes. At the same time, they provide carpoolers with greater freedom of movement in and out of HOV lanes. As a result, nearly every HOV lane in Orange County will be converted to allow for continuous access by the year 2013. **TABLE 2.3** highlights some of the Plan's major HOV projects and **EXHIBIT 2.1** provides a glance of major highway improvements proposed by the Plan.

TABLE 2.3 Major HOV Projects

County	Route	From	To	Completion Year*
HOV Lane Additions				
Los Angeles	I-10	I-605	Puente Ave	2014
Los Angeles	I-10	Puente Ave	SR-57/I-210	2018
Los Angeles	I-5	LA/OC County Line	I-605	2018
Los Angeles	I-5	Pico Canyon	Parker Rd	2030
Los Angeles	I-405	I-10	US-101	2018
Los Angeles	SR-14	Ave P-8	Ave L	2030
Orange	I-5	Avenida Pico	San Juan Creek Rd	2020
Orange	I-5	SR-55	SR-57	2035
Orange	SR-73	I-405	MacArthur	2035
Riverside	I-215	Nuevo Rd	Box Springs Rd	2030
Riverside	SR-91	Adams St	SR-60/I-215	2018
Riverside	I-15	Riv/SB County Line	I-15/I-215	2020
San Bernardino	I-10	Haven Ave	Ford St	2020
San Bernardino	I-10	Ford St	Riv/SB County Line	2030
San Bernardino	I-215	Spruce St	Orange Show Rd	2014
San Bernardino	I-215	SR-210	I-15	2030
San Bernardino	I-15	Riv/SB County Line	SR-18/Mojave River	2020
Freeway-to-Freeway HOV Connectors				
Los Angeles	I-5/SR-14	Connector		2014
Los Angeles	I-5/I-405	Connector (partial)		2030
Orange	I-405/SR-73	Connector		2035
San Bernardino	I-10/I-15	Connector (partial)		2020
San Bernardino	I-10/I-215	Connector		2030

*Represents the Plan network year for which the project was analyzed for the RTP modeling and regional emissions analysis

Our region's local streets and roads account for over 80 percent of the total road network and carry almost 50 percent of total traffic. They serve different purposes in different parts of the region, or even in different parts of the same city. Many streets serve as major thoroughfares or even alternate parallel routes to congested freeways. At the same time, within our urban areas, where a street right-of-way can account for as much as 40 percent of the total land area, streets shape the neighborhoods they pass through and often support different modes of transportation besides the automobile, including bicycles, pedestrians, and transit. The RTP contains a host of arterial projects and improvements to achieve different purposes in different areas. In all parts of the region, it includes operational and technological improvements to maximize system productivity in a more cost-effective way than simply adding capacity. Such strategic improvements include spot widening, signal prioritization, driveway consolidation and relocation, and grade separations at high-volume intersections. Finally, in a quickly growing number of areas, street improvement projects include new bicycle lanes and other design features such as lighting, landscaping, and modified roadway, parking, and sidewalk widths that work in concert to achieve both functional mobility for multiple modes of transportation, and a great sense of place.

TABLE 2.4 Arterial Investment Summary (in Nominal Dollars, Billions)

County	Investment*
Imperial	$ 1.6
Los Angeles	$ 6.7
Orange	$ 4.4
Riverside	$ 6.1
San Bernardino	$ 2.6
Ventura	$ 0.7
Total	**$ 22.1**

Strategically Expanding Our System

While the RTP/SCS's multimodal strategy aims to reduce per capita vehicle miles traveled (VMT) over the next 25 years, total demand to move people and goods will continue to grow due to the region's population increase. A strategic expansion of our transportation system is needed in order to provide the region with the mobility it needs. The RTP targets this expansion around transportation systems that have room to grow, including transit, high-speed rail, active transportation, Express/HOT lanes, and goods movement. Some of these systems, such as transit, active transportation, and Express/HOT lanes, have proven over the years to be a reliable and convenient form of transportation for those who are able to easily access it. However, these systems must be improved and expanded in order to provide the accessibility and connectivity needed to become a truly viable alternative for the region as a whole. Other systems, such as high-speed rail, are new to the region and are needed to expand the number of choices available to our residents for convenient longer-haul travel. In addition, to address both the need to move more goods throughout the region for our growing population and maintain regional economic benefits of our goods movement industry, we must strategically expand our goods movement system in a way that addresses the associated quality of life issues.

Transit

The Plan calls for an impressive expansion of transit facilities and service over the next 25 years. The local county sales tax programs, most recently Measure R in Los Angeles County, are providing for most of this expansion in facilities and services.

The region should be proud of what it has accomplished so far and what it plans to accomplish beyond that by 2035. **EXHIBITS 2.2, 2.3,** and **2.4** demonstrate this point. All three exhibits present passenger rail system in the region. In 1990, as shown in **EXHIBIT 2.2**, the region did not have any passenger rail service at all. **EXHIBIT 2.3** shows how successful the region has been in building an extensive passenger rail network by 2010, a mere 20 years later. This RTP/SCS builds upon this success and proposes to strategically expand our rail system over the next 25 years. A more robust network in 2035 is depicted in the **EXHIBIT 2.4**.

EXHIBIT 2.1 Major Highway Projects

EXHIBIT 2.2 Rail Transit System (1990)

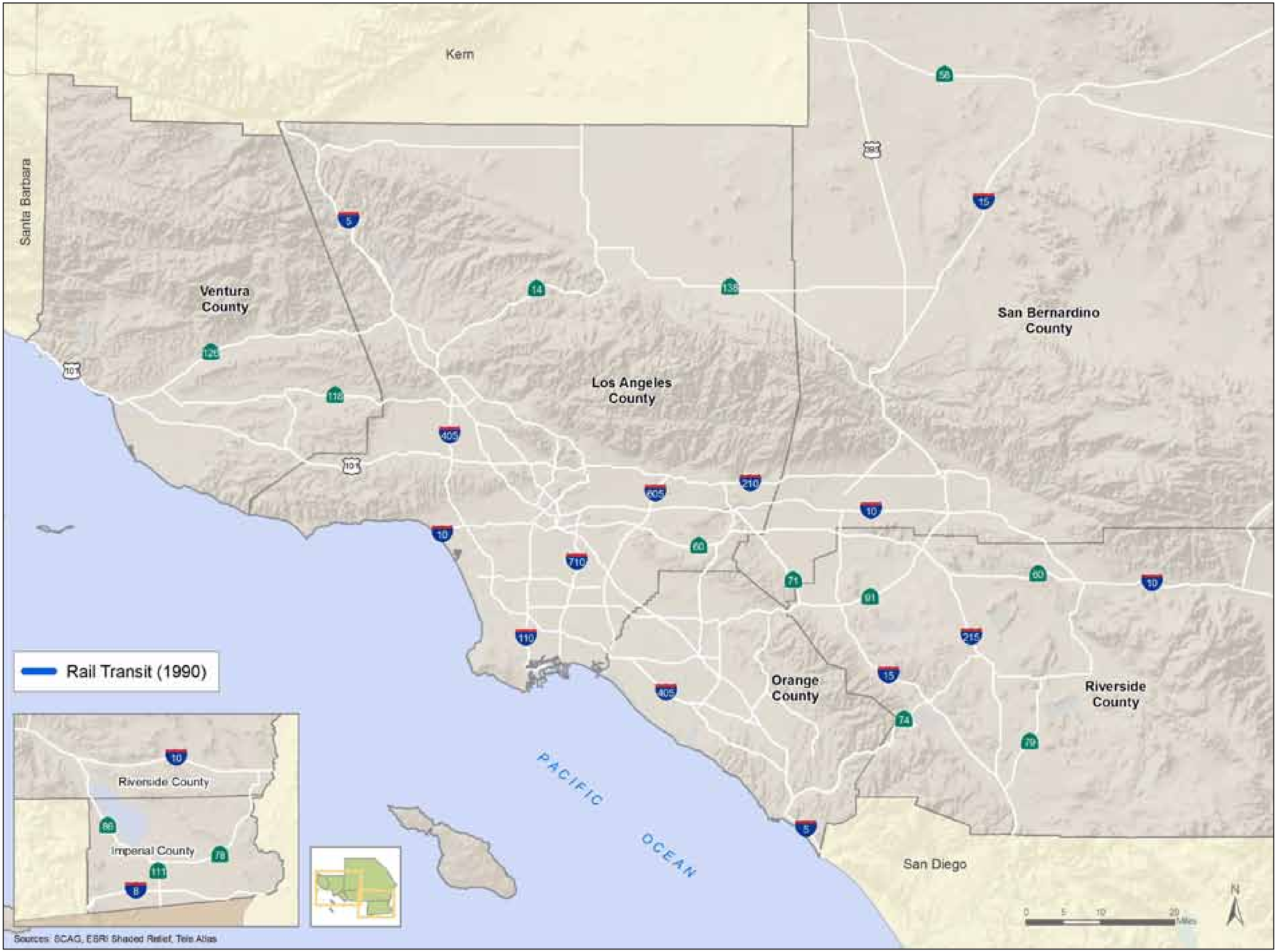


EXHIBIT 2.3 Rail Transit System (2010)

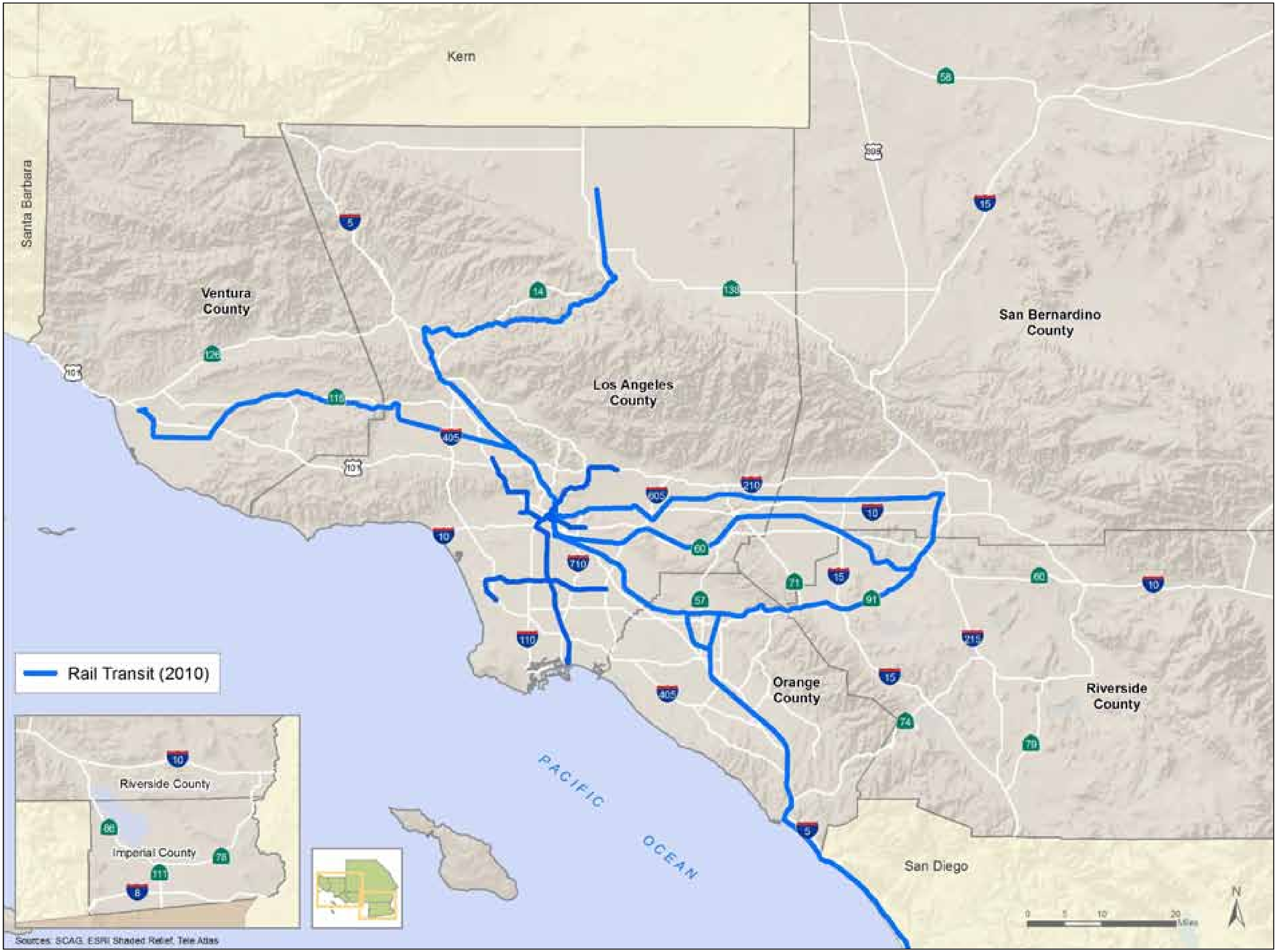
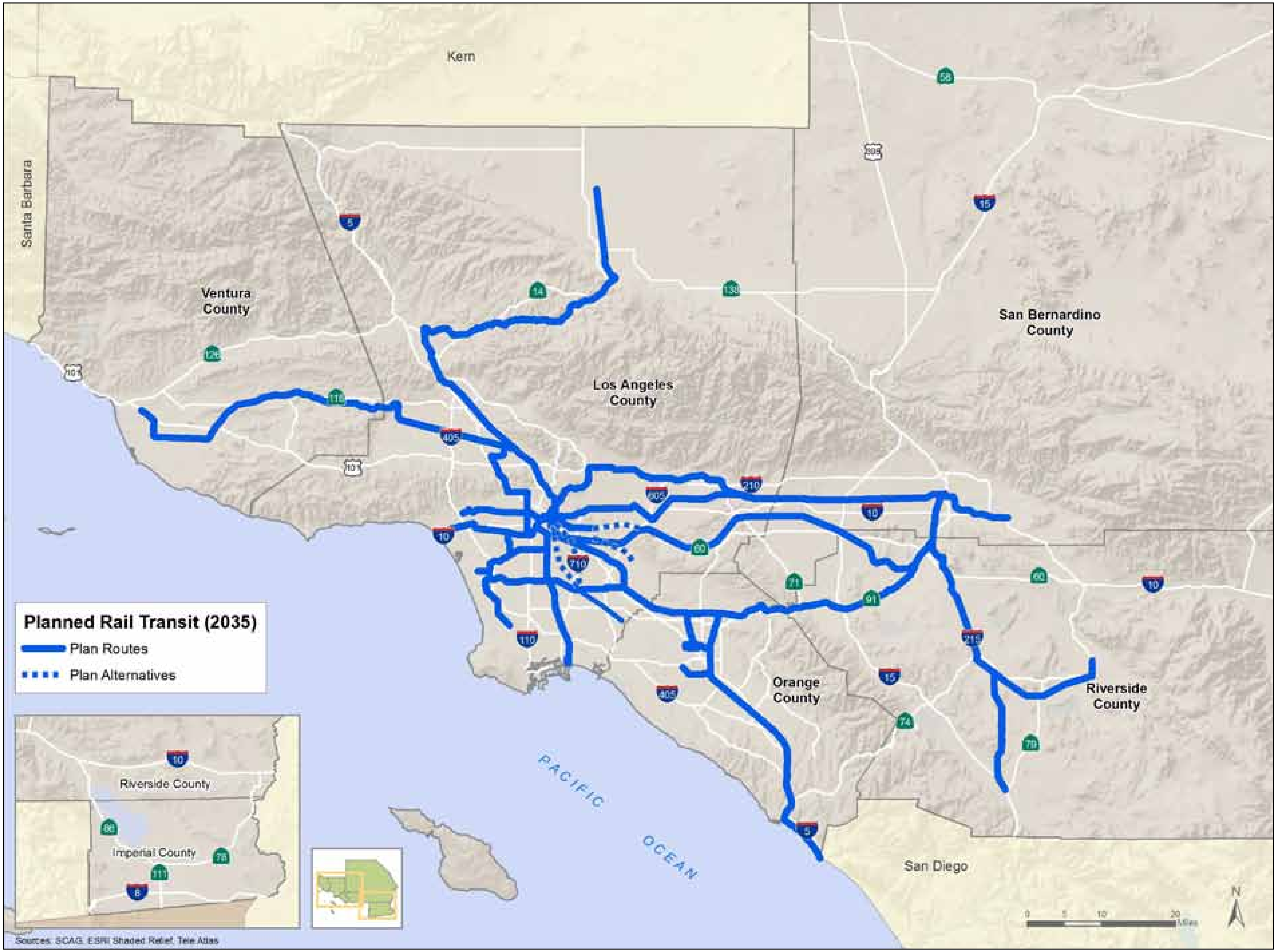


EXHIBIT 2.4 Rail Transit System (2035)



Once built out, Los Angeles County will have a greatly-expanded rail network, adding entire new corridors and lengthening existing ones. Orange County will greatly improve its Metrolink service and implement a slew of new bus rapid transit (BRT) routes, Riverside County will introduce various extensions to its Metrolink line, and San Bernardino County will introduce Redlands Rail.

TABLE 2.5 Major Transit Projects

County	Project	Completion Year*
Los Angeles	Crenshaw/LAX Transit Corridor	2018
Los Angeles	Gold Line Eastside Transit Corridor–Phase 2	2035
Los Angeles	Exposition Line–Phase 2 to Santa Monica	2018
Los Angeles	Gold Line Extension to Glendora	2018
Los Angeles	Gold Line Extension to Montclair	2035
Los Angeles	Green Line LAX Extension	2030
Los Angeles	South Bay Green Line Extension	2035
Los Angeles	Regional Connector	2020
Los Angeles	San Fernando Valley (East) North/South Rapidways	2018
Los Angeles	San Fernando Valley Orange Line Canoga Extension	2014
Los Angeles	West Santa Ana Branch Corridor	2030
Los Angeles	Westside Subway Extension to La Cienega	2023
Los Angeles	Westside Subway Extension to Century City	2030
Los Angeles	Westside Subway Extension to Westwood	2035
Orange	Anaheim Rapid Connection	2020
Orange	Bristol/State College, Harbor, and Westminster BRT	2030
Orange	Santa Ana/Garden Grove Fixed Guideway	2020
Riverside	Metrolink Perris Valley Line Extensions to San Jacinto and Temecula	2035
San Bernardino	E Street BRT (sbX)	2014
San Bernardino	Redlands Rail–Phase 1	2018
San Bernardino	Redlands Rail–Phase 2	2020

*Represents the Plan network year for which the project was analyzed for the RTP modeling and regional emissions analysis

While these capital projects will provide our region with a much more mature public transportation system, operational improvements and new transit programs and policies will also contribute greatly to attracting more trips to transit and away from single-occupant vehicle (SOV) travel. First, the expanding HOV and Express/HOT lane networks calls for the development of an extensive express bus point-to-point network. Second, transit oriented and land use developments call for increasing the frequency and quality of fixed-route bus service by virtue of adding new BRT service, limited-stop service, increased frequencies along targeted corridors, and the introduction of local community circulators to provide residents of smart growth developments with the option of taking transit over using a car to make short, local trips.

Another emphasis on transit network improvements includes transit priority facilities, such as bus lanes and traffic signal priority. Our region has virtually no bus lanes, especially compared to other major metropolitan areas. The Los Angeles County Metro Rapid Bus network employs bus signal priority that gives buses up to 10 percent more green light time from the normal green light phase. This should be expanded to other counties in our region.

Additional enhancements to our region's transit services include expanding bike-carrying capacity on transit vehicles, implementing regional and inter-county fare agreements and media, such as LA County's EZ Pass, and expanding and improving real-time passenger information systems.

TRANSIT POLICIES

In addition to the specific transit plans, projects and programs proposed, the 2012 RTP/SCS also supports the following policies and actions:

- Encourage the development of new transit modes in our subregions, such as BRT, rail, limited-stop service, and point-to-point express services utilizing the HOV and Express/HOT lane networks,
- Encourage transit providers to increase frequency and span-of-service in TOD and High Quality Transit Areas (HQTAs) and along targeted corridors where there is latent demand for transit service,
- Collaborate with local jurisdictions to provide a network of local community circulators that serve new TOD and HQTAs, providing an incentive for residents and employees to make trips on transit,

- Develop first mile/last mile strategies on a local level to facilitate access to the transit system via local circulators, active transport, scrip, or vehicle sharing. Continue partnering with member cities and subregions to do localized first mile/last mile planning,
- Encourage transit fare discounts and local vendor product and service discounts for residents and employees of TOD/HQTAs, or for a jurisdiction's local residents in general who have fare media,
- Advocate for increased operational funding for transit service from the state sources,
- Encourage transit properties to pursue cost containment strategies,
- Work with cities to identify and mitigate choke points in the regional transportation system that affect transit, and
- Work with county transportation commissions, municipalities, and transit operators to develop dedicated bus facilities.


Image courtesy of Metro © 2011 LACMTA

Passenger and High-Speed Rail

The Plan proposes three Passenger Rail strategies that will provide additional travel options for long-distance travel within our region and to neighboring regions. These are improvements to the LOSSAN Corridor, improvements to the existing Metrolink system, and the implementation of Phase I of the California High-Speed Train (HST) project.

The recent release of the draft CA HST Business Plan confirmed the funding and implementation challenges of the project. The plan now estimates a statewide Phase I cost of $98.5 billion (in year of expenditure dollars) with service extended to our region in 2033. Within the draft Business Plan, there are a variety of strategies to connect Northern and Southern California to the state network. This plan assumes that Southern California will be connected to the network in 2033, but that incremental improvements can be made in advance of and in preparation for that connection. Therefore, stakeholders throughout Southern California are seeking to implement a phased and blended implementation strategy for high-speed rail by employing state and federal high-speed rail funds to improve existing services, eventually meeting the Federal Rail Administration's (FRA) 110 MPH definition of high-speed service. These speed and service improvements to the existing LOSSAN and Metrolink corridors will deliver the California High-Speed Rail Authority's (Authority) new blended approach, and at the same time permanently improve our region's commuter and intercity rail services.

IMPLEMENTATION OF PHASE I OF THE CALIFORNIA HIGH-SPEED TRAIN (HST) PROJECT

The Authority has worked since 1996 to plan and build a HST system linking Northern and Southern California. In 2005, the Authority issued a Programmatic Environmental Impact Report (EIR) selecting a Phase I alignment that would travel from Anaheim to Los Angeles, on to the Antelope Valley via the San Fernando Valley, along SR-99 through the San Joaquin Valley, and into the Bay Area via San Jose and along the San Francisco Peninsula. Phase II would add connections to the Inland Empire, San Diego, Sacramento, and possibly the East Bay. In November of 2008, California voters approved Proposition 1A (Prop 1A), allocating $9 billion in bond funds for the project. In 2009 and 2010, the FRA awarded the Authority $3.6 billion in High-Speed and Intercity Passenger Rail discretionary grants, which will be used in the San Joaquin Valley as per FRA direction. As mentioned above, the new business plan has put total statewide Phase I construction costs at $98.5 billion (in nominal dollars). Prop 1A also included $950 million for upgrading and improving connectivity for current rail services that will connect with the HST project, so the need to make speed and service improvements for our current rail services, coupled with the CHSRA's new blended implementation approach, calls for the need to spend these funds in the next few years.

The primary benefits of Phase I will be realized on a statewide level; however, our region's interregional travel facilities will also benefit. If successful, the HST system will attract many interregional trips now made by car or airplane, providing an alternative to congested interregional highways and relieving ground congestion near local airports. The Los Angeles to the Bay Area travel market is currently the nation's seventh busiest aviation corridor, and our region's second busiest. Phase I has the potential to free up gate space at regional airports for more international and long haul routes, and relieve some airfield congestion. Similarly, when both Phase I and II are complete, the system will offer connectivity to Palmdale, Bob Hope (Burbank), Los Angeles, Ontario International and San Bernardino International Airports, helping to meet SCAG's long-term goal of regionalizing air travel in Southern California. Phase I will also provide excellent regional connectivity. The planned HSR stops at Sylmar, Burbank Airport, Los Angeles Union Station, Norwalk and Anaheim will readily connect with a robust network of inter-city and commuter rail, subway and light-rail, and fixed-route transit systems. All these connections will complement and feed each other, thereby boosting rail and transit ridership across our region.

IMPROVEMENTS TO THE LOS ANGELES TO SAN DIEGO (LOSSAN) RAIL CORRIDOR

Currently the SCAG region is served by a network of intercity passenger and commuter rail services. These services operate on the region's rail network, often sharing facilities with freight rail. They operate at higher speeds and have less frequent station stops than traditional transit services, and are more likely to serve intercity and interregional trips.

As discussed in Chapter 1, intercity passenger rail service is operated by Amtrak, and commuter services are operated by the Southern California Regional Rail Authority (Metrolink). Amtrak's Pacific Surfliner traverses the 351 mile long Los Angeles-San Diego-San Luis Obispo (LOSSAN) corridor. The Pacific Surfliner is the second most-used service in Amtrak's national fleet, moving nearly nine percent of the system's total national ridership. Surfliner ridership is growing over eight percent a year. While Amtrak service remains a small portion of all transit trips in the region, it does provide a significant option for travel between regions.

Since the 1990s, stakeholders along the LOSSAN corridor have been participating in the LOSSAN Rail Corridor Agency, a Joint Powers Authority (JPA) that coordinates planning along the corridor with the goal of increasing safety, ridership, revenue, and reliability. In early 2010, the agency released a Strategic Assessment, which found that capital investment in speed and capacity improvements could serve latent demand along the corridor.

As such, the LOSSAN JPA partners have begun work on a Strategic Implementation Plan, which will guide service and business planning and provide a corridor wide implementation plan for capital improvement projects. Strategies in the LOSSAN program will include grade closures, the installation of quad gates and raised medians, grade separations, the installation of sidings and double tracks, electronic and positive train control technologies, track straightening, and other speed capacity improvements. Ultimately, it is hoped that express services in the corridor will travel between San Diego and Los Angeles in under two hours.

Image courtesy of the Southern California regional Rail Authority (Metrolink)

IMPROVEMENTS TO THE EXISTING METROLINK SYSTEM

Similarly, the Southern California Regional Rail Authority is currently the sole operator of the Metrolink system, which serves primarily as a commuter rail service in our region. Metrolink operates 512 track miles of service along seven routes in Ventura, Orange, Los Angeles, San Bernardino, Riverside and San Diego Counties. Metrolink passengers travel much further than most transit passengers, having an average trip length of 36.9 miles. In Fiscal Year 2008–2009, Metrolink reported serving 12,241,830 passenger boardings. Four routes, the Ventura County Line, the Orange County Line, the Inland Empire/Orange County Line, and the SR-91 Line, share portions of the LOSSAN Corridor with the Pacific Surfliner.

Metrolink's service will also share a corridor with Phase I of the California High-Speed Train Project. By 2035, this project will provide a high-speed travel option to the Bay Area and the Central Valley via the existing valley subdivision, which is currently used by the Metrolink Antelope Valley Line (AVL). A recent express service demonstration project revealed the Metrolink AVL travel time between Palmdale and Los Angeles Union Station could be shortened by 33 percent simply by skipping less used station stops. An aggressive program of track straightening, grade separations, and track and siding expansion is expected to reduce express travel times to roughly one hour.

When Phase I of the State HST project is completed, Metrolink and Amtrak routes will serve as feeders, providing access to a new long distance travel mode. Travelers expected to access the State project at stations in the cities of Los Angeles, Burbank, San Fernando, Palmdale, Norwalk and Anaheim. The Authority's 2009 Business Plan posits that passengers will travel between Los Angeles and San Francisco in less than three hours, for about 80 percent of comparable airfare.

RAIL POLICIES

In addition to the specific plans, projects, and programs proposed, the 2012 RTP/SCS supports the following policies and actions related to our passenger and high-speed rail program:

- Implement cooperative fare agreements and media between Amtrak and LOSSAN, and CA HST when it begins revenue service,
- Implement cooperative marketing efforts between Amtrak and LOSSAN, and CA HST when it begins revenue service,
- Encourage regional and local transit providers to develop rail interface services at Metrolink, Amtrak and high-speed rail stations, and
- Work with the California High-Speed Rail Authority and local jurisdictions to plan and develop optimal levels of retail, residential and employment development that fully takes advantage of new travel markets and rail travelers.

Bus Transit

The RTP/SCS allocates additional funding to bus transit in the region. Fixed route bus lines in the region are continuously evaluated and adjusted. Los Angeles County also offers Rapid Bus Transit on many of its core corridors. In addition, new services are planned across the region, including:

- Orange County's first bus rapid transit (BRT) services and new trolley systems in Santa Ana, Anaheim, and Garden Grove,
- Riverside and San Bernardino Counties' first BRT services,
- Development of an extensive express bus point-to-point network based on the expanding HOV and Express/HOT lane networks,

Image courtesy of the Victor Valley Transit Authority

- Increasing the frequency and quality of fixed-route bus service and the introduction of local community circulators to provide residents of smart growth developments with the option of taking transit over using a car to make short, local trips, and
- The implementation of transit priority facilities, such as bus lanes and traffic signal priority.

Active Transportation

Active transportation refers to transportation such as walking or using a bicycle, tricycle, velomobile, wheelchair, scooter, skates, skateboard, push scooter, trailer, hand cart, shopping car, or similar electrical devices. For the purposes of the RTP, active transportation generally refers to bicycling and walking, the two most common methods. Walking and bicycling are essential parts of the SCAG transportation system, are low cost, do not emit greenhouse gases, can help reduce roadway congestion, and increase health and the quality of life of residents. As the region works towards reducing congestion and air pollution, walking and bicycling will become more essential to meet the future needs of Californians.

The majority of commuters within the SCAG region commute via car, truck, or van. According to the American Community Survey, in 2009, more than 85 percent of all commuters traveled to work by car, truck, or van; and less than 4 percent traveled to work via an active transportation mode (0.7 percent bicycled and 2.5 percent walked to work). In addition, the National Household Travel Survey (NHTS) data indicate that approximately 20.9 percent of all trips were conducted by walking (19.2 percent) or bicycling (1.7 percent). This represents an approximately 75 percent increase from the 11.9 percent active transportation mode share in 2000. In addition, NHTS data indicate that 75.0 percent of all trips in 2009 were conducted by driving, and this is an approximately 10.6 percent decrease from the 83.9 percent mode share in 2000.

Additional analysis regarding active transportation needs to be conducted in order to develop a better understanding of the users and their needs. The current level of data is extremely limited and does not provide a comprehensive overview of the current active transportation community. Active transportation users have differing levels of experience and confidence, which influences their decision to utilize active transportation. SCAG recognizes that there are a number of factors that motivate them to use active transportation. Increased data collection may provide a clearer understanding of the needs and deficiencies associated with active transportation.

Active transportation is not only a form of transportation in itself; it is also a means by which to access rail and bus service. Accessibility is one of the primary performance measures used to evaluate active transportation, by measuring how well the current infrastructure provides individuals with the opportunity to access destinations or facilities.

Using a two-mile buffer for bicyclists and a half-mile buffer for pedestrians, we found that our current transit infrastructures provides 97 percent of our residents access to transit via bicycle, and 86 percent access to transit by walking. While many individuals have access to transit stations by biking or walking, numerous other factors may influence an individual's decision to use active transportation.

Safety is an important factor that individuals consider when determining whether or not they should walk or bike to their destination. Based on data from the Statewide Integrated Traffic Records System (SWITRS), in 2008, 4.0 percent of all traffic-related fatalities in the SCAG region involved bicyclists, and 4.3 percent of all traffic-related injuries involved bicyclists. In addition, 20.9 percent of all traffic-related fatalities in the SCAG region involved a pedestrian, and 5.7 percent of traffic-related injuries involved pedestrians.

While each of the counties in the SCAG region currently have their own active transportation plan, the RTP/SCS aims at developing a regional active transportation system that closes the gap and provides connectivity between counties and local jurisdictions. While bicyclists are legally allowed to use any public roadway in California unless specifically prohibited, many bicyclists may be more inclined to utilize bikeways. Currently, 42.6 percent of the region's residents have easy access to 4,315 miles of bikeways. Local jurisdictions in the region have proposed an additional 4,980 miles of bikeways in this RTP/SCS that would increase this access to 62.4 percent of all residents. In order to close the remaining gaps in the bikeway network, this RTP/SCS goes a step further to include an additional 827 miles of bikeways to complete the SCAG Regional Bikeway Network.

In order to make active transportation a more attractive and feasible mode of travel for the different users in our region, additional infrastructure improvements need to be made. The 2012 RTP/SCS calls for improvements that would bring 12,000 miles of deficient sidewalks into compliance with the Americans with Disabilities Act (ADA). Given that all trips, including vehicular trips, start with walking, it is important to ensure that the sidewalks and streets are accommodating to all users. In all, the RTP's active transportation improvements exceed $6 billion.

COASTAL TRAILS

In addition to bikeways, local trails have played an important role to increase accessibility and provide opportunities for active transportation. Trails along the coast of California have been utilized as long as people have inhabited the region. In an effort to develop a "continuous public right-of-way along the California coastline; a trail designed to foster appreciation and stewardship of the scenic and natural resources of the coastal trekking through hiking and other complementary modes of non-motorized transportation," the California Coastal Trail (CCT) was established. SCAG proposes the completion of the CCT to increase active transportation access to the coast. Completion of the CCT would provide 183 miles of multi-purpose trails.

SAFE ROUTES TO SCHOOL

SAFETEA-LU established the Safe Routes to School (SRTS) program to "enable and encourage primary and secondary school children to walk and bicycle to school" and to support infrastructure-related and behavioral projects that are "geared toward providing a safe, appealing environment for walking and bicycling that will improve the quality of our children's lives and support national health objectives by reducing traffic, fuel consumption, and air pollution in the vicinity of schools." Safe Route to school programs can play a critical role in eliminating some of the vehicle trips that occur during peak periods to drop-off or pick up students by ensuring safe routes to bike or walk to school

COMPLETE STREETS

The Complete Streets Act of 2008 (AB 1358) requires cities and counties to incorporate the concept of Complete Streets in their general plan updates to ensure that transportation plans meet the needs of all users of our roadway system. SCAG supports and encourages implementation of Complete Street policies in the 2012 RTP. SCAG will work with the local jurisdictions as they implement Complete Streets strategies within their jurisdictions by providing information and resources to support local planning activities. SCAG also supports the following policies and actions related to active transportation:

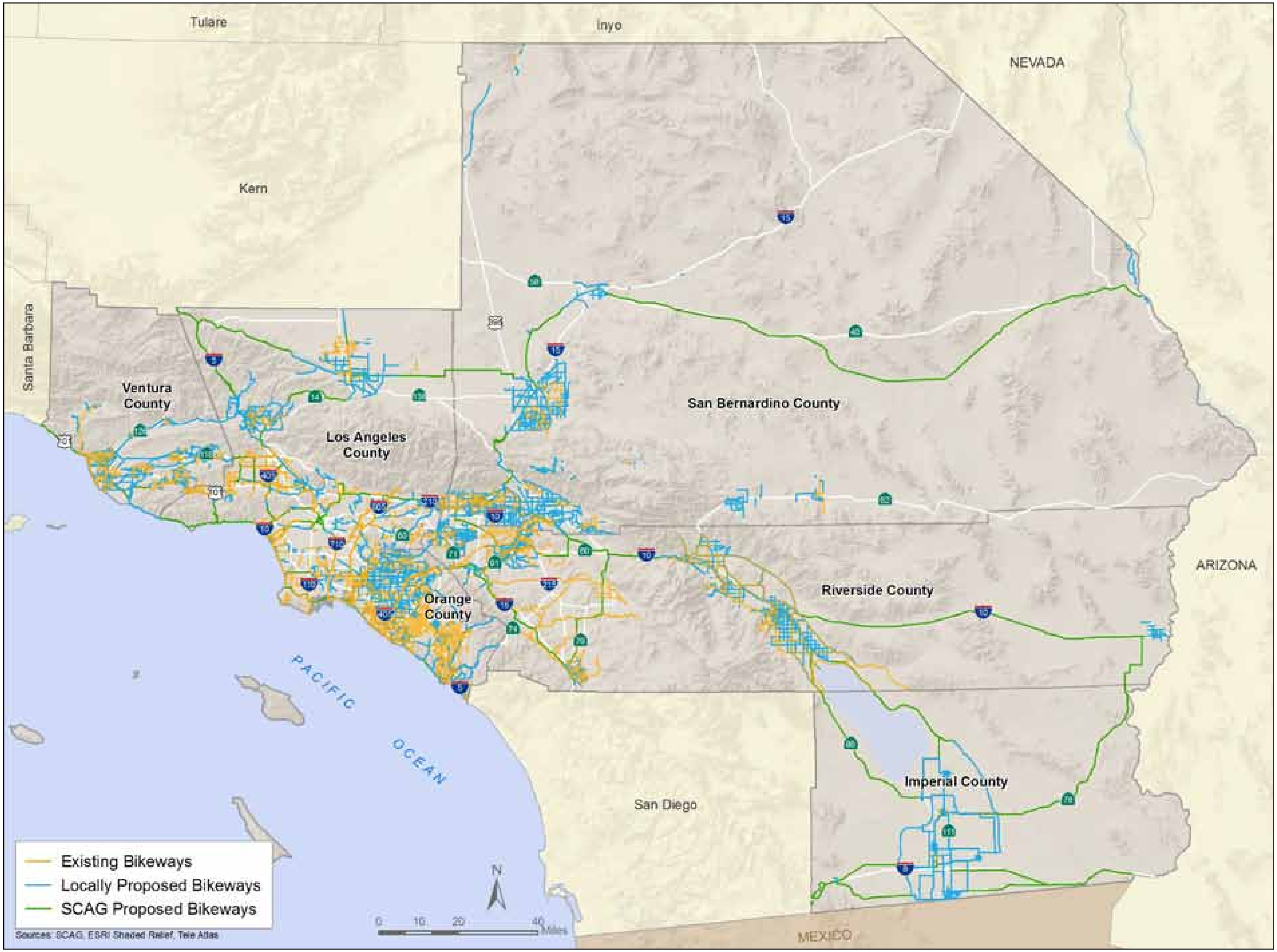
- Encourage and support local jurisdictions to develop 'Active Transportation Plans' for their jurisdictions if they do not already have one,
- Encourage and support local jurisdictions to develop comprehensive educational programs for all road users,
- Encourage local jurisdictions to direct enforcement agencies to focus on bicycling and walking safety to reduce multi-modal conflicts,
- Support local advocacy groups and bicycle related businesses to provide bicycle-safety curricula to the general public,
- Encourage children, including those with disabilities, to walk and bicycle to school,
- Encourage local jurisdictions to adopt and implement the proposed SCAG Regional Bikeway Network,
- Support local jurisdictions to connect all of the cities within the SCAG region via bicycle facilities,
- Encourage local jurisdictions to complete the California Coastal Trail,
- Encourage the use of Intelligent Traffic Signals and other technologies that detect slower pedestrians in signalized crosswalks and extend signal time as appropriate,
- Support the facilitation, planning, development and implementation of projects and activities that will improve safety, reduce traffic, and air pollution in the vicinity of primary and middle schools, and
- Encourage local jurisdictions to prioritize and implement projects/policies to comply with ADA requirements.

Express/HOT Lane Network

Despite our concerted effort to reduce traffic congestion through years of infrastructure investment, the region's system demands continue to exceed available capacity. Consistent with our regional emphasis on the mobility pyramid (**FIGURE 2.1**), recent planning efforts have focused on enhanced system management including integration of pricing to better utilize existing capacity and to offer users greater travel time reliability and choices. Express/HOT Lanes that are appropriately priced to reflect demand can outperform non-priced lanes in terms of throughput, especially during congested periods. Moreover, revenue generated from priced lanes can be used to deliver the needed capacity provided by the Express Lanes/HOT sooner and to support complementary transit investments.

Based on recent analysis of critical corridors performed for the CSMPs, inter-county trips comprise more than 50 percent—suggesting the value of a regional network of Express Lanes that would seamlessly connect multiple counties. As such, the 2012 RTP includes a regional Express/HOT Lane network that would build upon the success of the 91 Express

EXHIBIT 2.5 Regional Bicycle Network



Lanes in Orange County and two demonstration projects in Los Angeles County planned for operation in late 2012.

Image courtesy of the Orange County Transportation Authority

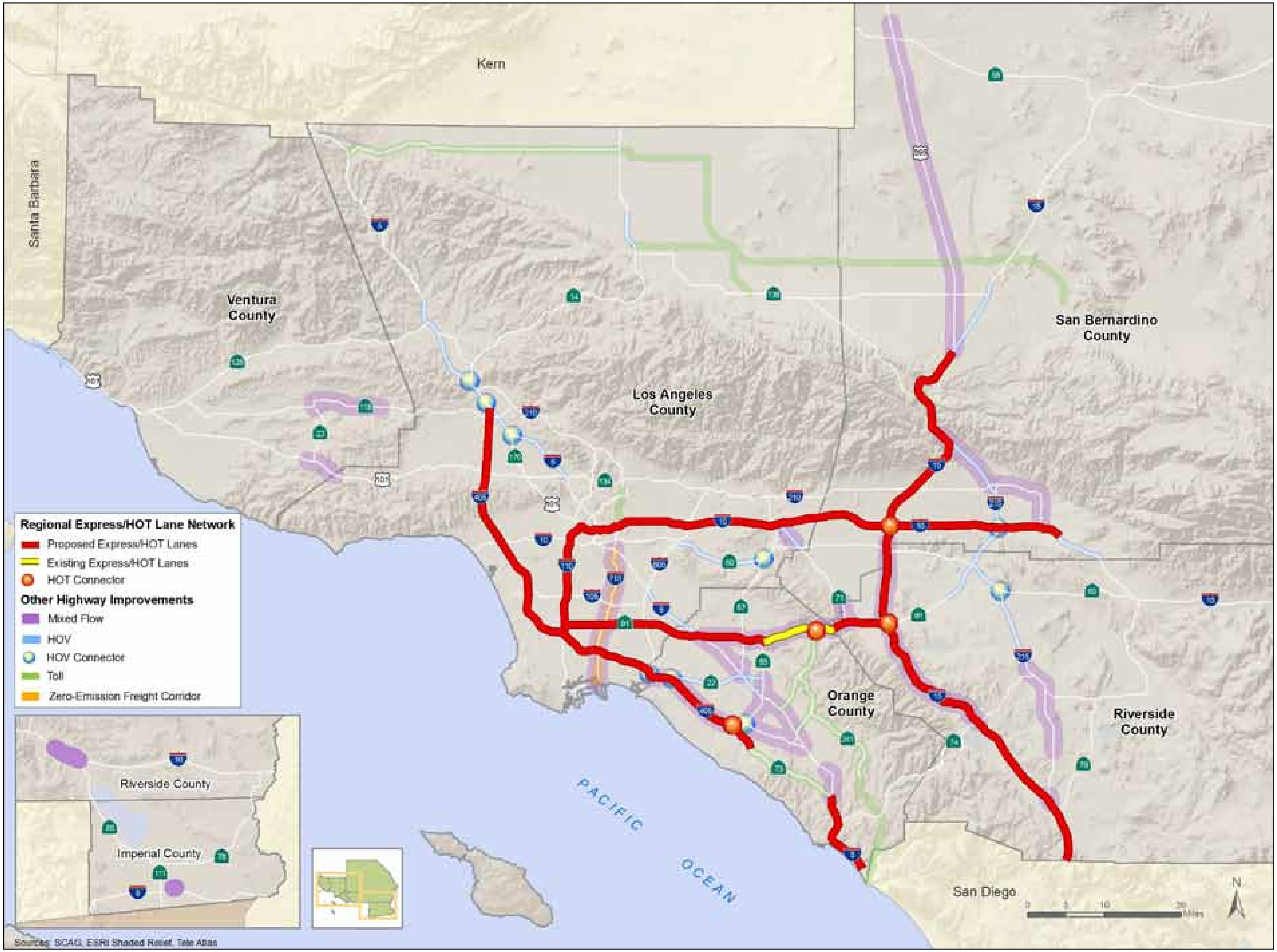
Additional efforts underway include the extension of the 91 Express Lanes to I-15 in Riverside County along with planned Express Lanes on the I-15. Also, traffic and revenue studies are proceeding for I-10 and I-15 in San Bernardino County.

TABLE 2.6 and **EXHIBIT 2.6** display the segments in the proposed Express Lane network.

TABLE 2.6 Express/HOT Lane Network

County	Route	From	To
Los Angeles	I-405	I-5 (North SF Valley)	LA/OC County Line
Los Angeles	I-110	Adams Blvd (s/o I-10)	I-405
Los Angeles	I and SR-110/	Adams Blvd	US-101
Los Angeles	US-101	SR-110	I-10
Los Angeles	I-10	US-101	I-710
Los Angeles	I-10	I-710	I-605
LA, Orange	SR-91	I-110	SR-55
LA, SB	I-10	I-605	I-15
Orange	I-405	LA/OC Line	SR-55
Orange	I-5	SR-73	OC/SD County Line
Orange	SR-73	I-405	MacArthur
Riverside	SR-91	OC/RV County Line	I-15
Riverside	I-15	Riv/SB County Line	SR-74
Riverside	I-15	SR-74	Riv/SD County Line
San Bernardino	I-10	I-15	SR-210
San Bernardino	I-10	SR-210	Ford St
San Bernardino	I-15	SR-395	Sierra Ave
San Bernardino	I-15	Sierra Ave	6th St
San Bernardino	I-15	6th St	Riv/SB County Line

EXHIBIT 2.6 Express/HOT Lane Network



Meeting Our Airport Demand

Although at a rate much slower than those seen in previous decades, air travel in the SCAG region continues to grow, and is expected to pick up the pace when the region economically recovers. This RTP's regional air passenger demand forecast of 145.9 million annual air passengers (MAP) in 2035 is a very conservative forecast compared to forecasts adopted by past SCAG RTPs, such as the 165.3 MAP 2035 forecast adopted by the 2008 RTP. However, like previous forecasts, this new long-range forecast is also based on interim forecasts that show the urban capacity-constrained airports of Los Angeles International (LAX), Bob Hope, Long Beach and John Wayne airports all reaching their defined legally allowable or physical capacity constraints well before 2035. The remaining air travel demand is served by the other, suburban airports with ample capacity to serve future demand, including Ontario International, San Bernardino International, March Inland Port, Palmdale Regional, Southern California Logistics, and Palm Springs airports. A small amount of future air passenger demand would also be served by the two commuter airports in the region, Oxnard and Imperial airports.

TABLE 2.7 displays Low Growth, Baseline/Medium Growth and High Growth air passenger forecast scenarios that were considered for inclusion in this RTP. At 164 MAP in 2035, the High Growth Scenario is only slightly less than the 165.3 MAP forecast adopted for the 2008 RTP in 2035, and its average annual growth rate is consistent with recent industry forecasts developed by the FAA, Boeing and Airbus. This Plan's aviation demand forecast is the Baseline/Medium Growth Forecast that is more conservative than the High Growth Scenario, and is consistent with recent passenger trends. At 145.9 MAP, it is virtually identical to the Constrained/No Project Scenario that was modeled for the 2008 RTP. **FIGURE 2.4** shows the airport allocations for this RTP's regional air passenger demand forecast.

At 5.61 million tons of cargo in 2035, this RTP's region air cargo demand forecast is also much more conservative than what was adopted by the 2008 RTP for 2035 (8.28 million tons). **FIGURE 2.5** shows the airport allocations for this RTP's regional air cargo demand forecast. A more complete discussion of the methodology use to develop these forecasts can be found in the Aviation technical appendix.

TABLE 2.7 2035 Airport Forecasts (Million Annual Air Passengers)

Airport	Low	Baseline	High
Bob Hope	9.4	9.4	9.4
John Wayne	10.8	10.8	10.8
LAX	78.9	78.9	78.9
Long Beach	4.2	4.2	4.2
March Inland Port	0.4	0.6	2.5
Ontario	19.2	30.7	31.6
Palmdale	1.6	2.6	6.1
Palm Springs	2.6	4.1	9.6
San Bernardino	1.8	2.8	6.7
SoCal Logistics	0.4	0.7	1.6
Imperial	0.6	0.9	2.1
Oxnard	0.1	0.2	0.5
Total	**130.0**	**145.9**	**164.0**

FIGURE 2.4 2035 Air Passenger Demand Airport Allocations

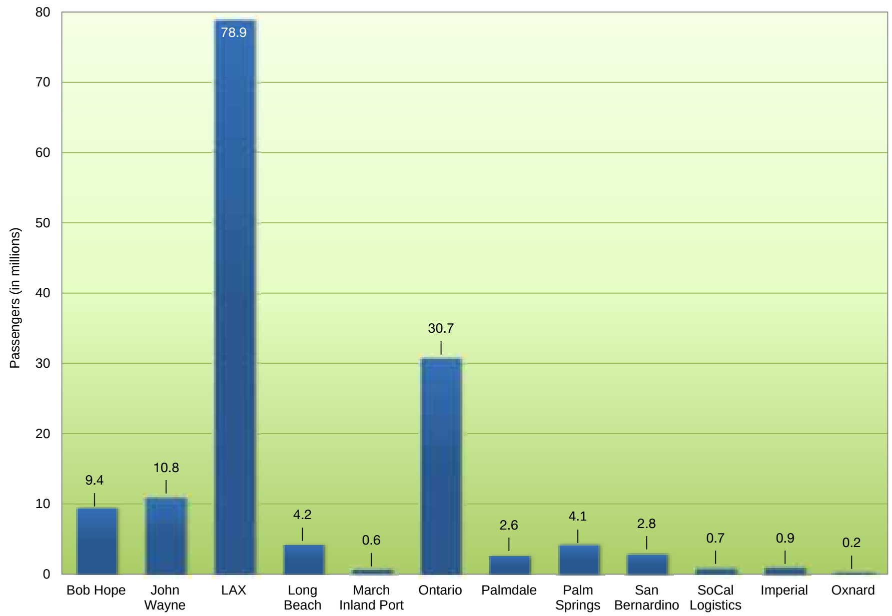
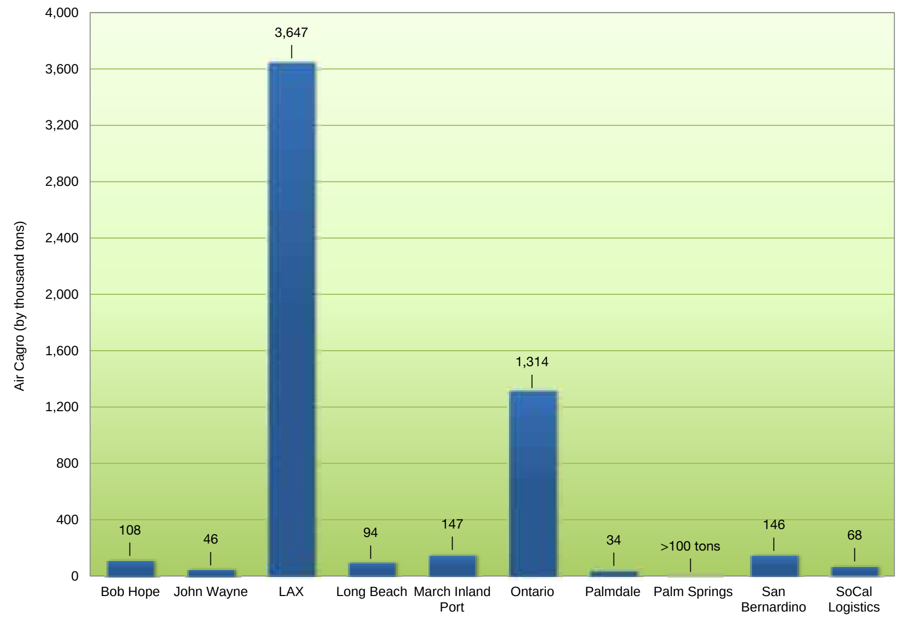


FIGURE 2.5 2035 Air Cargo Demand Airport Allocations



The past few years have seen deep cutbacks in flights by the airlines, particularly at mid-sized airports. There have also been several significant mergers in the U.S. airline industry. These mergers will likely lead to the elimination of duplicate service that may decrease airline competition, increase fares and reduce the number of flights in many markets. However, the merged carriers may find it advantageous to offer service at multiple airports in a given market, rather than add frequency at LAX. The other recent dynamic in the aviation industry has been the transition of the low-cost carriers, as they have gained market share, from primarily serving secondary airports in large metropolitan regions to competing directly with the legacy network carriers at the primary airport. A recent example is the decision by both Virgin America and Southwest to introduce or expand service at LAX, rather than primarily serve the region through the secondary airports. One consequence of this strategy has been a significant decline in passenger traffic at both Bob Hope Airport and Ontario International Airport.

These and other recent trends call into question the ability to shift air traffic from the existing constrained airports in the urban core to the outlying/suburban airports that have the capacity to accommodate the forecast growth, which is necessary to meet this RTP's 145.9 MAP forecast in 2035. In order to attract the number of passengers to the suburban airports envisaged in the 2035 regional air passenger demand forecast, some incentives are likely to be needed to encourage airlines to offer service at these airports. Potential incentives fall into three broad categories:

1. Improvements to the airport ground access system that would make the alternate airports more accessible to travelers from those parts of the region that currently find the core urban airports more convenient,
2. Measures that would reduce the cost to the airlines of offering service at the alternate airports, either through direct subsidy or by reducing airport fees and charges relative to the more congested airports, and
3. Marketing programs to encourage air travelers to consider using the air services at the alternate airports.

General Aviation

SCAG also updated regional general aviation demand forecasts for the 44 general aviation airports in the region, as well as for the 10 commercial airports in the region that support general aviation activity. Regional general aviation demand forecasts were last developed by SCAG in 2003. The new forecasts employed a sophisticated "cohort" methodology that considers the amount of flying done by pilots as they pass through different age groups, and the extent to which older pilots are replaced by new pilots. The forecast shows a decline in regional general aviation operations by about 32 percent from 2010 to 2035. The main reason for the anticipated decline is the fact that the aging pilot population is not expected to be adequately replenished by new student pilot starts. The regional general aviation demand forecast and methodology can be found in the Aviation technical appendix.

Airport Ground Access Strategy

Improvements to airport ground access (and egress) fall under SCAG's domain of responsibility. SCAG works closely with the airport authorities and county transportation commissions to identify and pursue implementation of specific projects. To be effective in attracting passengers to air service at the alternate airports, ground access improvements will need to significantly reduce the travel time and/or cost of accessing the alternate airports. This is likely to be a particular concern with airports such as Palmdale, which is almost 70 miles from downtown Los Angeles and around 50 miles from communities in the San Fernando Valley.

While the cost of significantly reducing freeway travel times beyond those improvements that will be implemented for other reasons would be prohibitive, particularly for the relatively small number of travelers likely to use the alternate airports, there may be opportunities to take advantage of improved transit and rail services that are being planned. These include the extension of the Metro Gold Line to Ontario and improvements to Metrolink service on the Antelope Valley and San Bernardino lines. While the volume of airport passengers alone would not justify the cost of these projects, if they are being done anyway to address other travel needs, SCAG can work with the relevant agencies to make sure that the connections to the alternate airports are well planned and marketed. In the case of Ontario Airport, airport passenger volumes may be high enough to support express bus service from remote terminals at such locations as the Anaheim Regional Transportation Intermodal Center, Los Angeles Union Station, and the Van Nuys FlyAway terminal in the San Fernando Valley. These facilities all currently exist or will by 2035, so it would only be necessary to operate the bus service. These services may need to be subsidized until ridership reaches a level where the fare revenue can support the operation, and SCAG could work with the airport authorities and regional transportation agencies to identify funding to subsidize the operation. Potential sources of funding could include charging fees for private vehicles picking up and dropping off passengers at the congested airports. This would not adversely impact existing airport revenues and would have a number of advantages:

- It would encourage resident passengers to use airport parking instead of being dropped off and picked up, which would increase airport revenues,
- By discouraging pick-up and drop off trips it would reduce vehicle trips generated by the airport on surrounding streets, and
- It would encourage more passengers to use public transportation or express buses from remote terminals, which would reduce vehicle miles of travel (VMT) on the region's arterial and freeway system.

It is unlikely that the volumes of air passengers at the other three alternate airports would be high enough to support dedicated express bus service, but it might be possible to serve San Bernardino International Airport as an extension of express bus service to Ontario Airport from Union Station or Van Nuys.

A more thorough discussion and listing of recommended ground access projects for each airport, both roadway and public transit projects, can be found in the Airport Ground Access Element in the Aviation technical appendix.

AIRPORT FINANCIAL STRATEGY

SCAG currently does not have a source of funding to provide subsidies for air service or to reduce airport fees and charges to the airlines. However, it can work with the various airport authorities in the region to establish a regional funding mechanism to support the development of airport facilities and infrastructure at the alternate airports using revenues generated at the congested airports as part of efforts to limit traffic growth at those airports. This is currently prohibited by the U.S. Department of Transportation regulations on airport revenue diversion, except in cases where both airports are operated by the same airport authority. SCAG may need to work with the Congressional representatives from the region to obtain legislation that allows joint programs by congested and uncongested airports, even if they are operated by different agencies. This should not be a controversial issue as long as it is sufficiently targeted and narrowly scoped. Congested airports have an interest in shifting traffic to less congested airports. For airports like LAX, which has a significant component of international traffic that generates more revenue than domestic flights, it may be more efficient to limit domestic flights that could be accommodated at other airports in the region, thereby freeing up capacity for more lucrative international flights.

AIRPORT MARKETING STRATEGY

SCAG does not currently have a source of funding to support marketing efforts to encourage air travelers in the region to consider using air service at the alternate airports. However, there is potential for the various airport authorities and the region's business community to develop an effective region-wide marketing effort to promote alternatives to the use of congested airports. This program could be funded through a variety of sources, such as airport parking and rental car transactions. SCAG would need to work with the various stakeholders to identify the benefits of an effective marketing program to all the region's airports and develop a consensus on how to fund and implement such a program.

AIRPORT POLICIES AND ACTION STEPS

This section outlines the additional policies and action steps associated with the aviation program contained in this RTP/SCS.

Regional Aviation Demand, Airport Infrastructure and Airport Ground Access

The following outlines key policies:

- The capability of uncongested secondary airports in the region to accommodate future aviation demand, where such growth is desired, should be preserved during periods of declining or stagnant air traffic
- Uncongested secondary airports in the region, where additional activity is desired, should be supported through appropriate incentives, marketing, and projects that enhance their capacity and regional accessibility
- The factors that most influence the growth in demand for air travel and the composition of the market should be identified
- A regional consensus should be developed on how best to support the development of new air services at uncongested secondary airports, where such growth is desired
- State-of-the-art aviation demand forecast methodologies should be employed to accurately forecast future aviation demand in the region's complex multi-airport system, and regional aviation demand forecasts should be regularly updated to address changing conditions
- Existing and planned regional highway and high-occupancy transit improvements should be leveraged to the extent possible to increase the regional accessibility of uncongested secondary airports, where traffic is desired, while minimizing improvement needs

The following outlines additional action steps to improve aviation and airport ground access in the region:

- Work with the region's airport operators to conduct a region-wide air passenger survey on an ongoing basis, designed to enhance and inform regional aviation demand forecasting and airport marketing efforts
- Develop an in-house aviation demand forecasting model that can support the development of future forecasts and allocation of forecast demand to airports in a complex multi-airport regional system. The model should be fully integrated with SCAG's regional transportation model, and should have airport ground access modeling capabilities

- Work with the region's airport operators and business community to define a region-wide marketing effort to promote alternatives to increased use of congested urban airports, consistent with the policy directions of airport operators
- Identify and define incentives that airports can effectively use to encourage airlines to provide new air service
- Establish a Regional Airport Ground Access Task Force to define potential projects and programs to improve airport accessibility to secondary airports, and reduce vehicular traffic generated by the large urban airports. The Task Force would help plan and promote rail and express bus service improvements and extensions to airports in the region, as well as an integrated regional system of remote air terminals ("FlyAways")

Airport Economics, Finance and Funding

The following policies are related to Airport Economics, Finance and Funding:

- New funding mechanisms should be identified for implementing regional infrastructure and airport ground access improvements
- Efforts by airport operators to develop strategic financial plans and explore non-aeronautical revenue-generating use of underutilized airport property should be supported
- Strategies that enhance the economic contribution of aviation to the regional economy should be identified and implemented

The following are recommended action steps:

- Sponsor and support new legislation that allows for more flexible use of airport revenues for off-airport ground access projects when requested by airport operators
- The Airport Ground Access Task Force should explore and develop potential new funding sources to support specific projects they have identified for improving regional airport accessibility
- Coordinate with the region's County Transportation Commissions and other transportation agencies to include joint funding of airport ground access projects identified in SCAG's Regional Transportation Plan in those agencies' plans
- Conduct regional aviation economic impact studies that identify the economic benefits to the region of different types and levels of regional aviation activity, and the likely economic impacts of implementing alternative policy options for serving future regional aviation demand

Airport Land Use Compatibility and Environmental Impacts

The following policies are related to Land-Use Compatibility and Environmental Impacts:

- Increased coordination between airport planning and land use planning on both regional and local levels should be promoted
- Regional support and coordination should be extended to the region's Airport Land Use Commissions
- Information on aviation environmental "best practices" should be shared and disseminated on a regional level
- Mechanisms for promoting cleaner and quieter aircraft at the region's airports should be identified and supported

The following are related action steps.

- Continue to pursue airport "smart growth" projects, using the Airport Smart Growth Framework developed for the Chino Airport Smart Growth Demonstration Project and applying it to different airport settings
- Incorporate airport "smart growth" land use principles in land use forecasts used by future regional transportation plans
- Periodically conduct information sharing forums for the region's Airport Land Use Commissions in cooperation with the Caltrans Division Aeronautics on "best practices" for airport land use compatibility planning
- Serve as a clearinghouse for information on aviation environmental "best practices" by airports for mitigating air, noise and water pollution and reducing greenhouse gas emissions
- Sponsor and support new legislation for creating substantial incentives for airlines to upgrade their aircraft fleets to cleaner, quieter aircraft and NextGen-compatible aircraft

Airspace Planning and New Technologies

The following are policies related to Airspace Planning and New Technologies:

- Modifications to the regional airspace system that reduce potential airspace conflicts, increase passenger safety, reduce costs to airlines, and reduce noise and air quality impacts should be identified and promoted
- Opportunities should be pursued for increasingly the region's airspace capacity, reducing potential future airspace conflicts and increasing airline efficiencies through new navigation and air traffic control technologies
- Existing and potential future airspace constraints should be incorporated into regional aviation planning

The following are related action steps:

- Continue to coordinate and provide input to the FAA's Optimization of Airspace and Procedures in the Metroplex (OAPM) Program for Southern California, and similar airspace modernization activities, including updated operational forecasts
- SCAG Aviation Technical Advisory Committee (ATAC) should continue and enhance its coordination with the Southern California Airspace Users Working Group (SCAUWG) on airspace issues of regional importance
- Continue to advocate that the region should serve as an early "test bed" for the phased implementation of new airspace technologies, including new satellite-based NextGen technologies developed by the FAA, that have the potential to reduce airspace conflicts and reduce noise and air quality impacts on local communities
- Explore how new navigation and air traffic control technologies can contribute to the region's airspace capacity, and should incorporate potential airspace constraints in aviation demand forecasts developed for future regional transportation plans

Goods Movement System

System Vision

Goods movement and freight transportation are essential to support the SCAG regional economy and quality of life. In 2010, over 1.15 billion tons of cargo valued at almost $2 trillion moved across the region's system.[1] Whether carrying imported goods from the San Pedro Bay Ports to regional distribution centers, supplying materials for local manufacturers, or delivering consumer goods to SCAG residents, the movement of freight provides the goods and services needed to sustain regional industries and consumer needs on a daily basis.

Working with its public and private sector partners, SCAG has established a vision for the goods movement system that is reflected in the 2012 RTP.

A world-class coordinated Southern California goods movement system that accommodates growth in the throughput of freight to the region and nation in ways that support the region's economic vitality, attainment of clean air standards, and the quality of life for our communities.

1 FHWA Freight Analysis Framework: http://faf.ornl.gov/fafweb/Extraction0.aspx

Key Function and Markets

The goods movement system has developed in the SCAG region to serve a wide range of user markets. Each of these markets has unique performance needs that dictate the components of the system that they will use. A brief summary of these markets follows.

INTERNATIONAL TRADE

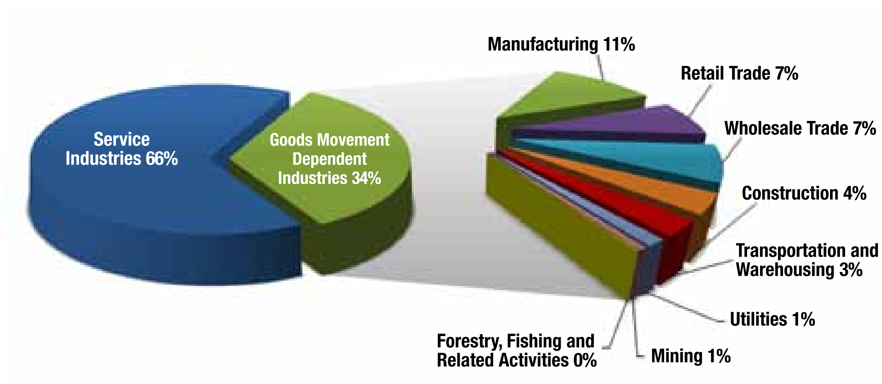
The SCAG region is the largest international trade gateway in the U.S. In 2010, the Los Angeles Customs District (which includes the Ports of Los Angeles, Long Beach and Hueneme and Los Angeles International Airport) handled $336 billion of maritime cargo and $78 billion of air cargo. In the same year, $10.4 billion of trade passed through the three international Ports of Entry (POEs) between the U.S. and Mexico in Imperial County. Trade moving through these international gateways is supported by an extensive transportation system including a highly-developed network of roadways and railroads, air cargo facilities, intermodal facilities, and an abundance of regional distribution and warehousing clusters.

LOCAL GOODS MOVEMENT – DEPENDENT INDUSTRY SUPPORT

An overwhelming majority of the goods movement activity in the SCAG region is generated by local businesses moving goods to local customers and supporting national domestic trade systems. These businesses are sometimes referred to as "goods movement-dependent industries." In 2010, these industries including manufacturing, wholesale and retail trade, construction and warehousing, employed over 2.9 million people throughout the region, and contributed $253 billion to the regional Gross Domestic Product (GDP) (**FIGURE 2.6**).[2] These industries are anticipated to grow substantially with manufacturing forecast to increase its GDP contribution 130 percent by 2035 and wholesale trade growing 144 percent.

Over 85 percent of truck trips in the SCAG region are related to goods movement-dependent industries.[3] Domestic manufacturers, wholesalers, and retailers also use the rail system and the air cargo system, though to a much more limited extent than international shippers.

FIGURE 2.6 GDP Contribution of Goods Movement Dependent Industries (2010)



LOGISTICS ACTIVITIES – INCLUDING WAREHOUSE AND DISTRIBUTION FACILITIES

The SCAG region hosts one of the largest clusters of logistics activity in North America. Logistics activities, and the jobs they provide, depend on a network of warehousing and distribution facilities, highway and rail connections, and intermodal rail yards. In addition to carrying needed inventories, many warehouses and distribution centers in the SCAG region provide transloading services, or the deconsolidation and reloading of freight from marine containers to domestic containers. Because domestic containers are larger than marine containers, importers and shippers are able to realize significant cost savings in transportation costs through economies of scale by transloading. The abundance of warehousing and distribution facilities, along with the highly-developed highway and rail network, serves as a competitive advantage for the SCAG region by attracting transloading activities that supply numerous local and regional jobs and revenue. Trucking access is particularly critical to warehousing and logistics businesses, and the transloading industry. However, distribution centers serving national demand also need access to rail intermodal terminals and air cargo facilities.

2 SCAG Comprehensive Regional Goods Movement Plan and Implementation Strategy, REMI
3 SCAG HDT Model

Components of the Regional Goods Movement System

EXHIBIT 2.7 depicts the region's multi-modal goods movement system. This system is comprised of the following major elements:

- **Seaports (Ports of Los Angeles, Long Beach and Hueneme):** Serving as the largest container port complex in the U.S., the Ports of Los Angeles and Long Beach handled 76 million tons, or $269 billion of imports, and 48 million tons, or $67 billion of exports in 2009.[4] Port Hueneme, in Ventura County, specializes in the import and export of automobiles, fresh fruit and produce and serves as the primary support facility for the offshore oil industry.
- **Land Ports:** The international border crossings in Imperial County are busy commercial land ports responsible for over $7 billion in imports and $5 billion in exports in 2007 driven by the maquiladora trade and movement of agricultural products.
- **Air Cargo Facilities:** The SCAG region is home to numerous air cargo facilities including Los Angeles International Airport (LAX) and Ontario International Airport (ONT) that together handled over 96 percent of the region's air cargo in 2010.
- **Interstate, Highways and Local Roads:** The region has about 53,400 road miles, 1,630 miles of which are interstate and freeway type.[5] Sections of I-710, I-605, SR-60, and SR-91 carry the highest volumes of truck traffic in the region, averaging over 25,000 trucks per day in 2008. Other major components of the regional highway network also serve significant numbers of trucks including I-5, I-10, I-15, and I-210, some with sections that carry over 20,000 trucks per day. These roads carry a mix of local, domestic trade, and international cargoes. The arterial roadway system also plays a critical role providing "last mile" connections to regional ports, manufacturing facilities, intermodal terminals and warehouses and distribution centers.
- **Class I Railroads:** Critical to the growth of the region's economy, the Burlington Northern Santa Fe Railway (BNSF) and Union Pacific (UP) carry international and domestic cargo to and from distant parts of the country. The BNSF mainline operates on the Transcontinental Line (and San Bernardino Subdivision) while the UP operates on Coast Line, Santa Clarita Line, Alhambra Line, LA Subdivision, and El Paso Line. Both railroads operate on the Alameda Corridor that connects directly to the San Pedro Bay Ports. The San Pedro Bay Ports also provide several on-dock rail terminals along with the six major intermodal terminals operated by the BNSF and UP.
- **Warehouse and Distribution Centers:** In 2008, the region had about 837[6] million square feet of warehousing space and another 185 million square feet in developable land.[7] An estimated 15 percent of the occupied warehouse space served port-related uses while the remaining 85 percent supported domestic shippers.[8] Many of these warehouses are clustered along key goods movement corridors (**EXHIBIT 2.7**). Port-related warehousing is concentrated in the Gateway Cities subregion while national and regional distribution facilities tend to be located in the Inland Empire.

4 America's Freight Transportation Gateways: Connecting Our Nation to Places and Markets Abroad. Research and Innovative Technology Administration, Bureau of Transportation Statistics, U.S. Department of Transportation, 2009

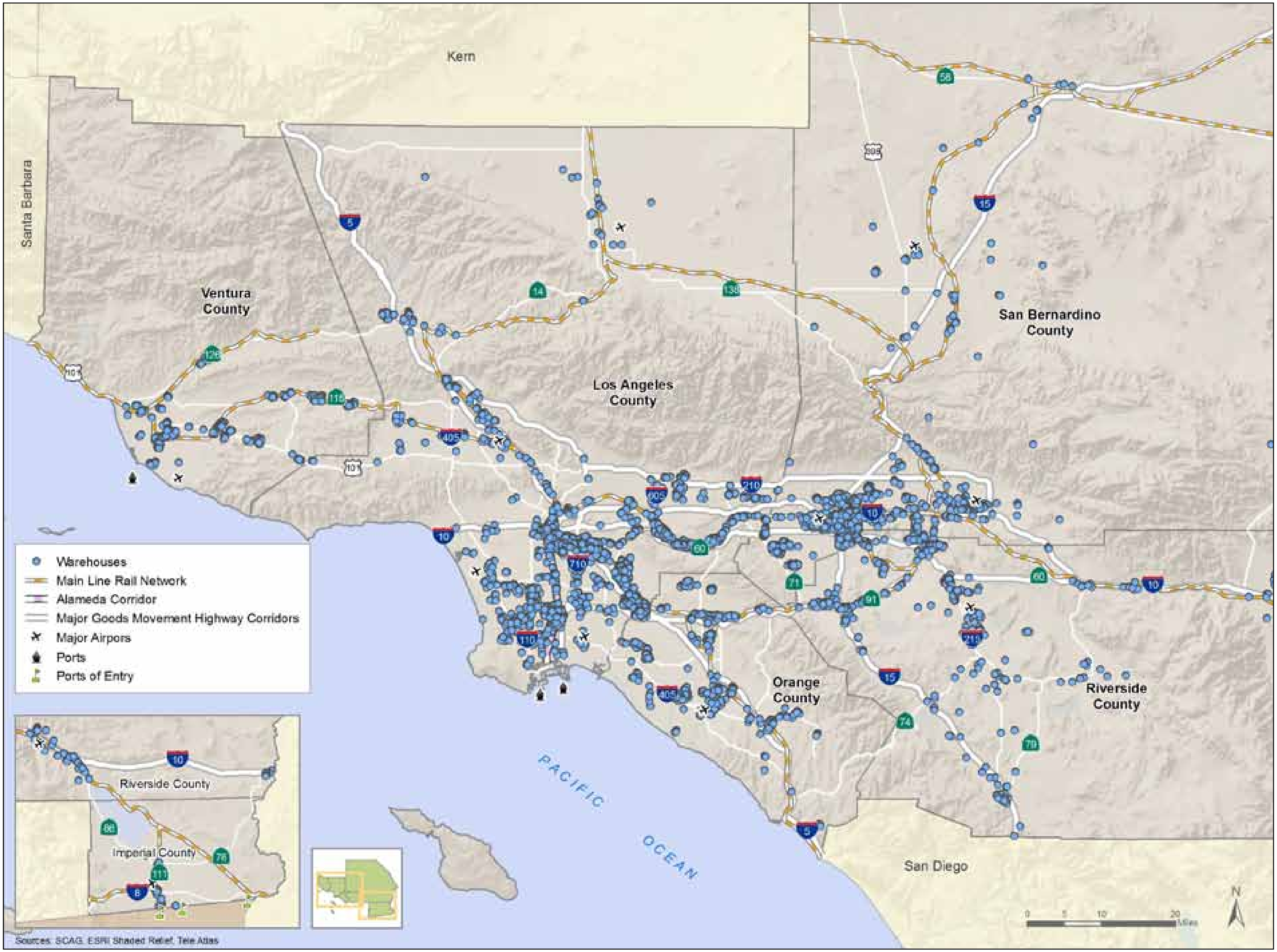
5 http://www.dot.ca.gov/hq/tsip/hpms/hpmslibrary/hpmspdf/2009PRD.pdf (last accessed on December 10, 2010

6 SCAG Comprehensive Regional Goods Movement Plan and Implementation Strategy

7 Potentially developable warehouse space is estimated based on land zoned and suitable for warehouse development

8 Some domestic warehouse space may include use by domestic shippers mixing internationally-sourced and domestically-sourced goods

EXHIBIT 2.7 Regional Goods Movement System



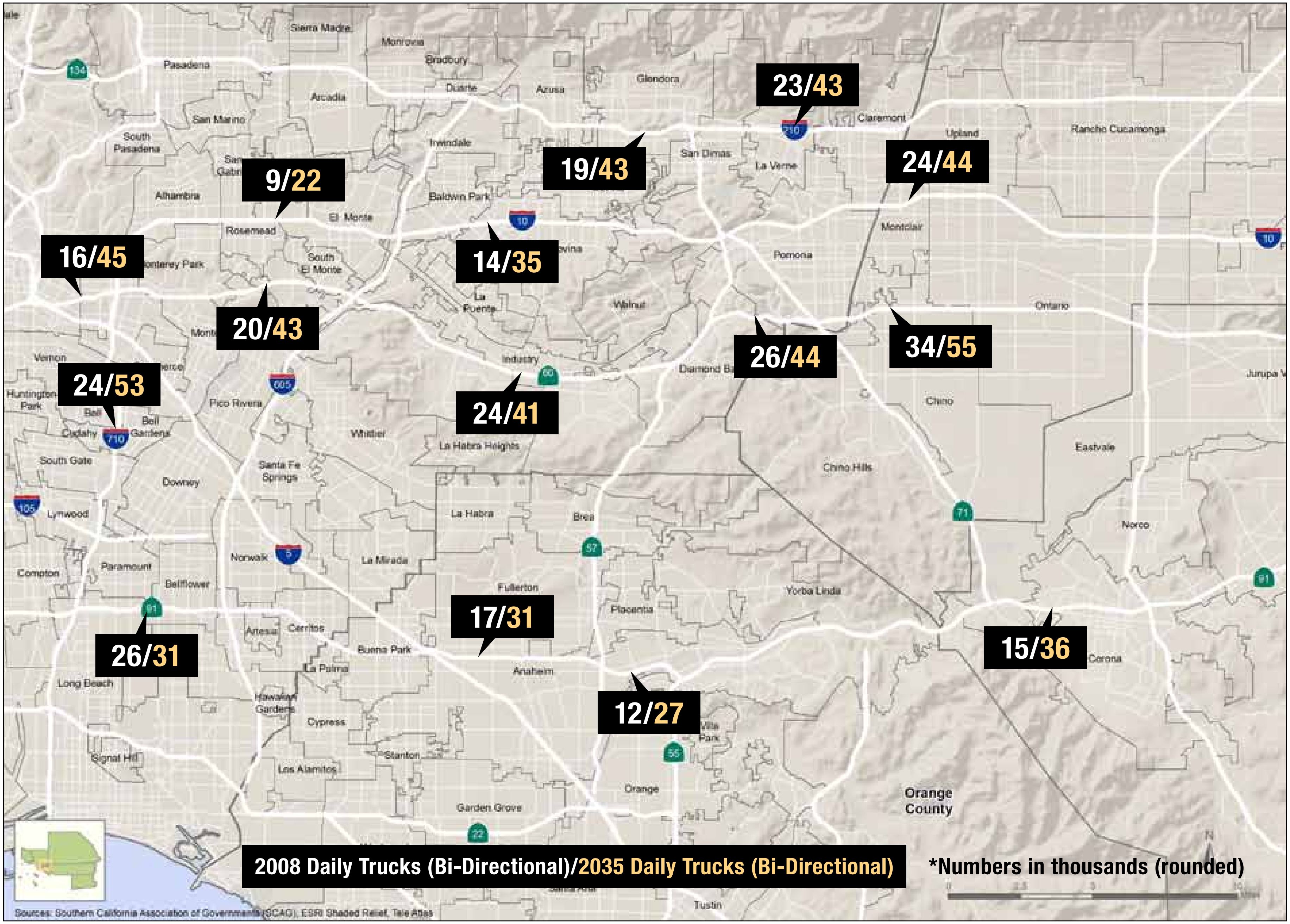
Goods Movement Trends and Drivers

There are a number of key trends that are anticipated to have major impacts on the goods movement system. These trends include:

- **Population and General Economic Growth:** Despite a current economic downturn brought on by challenging global conditions, population and employment in the SCAG region are expected to grow by approximately 24 percent and 22 percent by 2035, respectively. This growth will create increased consumer demand for products and the goods movement services that provide them. The increased demand will drive stronger growth in freight traffic on shared highway and rail facilities. Truck traffic on many key east-west corridors is anticipated to grow by 70–100 percent. Without an increase in capacity, truck and auto delay will increase substantially, truck-involved accidents will be more frequent, and the levels of harmful emissions will rise. Moreover, growing demand for commuter rail services on rail lines owned by the freight railroads will create needs for expanded capacity on these facilities.
- **Recovery and Expansion of International Trade:** Within the RTP time horizon, international trade is anticipated to recover with renewed demand for both import and export capabilities. Despite increasing competition with other North American ports and the expansion of the Panama Canal, the San Pedro Bay Ports anticipate cargo volumes to grow to 43 million containers by 2035[9]—more than tripling from current levels. This will create the need to expand marine terminal facilities, improve highway connections (particularly those connecting directly to the San Pedro Bay Ports, like I-710 and SR-47), and address on-dock and off-dock intermodal terminal capacities. If port-related rail traffic and commuter demand are to be satisfied, additional mainline capacity improvements will be required. Mitigating the impacts of increased train traffic on communities will continue be a considerable challenge.
- **Continued Expansion of Warehouse and Logistics Activity:** Southern California is an ideal place for expanded distribution and logistics activity and will continue to be a significant source of well-paying jobs in the region through 2035. Demand for port-related warehouse space is projected to grow at a faster pace than demand for domestic warehousing. As space near the San Pedro Bay Ports reaches capacity, port warehousing will push out to the Inland Empire. Expansion in national and regional distribution facilities is also likely to occur in the Inland Empire resulting in substantial congestion problems due to the increased truck volumes on regional highways. By 2035, the region may experience a shortfall of more than 228 million square feet in warehouse space relative to demand.
- **Air Quality Issues:** Much of the SCAG region does not meet federal ozone and fine particulate ($PM_{2.5}$) air quality standards. Goods movement is a major source of emissions that contribute to these regional air pollution problems (NO_X and $PM_{2.5}$). While emissions from goods movement are being reduced through efforts such as the San Pedro Bay Ports Clean Air Action Plan, these reductions are unlikely to be sufficient to meet regional air quality goals.

[9] San Pedro Bay Ports Container Forecast

EXHIBIT 2.8 Rising Truck Volumes in the Region



Goods Movement Strategy

To realize the benefits of efficient and sustainable goods movement, it is critical to identify strategies and projects that address expected growth trends. Recent regional efforts have focused on strategies to develop a coherent, refined, and fully integrated regional goods movement system. Following the completion of the 2008 RTP, SCAG initiated the Comprehensive Regional Goods Movement Plan and Implementation Strategy. This effort, involving diverse regional stakeholders, is intended to identify a multimodal regional freight plan that integrates existing strategies and projects with newly developed regional initiatives advanced through the study. Some of these strategies are highlighted below.[10]

REGIONAL CLEAN FREIGHT CORRIDOR SYSTEM

In past RTPs, SCAG has envisioned a system of truck-only lanes extending from the San Pedro Bay Ports to downtown Los Angeles along the I-710, connecting to an east-west segment, and finally reaching the I-15 in San Bernardino County. Such a system would address the growing truck traffic on core highways through the region and serve key goods movement industries in a manner that mitigates negative impacts on communities and the environment. Truck-only freight corridors are effective as they add capacity in congested corridors, improve truck operations and safety by separating trucks and autos, and provide a platform for the introduction and adoption of zero-emission technologies. Significant progress towards a regional freight corridor system has continued as evidenced by recent work on an environmental impact report (expected to be completed in 2012) for the I-710 segment. As part of the 2012 RTP, SCAG includes a refined concept for the east-west corridor component of the system and connections to an initial segment of I-15.

While numerous potential east-west freight corridor options were examined, the 2012 RTP identifies a corridor concept to be explored further that could fall within a five-mile span of the route illustrated in **EXHIBIT 2.9**.

EXHIBIT 2.9 Potential East West Freight Corridor

Non-freeway alignments may provide an opportunity to move the facility away from neighborhoods and closer to industrial uses that it would serve. Approximately 50 percent of the region's warehousing space, and 25 percent of its manufacturing employment lies along the identified route. After adoption of the 2012 RTP, it is anticipated that significant additional study of alignments will be conducted, including an alternatives analysis completed as part of a full environmental review.

The East-West Freight Corridor would carry between 58,000 and 70,000 trucks per day—trucks that would be removed from adjacent general purpose lanes and local arterial roads. As highlighted in **TABLE 2.8**, the corridor would benefit a broad range of goods movement markets: between 25–40 percent of the trucks would be port-related, almost 40 percent would serve local goods movement dependent industries, and the remainder would support domestic trade. Truck delay would be reduced by up to 11 percent while

[10] For more detailed information on the SCAG Comprehensive Regional Goods Movement Plan and Implementation Strategy, please see the Goods Movement Technical Appendix.

speeds for autos on SR-60 would be improved by 11–12 percent. Truck traffic on the SR-60 general purpose lanes would be reduced by 42–82 percent, depending on location, by as much as 33 percent on I-10, and by as much as 20 percent on adjacent arterials. Separating trucks and autos would also reduce truck involved accidents on east-west freeways that currently have some of the highest accident levels in the region (20–30 accidents a year on certain segments).[11]

For the 2012 RTP, the regional freight corridor system also includes an initial segment of I-15 that would connect to the East-West Freight Corridor, reaching just north of I-10. Additional study will be undertaken to complete specification of the I-15 component of this project.

TABLE 2.8 Benefits of an East-West Corridor Strategy

Benefits of an East-West Corridor Strategy	
Mobility	▪ Truck delay reduction of approximately 11% ▪ All traffic delay reduction of approximately 4.3% ▪ Reduces truck volumes on general purpose lanes—42–82% reduction on SR-60
Safety	▪ Reduced truck/automobile accidents (up to 20–30 per year on some segments)
Environment	▪ 50% clean truck utilization removes: 2.4 tons NO_X, 0.08 tons $PM_{2.5}$, and 2,001 tons CO_2 daily (2.7–6% of region's total)
Community	▪ Preferred alignment has least impact on communities ▪ Removes traffic from other freeways ▪ Zero-emissions technology (ZET)—reduces localized health impacts
Economic	▪ Supports mobility for goods movement industries—comprise 34% of SCAG regional economy and jobs

[11] SCAG Comprehensive Regional Goods Movement Plan and Implementation Strategy

BOTTLENECK RELIEF STRATEGY

In recent analysis of critical issues affecting the trucking industry conducted by the American Transportation Research Institute (ATRI), traffic congestion ranked near the top in 2011 after being less of a concern in 2009–2010 as a result of the economic downturn.[12] Besides causing delays to other highway users, heavy truck congestion results in wasted labor hours and fuel. In 2010, it was estimated that the cost of truck congestion in 439 major urban areas was approximately $23 billion.[13] Truck congestion in urban areas within the SCAG region resulted in approximately $2.6 billion in costs.[14] Given that driver wages and fuel costs represent over 50 percent of total motor carrier costs, truck congestion has major impacts on the bottom line of the trucking industry. Truck bottlenecks are also emission "hot spots," and generally have significantly degraded localized air quality caused by increased idling from passenger vehicles and trucks.

A coordinated strategy to address the top-priority truck bottlenecks is a cost-effective way to improve the efficiency of goods movement in the SCAG region. Bottleneck projects may also be easier to implement since they are often less intrusive than other types of projects, contribute to the region's environmental goals (by reducing emissions "hot spots"), and result in substantial, tangible benefits to commuters and goods movement industries alike.

SCAG recently studied key regional truck bottlenecks and associated projects. Through this analysis, project concepts that may address the highest priority truck bottlenecks and have the most significant impact on delay were identified and continue to be evaluated. The 2012 RTP allocates an estimated $5 billion to address goods movement bottleneck relief strategies. Examples of bottleneck relief strategies include ramp metering, extension of merging lanes, ramp and interchange improvements, capacity improvements, and auxiliary lane additions. Annually, 3.6 million hours of heavy truck delay during the most congested time periods on area roadways could be eliminated if the highest priority truck bottlenecks in the region are addressed.

[12] http://www.atri-online.org/2011_top_industry_issues.pdf
[13] Texas Transportation Institute 2011 Urban Mobility Report
[14] Texas Transportation Institute 2011 Urban Mobility Report. Urban areas as defined in the report include Los Angeles-Long Beach-Santa Ana, Riverside-San Bernardino, Lancaster-Palmdale, Bakersfield, Indio-Cathedral City-Palm Springs, and Oxnard-Ventura.

RAIL STRATEGY

The health of the Southern California economy depends on an efficient railroad system that has the capacity to accommodate projected growth in international and domestic freight rail. The railroad system in the SCAG region provides a critical connection between the largest port complex in the country and producers and consumers throughout the U.S. Over half of the international cargo arriving at the San Pedro Bay Ports utilizes rail (including on, near- and off-dock). Railroads also serve a myriad of domestic industries, predominantly for long-haul freight leaving the region. The extensive rail network in the SCAG region is a critical link in the regional supply chain offering shippers the ability to move large volumes of goods over long distances at lower costs versus other transportation options.

The SCAG region is served by two Class I freight railroads: Burlington Northern Santa Fe Railway (BNSF) and Union Pacific Railroad (UP). BNSF operates a single main line extending from connections to the Alameda Corridor near downtown Los Angeles to Barstow with a terminus in Chicago. UP operates two main lines between downtown Los Angeles and the City of Colton. Both railroads share trackage rights on rail segments between West Riverside and Barstow through existing agreements. The Alameda Corridor, a 20-mile, multi-track freight rail expressway, connects the San Pedro Bay Ports with railyards and BNSF and UP rail lines in downtown Los Angeles.

The railroad network connects the SCAG region with many locations in the U.S. Major rail hubs in Illinois (Chicago in particular) and Texas constitute over 50 percent of total tonnage moving to and from the SCAG region. In order to deliver the benefits of rail transport to the region and the nation, the Southern California freight rail system needs to address future capacity needs on both the Class I mainlines and at intermodal terminals where capacity is likely to be strained in light of future demand. The investments needed to meet these capacity needs will be made largely by the private railroads.

At the same time that the rail system is expanding to meet future demand, rail emissions need to be reduced further in order to contribute to the region's goal of meeting ambient air quality standards for the South Coast Air Basin. In addition, issues of grade crossing delay and safety in communities will need to be addressed. Lastly, growth in passenger rail services is an important component of regional mobility strategies and this will require expanded capacity. To the extent that passenger rail shares space on the freight rail system, the ability of the public sector to achieve regional goals within this capacity constrained environment will be challenged. SCAG's recent analysis of train volumes for selected rail segments is shown in **TABLE 2.9**.[15]

TABLE 2.9 Regional Train Volumes (Freight and Passenger)

Rail Line	Segment	2010	2035
BNSF San Bern Sub	Hobart to Fullerton	85	159
	Atwood to W. Riverside	59	133
	W. Riverside to Riverside	90	190
UP Alhambra Sub	LA to El Monte	22	48
	Industry to Pomona	28	54
	Kaiser to W. Colton	29	60
UP LA Sub	LA to Pomona	25	54
	Mira Loma to W. Riverside	30	58
BNSF Cajon Sub	Keenbrook to Silverwood	70	142
UP Yuma Sub	Colton to Indio	44	91

As part of the Comprehensive Regional Goods Movement Plan and Implementation Strategy, SCAG worked closely with regional stakeholders to develop a set of rail strategies aimed at increasing freight and passenger mobility, promoting job creation and retention, improving safety, and mitigating environmental impacts.

Several different components comprise this rail package:

Mainline rail improvements and capacity expansion: This includes rail-to-rail grade separations, double or triple-tracking certain rail segments, implementing new signal systems, building universal crossovers, and constructing new sidings. These improvements would benefit both freight rail and passenger rail service depending on their location.

15 These forecasts are based upon simulation analysis conducted for planning purposes only as part of the SCAG Comprehensive Regional Goods Movement Plan and Implementation Strategy. BNSF and UP do not forecast train volumes through 2035.

Rail yard improvements: This includes upgrades to existing railyards as well as construction of new yards. These projects would provide vital improvements to the region's ability to handle the projected growth in cargo volumes.

Rail operation safety improvements: This includes technology such as Positive Train Control (PTC) that can greatly reduce the risk of rail collisions.

Grade separations of streets from rail lines: These projects reduce vehicular delay, improve emergency vehicle access, reduce the risk of accidents, and lower emissions levels.

Key rail projects in the 2012 RTP include:

- Rail-to-rail grade separation at Colton Crossing
- Additional mainline tracks for the BNSF San Bernardino and Cajon Subdivisions and the UPRR Alhambra and Mojave Subdivisions
- Southern California International Gateway (SCIG)
- Modernization of the Intermodal Container Transfer Facility (ICTF)
- Highway-rail grade separations
- Port-area rail improvements, including on-dock rail enhancements

The benefits of the rail strategies to the region are considerable, and include mobility, safety, and environmental gains. As shown in **TABLE 2.10**, these strategies could eliminate almost 6,000 hours of vehicle delay per day at grade crossings, decrease emissions (NO_X, CO_2, and $PM_{2.5}$) by almost 23,000 lbs. per day, and reduce overall train delay to 2005 levels.

TABLE 2.10 Benefits of the SCAG Regional Rail Strategy

Mobility	▪ Reduces train delay to 2005 levels ▪ Provides mainline capacity to handle projected demand in 2035 (includes 43.2 million TEU port throughput) ▪ Eliminates 5,782 vehicle hours of delay per day at grade crossings in 2035
Safety	▪ Eliminates 69 at-grade railroad crossings
Environment	▪ Reduces 22,789 lbs of emissions per day (CO_2, NO_X and $PM_{2.5}$ combined) from idling vehicles at grade crossings ▪ Facilitates on-dock rail ▪ Reduces truck trips to downtown rail yards and associated emissions

GOODS MOVEMENT ENVIRONMENTAL STRATEGY

In Southern California, goods movement and air quality are inextricably linked. Much of the SCAG region (and nearly all of the urbanized area) does not meet federal ozone and fine particulate ($PM_{2.5}$) air quality standards. Goods movement is a major source of emissions that contributes to these regional air pollution problems as well as localized air pollution "hot spots" that can have adverse health impacts.

Goods movement is also a major source of greenhouse gas (GHG) emissions that contribute to global climate change. Although reduction in GHG emissions from goods movement is not required under California Senate Bill 375 (which focuses solely on light-duty vehicle emissions), the State has established GHG reduction goals under California Assembly Bill 32. Clean goods movement activities can contribute to these goals. As such, the region's goods movement strategy is complementary to sustainable communities planning.

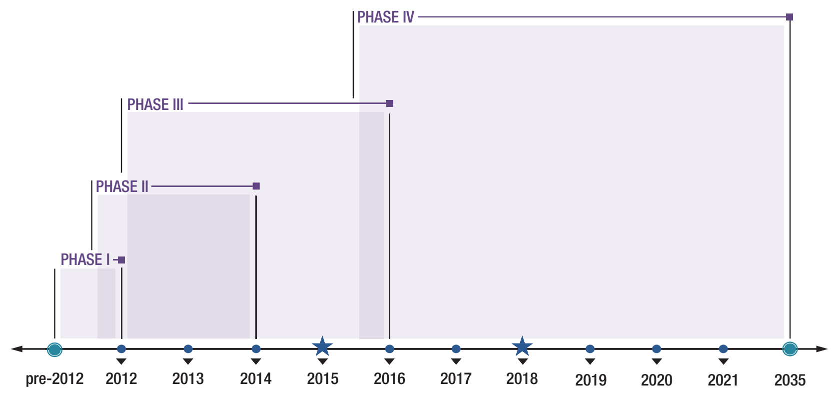
The two air pollutants of greatest concern in Southern California are nitrogen oxides (NO_X) and fine particulate matter ($PM_{2.5}$). The South Coast Air Basin is classified as an extreme nonattainment area per the federal ambient ozone standard, with a required attainment date of 2023. By approximately 2031, a second more stringent federal ozone standard must be attained. The federal Clean Air Act requires the region to demonstrate timely attainment of these standards or federal sanctions may result such as interruption or curtailment of funding for transportation projects. To attain the federal ozone standards, the region will need broad deployment of zero and near-zero emission transportation technologies in the 2023 to 2035 timeframe. The 2012 RTP includes a path forward to achieve this objective. Integration of advanced technologies into the region's goods movement strategies can contribute to other regional objectives such as energy security, economic development opportunities, and potentially broader public support for infrastructure initiatives.

The 2012 RTP focuses on a two-pronged approach for achieving an efficient freight system that reduces environmental impacts. For the near-term, the regional strategy supports the deployment of commercially-available, low-emission trucks and locomotives while centering on continued investments into improved system efficiencies. For example, upgrading switcher locomotive engines could reduce 1 to 3 percent of regional rail emissions. Additionally, heavy-duty hybrid trucks are already in use, but market penetration can be increased. In the longer term, the strategy focuses on a more fundamental shift in technology—taking critical steps toward phased implementation of a zero-emission or near zero-emission freight system. Two of many promising technologies that merit further investigation are electric trucks and electrified rail systems. Additionally, SCAG's planning efforts are cognizant of the need to incorporate evolving technologies into new infrastructure. These include technologies to fuel vehicles, as well as to charge batteries and provide power.

Both near-term and long-term approaches require substantial investment. A path forward to development and deployment of a zero and near-zero emission freight system follows and is summarized in **FIGURE 2.7**. This path is discussed in greater detail in the Technical Appendix.

Phase I: Project Scoping—current research and technology testing of some vehicle prototypes constitutes Phase 1.

FIGURE 2.7 Timeline to Implement a Zero & Near Zero Emission Freight System



Major Milestones
• 2012 – Identify potential funding to support truck, wayside power and rail evaluation and prototype demonstration efforts; incorporate into financially constrained RTP as appropriate
• 2012 - Implement plan of advocacy to secure action by federal or other governments
• 2012-2014- Continue to evaluate truck technology implementation and funding mechanisms
• 2012-2013 – Continue to evaluate practicability of applying existing electrified rail technologies, and evaluate funding and implementation mechanisms
• 2015-2016 – Incorporate decisions on wayside power and technology direction, including strategy, funding and timeframe into 2016 RTP update and SIP revisions; if existing rail technologies are practicable, identify technologies, infrastructure and implementation mechanisms in RTP update and SIP
• 2016- Begin deployment of appropriate zero emission trucks and continue operational demonstration
• 2018-2020 – If existing rail applications were not practicable, resolve need for new rail technologies and incorporate planning into the 2020 RTP

Phase II: Evaluation, Development, and Prototype Demonstrations—convene working groups and increase understanding of logistics. Evaluate, develop and test prototype trucks and rail locomotives, as well as wayside power options. Work with public and private sector partners to secure funding commitments for the development of new technology prototypes and demonstrations.

Phase III: Initial Deployment and Operational Demonstration—Truck fleet evaluation testing and advanced technology locomotive demonstrations.

Phase IV: Full Scale Demonstrations and Commercial Deployment—includes implementation of regulatory and market mechanisms needed to launch commercialization.

It is important that the region work collaboratively to pursue advanced technologies and secure funding for their development and deployment. Although several regional forums currently exist, SCAG anticipates building on these efforts by establishing a logistics working group with key stakeholders. Participants may include government agencies, logistics industry representatives, and original equipment manufacturers (OEMs).

Modeling of environmental strategies has determined that significant emissions benefits could be achieved from implementation of different zero and near-zero emission environmental strategies. As summarized in **TABLE 2.11**, the zero-emission East-West Freight Corridor would eliminate 4.7 tons of NO_X, 0.16 tons of $PM_{2.5}$, and 4,000 tons of CO_2 emissions daily, and would set the stage for broader regional deployment of zero-emission technologies and additional emission reductions. Full electrification of the rail system, though still a concept at this point, would remove comparable amounts of NO_X, $PM_{2.5}$, and CO_2. Regionally, a 20 percent market penetration of plug-in hybrid trucks would achieve a reduction of 8.3 tons of NO_X, 0.16 tons of $PM_{2.5}$, and 3,200 tons of CO_2 daily.

TABLE 2.11 Environmental Benefits

Strategy	Impact		
	NO_X	$PM_{2.5}$	CO_2
East-West Freight Corridor with 100% Zero-Emission Vehicles (ZEVs)	4.7	0.16	4,000
Full Railroad Main Line Electrification*	10.4	0.19	2,400
20% Penetration of Plug-in Hybrid Trucks	8.3	0.16	3,200

* Further evaluation is required to determine feasible options for implementation of rail electrification or other zero-emission rail systems.

2012 RTP Environmental Mitigation

SAFETEA-LU, the reauthorization of TEA-21, was enacted into law by President Bush on August 10, 2005. Pursuant to Section 6001 of this legislation, statewide or metropolitan long-range plans must include a discussion of potential environmental mitigation activities and potential areas to carry out these activities. This includes activities that may have the greatest potential to restore and maintain the environmental functions affected by the plan." As such, the RTP includes a discussion of mitigation measures in order to comply with this requirement. As a public agency in California, SCAG first and foremost fulfills mitigation requirements by complying with CEQA.

In addition, as part of the planning process, states and MPOs "shall consult, as appropriate, with state and local agencies responsible for land use management, natural resources, environmental protection, conservation, and historic preservation concerning the development of a long-range transportation plan." They also must consider, if available, "conservation plans and maps" and "inventories of natural or historic resources."

California law requires SCAG to prepare and certify a Program Environmental Impact Report (PEIR) prior to adopting the RTP. The PEIR evaluates the environmental impacts of the RTP and proposes specific measures to mitigate impacts to the maximum extent feasible. Although the 2012 RTP, in and of itself, is a plan to mitigate the transportation-related effects of population growth, such as traffic congestion and poor air quality, because the transportation improvements can result in additional growth, the PEIR goes further by recommending additional environmental mitigation at the program level for those resource areas that would be affected by the Plan (and associated growth) such as land use, biological resources and open space, water and greenhouse gases.

The section below summarizes the mitigation program. A list of all the mitigation measures included in the 2012 RTP PEIR will be included in the Environmental Mitigation Report of the Final 2012 RTP. The general purpose of the mitigation measures included in the PEIR is to identify how to protect the environment, improve air quality, and promote energy efficiency in concert with the proposed transportation improvements and related planning. This provides a framework through which implementing agencies and subregions can address the environmental impacts of RTP projects, while implementing RTP goals and policies.

Mitigation Strategies

The PEIR provides three different categories of mitigation measures for consideration and implementation, as indicated below:

- Regional Mitigation Measures: Within this category are mitigation measures that can be implemented by SCAG at the regional level. These measures are generally aimed at gathering additional information that can assist in measuring impacts and determining appropriate mitigation and promoting policies and programs that would reduce impacts.
- Local Mitigation Measures: The second type of mitigation measures are those that would be implemented at the local level by individual cities and counties. These measures can strengthen planning documents to ensure the provision of appropriate mitigation measures in the planning process.
- Project-Specific Mitigation Measures: This category includes project-specific mitigation measures that are required by the appropriate agency under whose jurisdiction the project falls (i.e., city or county). As a programmatic document, many of the measures in the PEIR refer to performance standards because site-specific conditions cannot reasonably evaluated at the programmatic level.

Conservation Planning Policy

SAFETEA-LU requires that the RTP contain a discussion of types of potential environmental mitigation activities and potential areas to carry out these activities. This includes activities that may have the greatest potential to restore and maintain environmental functions affected by the plan [Sec. 6001(i)(2)(B)(i)]. As such, this is being addressed in the RTP and is separate and distinct from the mitigation measures addressed in the PEIR. SCAG could demonstrate progress and satisfy SAFETEA-LU requirements through the large-scale acquisition and management of critical habitat to mitigate impacts related to future transportation projects.

Suggested steps to develop a conservation policy of this type could include the following:

- Engage in a strategic planning process to determine the critical components and implementation steps for identifying and addressing open space resources
- Identify and map regional priority conservation areas based on the most recent land use data for future consideration and potential inclusion in future plans.
- Engage with various partners, including CTCs, to determine priority conservation areas and develop an implementable plan.
- Develop regional mitigation policies or approaches for the 2016 RTP.

This strategy supports natural land restoration, conservation, protection and acquisition offering Greenhouse Gas (GHG) emissions reduction benefits. Post-RTP strategic planning efforts would include addressing various pertaining to this proposed approach such as identifying appropriate agencies to partner with and determining specific mapping parameters (for example, geographic scale).

In addition, this type of strategic planning approach could also be applied to address impacts to other resource areas.

Summary of the Environmental Mitigation Program

As required by SAFETEA-LU, the RTP includes an environmental mitigation program that links transportation planning to the environment. Building on its strong commitment to the environment as demonstrated in the 2008 PEIR, SCAG's mitigation program creates an implementation strategy to show varying levels of authority (state, regional, and local). This mitigation discussion also utilizes documents created by federal, state and local agencies to guide environmental planning for transportation projects. The following discussion focuses on specific resource areas and the proposed approaches to mitigate impacts to these areas.

BIOLOGICAL RESOURCES AND OPEN SPACE

The RTP Programmatic Environmental Impact Report (PEIR) includes two regional scale maps that identify sensitive environmental resources, such as protected lands and sensitive habitats.

According to the Federal Highway Administration, there are more than 3.9 million centerline miles of public roads that span the United States. Each day, an estimated one million animals are killed on roads, making road kill the greatest human cause of wildlife mortality in the country. As in previous RTPs, the 2012 RTP seeks to minimize transportation-related impacts on wildlife, and also better integrate transportation infrastructure into the environment.

Impacts to biological resources generally include displacement of native vegetation and habitat on previously undisturbed land; habitat fragmentation and decrease in habitat connectivity; and displacement and reduction of local, native wildlife including sensitive species. Building new transportation routes and facilities through undisturbed land or expanding facilities and increasing the number of vehicles traveling on existing routes will directly injure wildlife species, cause wildlife fatalities, and disturb natural behaviors such as breeding and nesting. This will result in the direct reduction or elimination of species populations (including sensitive and special-status species) and native vegetation (including special-status species and natural communities) as well as the disruption and impairment of ecosystem services provided by native habitat areas.

The biological resources mitigation program includes the following types of measures:

- Planning transportation routes to avoid/minimize removal of native vegetation,displacement of wildlife, and impacts to regionally and locally significant habitat types such as oak woodlands, vernal pools, estuaries, lagoons, and other riparian areas
- Including provisions for habitat enhancement such as mitigation banking, improving/retaining habitat linkages, preserving wildlife corridors and wildlife crossings to minimize the impact of transportation projects on wildlife species and habitat fragmentation
- Conducting appropriate surveys to ensure no sensitive species' habitator special-status natural communities is unnecessarily destroyed
- Avoiding and minimizing impacts to wildlife activities (such as breeding, nesting, and other behaviors) during construction of the project by avoiding construction during critical life stages or sensitive seasons
- Avoiding and minimizing impacts to habitat during project construction through actions such as fencing off sensitive habitat, minimizing vehicular accessibility, and salvaging native vegetation and topsoil
- Minimizing further impacts to wildlife and their habitats after project construction by replanting disturbed areas; providing vegetation buffers at heavily trafficked transportation facilities; and restoring local, native vegetation

LOCATIONS FOR MITIGATION

As part of the 2008 Regional Comprehensive Plan, SCAG mapped locations of the protected and unprotected areas in relation to wildlife linkages, linkage design areas, park and recreation areas (from SCAG's 2008 land use inventory), agricultural lands, and developed lands. Together, these form the region's open space infrastructure. Maps were created showing the distribution of protected and unprotected lands within the SCAG region and its vicinity. It also shows the location of county-level conservation efforts such as Habitat Conservation Plans (HCPs) and Natural Communities Conservation Plans (NCCPs). Although portions of these areas fall within the "protected" category, large portions of habitat within these areas remain "unprotected" and therefore should still be considered for mitigation activities. These maps will be updated as a function of post-RTP planning efforts.

Specifically, those areas that are "unprotected" could be possible locations for mitigation. SCAG does not have the authority to purchase or manage lands. Conservation of these areas will be achieved through already-established programs. SCAG will continue to work with its regional partners to help facilitate conservation.

Types of Mitigation Activities

The mitigation program of the 2012 RTP generally includes strategies to reduce impacts where transportation and sensitive lands intersect and also encourages smart land use strategies that maximize the existing system and eliminate the need for new facilities that might impact open space and habitat. Potential mitigation programs include better planning of transportation projects to avoid or lessen impacts to open space, recreation land, and agricultural lands through information and data sharing, increasing density in developed areas and minimizing development in previously undeveloped areas that may contain important open space.

The mitigation program also emphasizes the importance of integrating consideration of wildlife and habitat into the design of transportation facilities in those areas where impacts cannot be avoided. SCAG encourages project sponsors to review Ventura County's Wildlife Crossing Guidelines and FHWA's Critter Crossings. Both documents provide examples of context-sensitive solutions (CSS) which is a way of involving all stakeholders to develop transportation facilities that fit their physical setting and preserve scenic, aesthetic, historic and environmental resources, while maintaining safety and mobility. CSS is an approach that considers the total context within which a transportation improvement project will exist. CSS principles include the employment of early, continuous, and meaningful involvement of the public and all stakeholders throughout the project development process. Additional information on CSS is available on FHWA's website at: http://www.fhwa.dot.gov/context/index.cfm

In summary, the biological resources and open space mitigation programs include the following types of measures:

- Identifying open space areas that can be preserved and developing mitigation measures such as mitigation banking, transfer of development rights (for agricultural lands), and payment of in lieu fees
- Updating General Plan information from cities to provide the most recent land use data to the region
- Coordinating with cities and counties to implement growth strategies that maximize the existing transportation network
- Evaluating project alternatives and alternative route alignments where projects intersect with sensitive habitats
- Integrating the planning of transportation facilities with context-sensitive design elements such as wildlife crossings

GREENHOUSE GASES

California is the fifteenth largest emitter of GHGs on the planet. The transportation sector, primarily, cars and trucks that move goods and people, is the largest contributor with 36.5 percent of the State's total GHG emissions in 2008. On road emissions (from passenger vehicles and heavy duty trucks) constitute 93 percent of the transportation sector total. In order to disclose potential environmental effects of the RTP, SCAG has prepared an estimated inventory of the region's existing GHG emissions, identified mitigation measures, and compared alternatives in the PEIR.

The GHG mitigation program includes, but is not limited to, the following types of measures:

- Land use changes included in the SCS that reduce number and length of trips
- Encouragement of green construction techniques such as using the minimum amounts of GHG emitting construction equipment;
- Public outreach campaigns publicizing the importance of reducing GHG emissions
- Promotion of pedestrian and bicycle as modes of transportation

AIR QUALITY

The 2012 RTP includes programs, policies and measures to address air emissions. Measures that help mitigate air emissions are comprised of strategies that reduce congestion, increase access to public transportation, improve air quality, and enhance coordination between land use and transportation decisions. SCAG's vision includes the introduction of a high-speed, high-performance regional transport system that may potentially reduce airport and freeway congestion and provide an alternative to the single-occupancy automobile. In order to disclose potential environmental effects of the RTP, SCAG has prepared an estimated inventory of the region's emissions, identified mitigation measures, and compared alternatives in the PEIR. The mitigation measures seek to achieve the maximum feasible and cost-effective reductions in emissions.

The air quality mitigation program includes, but is not limited to, the following types of measures:

- ARB measures that set new on-road and off-road engine standards and accelerate turnover of higher emitting engines from the in-use fleet;
- Project specific measure to reduce impacts from construction activities such as the use of water and dust suppressants and restrictions on trucks hauling dirt, sand and soil; and
- Incorporating planting of shade trees into construction projects where feasible

In addition, the RTP includes Transportation Control Measures (TCMs), which are those mitigation measures that reduce congestion and improve air quality in the region.

TRANSPORTATION AND SAFETY

The 2035 transportation model takes into account the population, households, and employment projected for 2035, and therefore the largest demand on the transportation system expected during the lifetime of the 2012 RTP. In accounting for the effects of regional population growth, the model output provides a regional, long-term and cumulative level of analysis for the impacts of the 2012 RTP on transportation resources. The regional growths, and thus, cumulative impacts, are captured in the VMT, VHT, and heavy-duty truck VHT data.

Implementation of the 2012 RTP/SCS includes implementation of a series of projects which are described in the RTP. The 2035 transportation system performance is compared to the performance of the existing (2011) system for the purpose of determining the significance of impacts. The SCAG region is vulnerable to numerous threats that include both natural and human-caused incidents. As such, a mitigation program related to safety is included in the 2012 PEIR. The mitigation program for the 2012 RTP aims for extensive coordination, collaboration and flexibility among all of the agencies and organizations involved in planning, mitigation, response and recovery.

The transportation and safety mitigation program includes the following types of measures:

- Increasing rideshare and work-at-home opportunities to reduce demand on the transportation system
- Investments in active transportation and maximizing the benefits of the land use-transportation connection
- Transportation Demand Management (TDM) measures
- Goods movement capacity enhancements
- Key transportation investments targeted to reduce heavy-duty truck delay
- Establishing transportation infrastructure practices that promote and enhance security
- Helping to enhance the region's ability to deter and respond to terrorist incidents, and human-caused or natural disasters by strengthening relationships and coordination with transportation agencies
- Working to enhance emergency preparedness awareness among public agencies and with the public at large

POPULATION AND HOUSING

Transportation projects including new and expanded infrastructure are necessary to improve travel time and can enhance quality of life for those traveling throughout the region. However, these projects also have the potential to induce population growth in certain areas of the region. Although SCAG does not anticipate that the RTP would affect the total growth in population in the region, the RTP has the ability to affect the distribution of that growth.

In addition to induced population growth, transportation projects in the RTP also have the potential to divide established communities, primarily through acquisition of rights-of-way.

The population and housing mitigation program includes the following types of measures:

- Develop advisory land use policies and strategies that utilize the existing transportation network and enhance mobility while reducing land consumption
- Require project implementation agencies to provide relocation assistance, as required by law, for residences and businesses displaced
- Require project implementation agencies to design new transportation facilities that consider existing communities

LAND USE

The 2012 RTP contains transportation projects to help more efficiently distribute population, housing, and employment growth. These transportation projects are generally consistent with the county- and regional-level general plan data available to SCAG; however, general plans are not updated consistently. In addition, the RTP's horizon year of 2035 is beyond the timeline of even the most recent general plans.

The land use mitigation program includes the following types of measures:

- Encourage cities and counties to update their general plans and provide the most recent plans to SCAG
- Work with member cities to ensure that transportation projects are consistent with the RTP and general plans
- Work with cities and counties to ensure general plans reflect RTP policies

AESTHETICS

The SCAG region includes several highway segments that are recognized by the State as designated scenic highways or are eligible for such designation. Construction and implementation of projects in the RTP could impact designated scenic highways and restrict or obstruct views of scenic resources such as mountains, ocean, rock outcroppings, etc. In addition, some transportation projects could add urban visual elements, such as transportation infrastructure (highways, transit stations) to previously natural areas.

In summary, the aesthetics mitigation program includes the following types of measures:

- Require project implementation agencies to implement design guidelines to protect views of scenic corridors Require project implementation agencies to use construction screens and barriers that complement the existing landscape
- Require project implementation agencies to complete design studies for projects in designated or eligible scenic highways
- In visually sensitive areas, require local land use agencies to apply development standards and guidelines that maintain compatibility

PUBLIC SERVICES AND UTILITIES

Impacts to public services from the 2012 RTP generally include additional demands on fire and police services, schools and landfills. Additional police and fire personnel would be needed to adequately respond to emergencies and routine calls, particularly on new or expanded transportation facilities.

The 2012 RTP's influence on growth could contribute to impacts on public schools, requiring additional teachers and educational facilities. Additional population growth could result in a greater demand for solid waste disposal facilities. Furthermore, collecting solid waste and transporting it to an available disposal facility would impact roads and railways.

In summary, the public services mitigation program includes the following types of measures:

- Require the project implementation agencies to identify police protection, fire service, emergency medical service, waste collection and public school needs and coordinate with local officials to ensure that the existing public services would be able to handle the increase in demand for their services
- Require the project implementation agencies to identify the locations of existing utility lines and avoid all known utility lines during construction
- Encourage green building measures to reduce waste generation and reduce the amount of waste sent to landfills
- Encourage the use of fire-resistant materials and vegetation when constructing projects in areas with high fire threat

As the region continues to add more people, households and jobs, the demand for energy will continue to grow. Every day, the SCAG region consumes more than 23 million gallons of oil and the SCAG region's vehicle fuel consumption has increased 20 percent over the last ten years. In the face of this growth in energy demand and concerns about future oil supplies, there is the mounting realization that we are living in an energy-constrained world. As such, the 2012 RTP includes strategies to reduce Vehicle Miles Traveled (VMT), and as a result, per capita energy consumption from the transportation sector. The PEIR also includes mitigation measures relating to energy designed to reduce consumption and increase the use and availability of renewable sources of energy in the region. Since these measures not only reduce energy consumption but also reduce GHG emissions they are addressed above under GHG.

GEOLOGY, SOILS, AND SEISMICITY

Impacts to geological resources generally include the disturbance of unstable geologic units (rock type) or soils, causing the loss of topsoil and soil erosion, slope failure, subsidence, project-induced seismic activity and structural damage from expansive soils. These activities, in addition to building projects on and around Alquist-Priolo Fault Zones and other local faults, could expose people and/or structures to the risk of loss, injury, or death.

The geological mitigation program includes the following types of measures:

- Employing appropriate grading, construction practices, siting, and design standards, such as adherence to the California Building Code and State of California design standards
- Obtaining site-specific geotechnical data from qualified geotechnical experts
- Complying with all relevant local, state, and federal construction and design requirements for structures located on or across Alquist-Priolo Fault Zones and other local faults

CULTURAL RESOURCES

Impacts to cultural resources generally include substantial adverse changes to historical and archaeological resources and direct or indirect changes to unique paleontological resources or sites or unique geological features. Adverse changes include the destruction of culturally and historically (recent or geologic time) significant and unique historical, archaeological, paleontological, and geological features.

The cultural resources mitigation program includes the following types of measures:

- Obtaining consultations from qualified cultural and paleontological resource experts to identify the need for surveys and preservation of important historical, archaeological, and paleontological resources
- Implementing design and siting measures that avoid disturbance of cultural and paleontological resource areas, such as creating visual buffers/landscaping or capping/filling the site to preserve the contextual setting of the resource
- Monitoring construction activity in areas with moderate to high potential to support paleontological resources and overseeing salvage operations of paleontological resources
- Consulting local tribes and the Native American Heritage Commission for project impacts to sacred lands and burial sites

WATER RESOURCES

Impacts to water resources from the 2012 RTP include potential water quality impairment from increased impervious surfaces. Increased impervious surfaces in water recharge areas potentially impact groundwater recharge and groundwater quality. Cumulative impacts from the projected growth induced by the RTP include increased impervious surfaces; increased development in alluvial fan floodplains; and increased water demand and associated impacts, such as drawdown of groundwater aquifers. Increased output of greenhouse gases from the region's transportation system impacts the security and reliability of the imported water supply.

The water resources mitigation program includes the following types of measures:

- Utilizing advanced water capture and filtration techniques, showing a preference for naturalized systems and designs, to control stormwater at the source

- Avoiding any new construction of impervious surfaces in non-urbanized areas, such as wetlands, habitat areas, parks, and near river systems
- Avoiding any new construction that provides access to flood-prone areas,such as in alluvial fans and slide zones
- Protection and preservation of existing natural flood control systems, such as wetlands and riparian buffers, and expansion of such systems in areas where they do not currently exist
- Constructing projects according to Best Management Practices for water quality protection and water conservation, including low-impact development and green building standards
- Coordinating project development and construction efforts across jurisdictional, agency, and departmental boundaries, to increase project benefits

HAZARDOUS MATERIALS

Implementation of the 2012 RTP would affect the transportation and handling of hazardous materials in the SCAG region. Expected significant impacts include risk of accidental releases due to an increase in the transportation of hazardous materials and the potential for such releases to reach neighborhoods and communities adjacent to transportation facilities. The hazardous materials mitigation program aims to minimize the significant hazard to the public or the environment that involves the release of hazardous materials into the environment. Potential mitigation programs include active coordination with regulatory agencies and first responders in order to ensure proper handling and transport of hazardous materials and their containers.

Mitigation measures also involve ensuring that the project implementation agency complies with all applicable laws, regulations, and health and safety standards set forth by federal, state, and local authorities that regulate the proper handling of such materials and their containers and that the routine transport, use, and disposal of hazardous materials does not create a significant hazard to the public or the environment.

The hazardous materials mitigation programs include the following types of measures:

- Coordinating with regulatory agencies and first responders in order to continue to govern goods movement and hazardous materials transportation throughout the region
- Considering existing and known planned school locations when determining the alignment of new transportation projects and modifications to existing transportation facilities
- Encouraging project sponsors to consider published lists of contaminated properties, which are continually updated, in order to identify cases where new development would involve the disturbance of contaminated properties
- Developing appropriate mitigation measures to assure that worker and public exposure is minimized to an acceptable level and to prevent any further environmental contamination as a result of construction
- Ensuring that project implementation agencies comply with all applicable laws, regulations, and health and safety standards set forth by federal, state, and local authorities that regulate the proper handling of such materials and their containers and that the routine transport, use, and disposal of hazardous materials does not create a significant hazard to the public or the environment

NOISE

Some of the principal noise generators within the SCAG region are associated with transportation (i.e., airports, freeways, arterial roadways, seaports, and railroads). Additional noise generators include stationary sources, such as industrial manufacturing plants and construction sites. Noise impacts resulting from the 2012 RTP generally include exposure of sensitive receptors to noise in excess of normally acceptable noise levels or substantial increases in noise as a result of the operation of expanded or new transportation facilities. As such, the noise mitigation program includes mitigation measures designed to minimize the impact of noise on sensitive receptors as a result of the implementation of the 2012 RTP. These mitigation measures include ensuring that project implementing agencies comply with all local sound control and noise level rules, regulations, and ordinances; utilizing the best available noise control techniques (including mufflers, intake silencers, ducts, engine enclosures and acoustically attenuating shields or shrouds) in order to minimize construction noise impacts; and utilizing land use planning measures, such as zoning, restrictions on developments, buffers, etc., to minimize exposure to sensitive receptors.

The noise mitigation programs include the following types of measures:

- Encouraging project implementing agencies to comply with all local sound control and noise level rules, regulations, and ordinances
- Developing the best available noise control techniques in order to minimize construction noise impacts
- Conducting a project-specific noise evaluation as part of the appropriate environmental review of each project
- Encouraging project implementation agencies to maximize the distance between noise-sensitive land uses and new roadway lanes, roadways, rail, transit centers, park-and-ride lots, and other new noise-generating facilities

EXECUTIVE SUMMARY

ES.1 INTENDED USES AND AUTHORIZING ACTIONS

The United States Army Corps of Engineers (hereinafter “Corps” or “USACE”) and the City of Long Beach acting by and through its Board of Harbor Commissioners for the Port of Long Beach (hereinafter “Port” or “POLB”), have prepared this draft Environmental Impact Statement/Environmental Impact Report (EIS/EIR) to identify and evaluate the potential environmental impacts associated with implementation of the proposed modified Pier S Marine Terminal and Back Channel Improvement Project (hereinafter “Project” or “Proposed Project”).

The Corps is the federal lead agency for the National Environmental Policy Act (NEPA) and is responsible for preparation of the EIS portions of this document. The Port, as the state lead agency under the California Environmental Quality Act (CEQA), is responsible for preparation of the Subsequent EIR portions of this document, and is the Project proponent for the Proposed Project. The Corps and the Port have prepared this joint EIS/EIR as a single document to optimize efficiency and avoid duplication of effort.

This EIS/EIR describes the affected environmental resources and evaluates the potential impacts to those resources as a result of constructing and operating the Project or the proposed alternatives to the Project. This document would be used to inform agencies and the public of significant environmental effects associated with the Project and reasonable alternatives, and to propose mitigation measures that would avoid or reduce significant environmental effects.

This document was prepared in accordance with the requirements of NEPA (42 U.S. Code [USC] 4341 et seq.) and Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 Code of Federal Regulations [CFR] 1500–1508), which require the evaluation of potential environmental impacts resulting from federal actions. The federal action associated with the Project is the issuance of permits by the Corps that would authorize the construction of wharves and related dredge and fill activities in navigable waters of the United States (U.S.) under Section 10 of the Rivers and Harbors Act (RHA) and the discharge of fill in the “waters of the U.S.” in accordance with Clean Water Act (CWA) Section 404 (b)(1) Guidelines (40 CFR 230) and Marine Protection, Research, and Sanctuaries Act (MPRSA) Section 103 (50 CFR 600) of the CWA. Because the Corps has determined that these federal actions may result in “significant effects on the quality of the human environment,” an EIS has been prepared for this Project.

This EIS/EIR also fulfills the requirements of CEQA (Public Resources Code [PRC], Section 21000 et seq.), State CEQA Guidelines (14 California Code of Regulations [CCR], Section 15000 et seq.), and POLB Procedures for the Implementation of CEQA (Resolution No. JD-1973). According to CEQA Guidelines Section 15121(a) (CCR, Title 14, Division 6, Chapter 3), the purpose of an EIR is to serve as an informational document that does as follows:

> *…inform public agency decision-makers and the public generally of the significant environmental effect of a project, identify possible ways to minimize the significant effects, and describe reasonable alternatives to the project.*

This EIS/EIR constitutes a Subsequent EIR for the Project. A prior EIR was prepared and certified for the Pier S Marine Terminal Project. This EIS/EIR evaluates the direct, indirect, and cumulative impacts of the Project in accordance with the provisions set forth in the CEQA Guidelines. It addresses potentially significant environmental issues and recommends adequate and feasible mitigation measures that, could reduce or eliminate significant environmental impacts.

Other state and local agencies that have jurisdiction or regulatory responsibility over components of the Project would also rely on this EIS/EIR for CEQA compliance as part of their decision-making processes (refer to Section 1.8 for additional details).

ES.2 PROJECT PURPOSES AND NEED AND PROJECT OBJECTIVES

NEPA requires an EIS to discuss the "purpose and need" for a proposed federal action. Similarly, CEQA requires an EIR to discuss the "objectives" of a proposed project. These respective discussions are essential to explaining the underlying reasons why the project is being recommended. Additionally, the purpose and need and the objectives are key in defining the alternatives and determining which should be included in the document.

The purpose, need, and objectives of this Project are based on the goals of the Port of Long Beach Master Plan (Section 1.3.1.1) and on the Port's need and ability to accommodate future cargo volumes and cargo vessels (Sections 1.3.1.2 and 1.3.1.3).

Project Purpose and Need/Objectives

NEPA Project Purpose and Need

The NEPA overall purpose with respect to Port projects is to optimize the use of waterfront facilities and waters of the U.S. that are devoted to maritime commerce. To comply with Corps' Clean Water Act Section 404 requirements (i.e., 404[b][1] guidelines), the overall Project purpose is further defined as to increase container terminal efficiency to accommodate a portion of the predicted future containerized cargo throughput volume and the modern cargo vessels that transport those goods to and from the Port. USACE, on the basis of information furnished by the POLB, identified a need to increase container terminal capacity and improve navigational safety to accommodate a portion of the predicted future containerized cargo throughput and the modern cargo vessels that will transport those goods.

The Project's purpose, therefore, is to provide waterside improvements at Pier S in support of a new maritime cargo terminal and in-water improvements to the Back Channel and Cerritos Channel to correct navigational safety issues and accommodate modern cargo vessels. These improvements would increase and optimize the cargo handling efficiency and capacity of the Port, enabling it to accommodate a proportional share of foreseeable increases in containerized cargo.

CEQA Project Objectives

The Port has proposed that the Project meet the identified needs to increase cargo-handling capacity and navigational safety. The basic objectives of the Project, therefore, are the following:

- Construct and operate marine terminal facilities that maximize the use of existing waterways, available shoreline, and existing land;
- Construct and operate berthing and infrastructure to accommodate forecasted cargo volumes;
- Provide efficient access to land-based rail and truck infrastructure systems that maximizes the use of rail;
- Provide needed container terminal accessory buildings and structures; and
- Provide channel improvements that would provide navigational safety in the Back Channel.

Baselines

NEPA Baseline

Despite the similarities between CEQA and NEPA, there are some areas where the two laws and their implementing regulations differ. In the case of the Corps' NEPA regulations, the analysis of a Proposed Project in joint NEPA/CEQA format requires the Corps to distinguish the scientific and analytical basis of its decisions from those of the CEQA lead agency. For example, whereas CEQA requires agencies to use "existing conditions" as the baseline for analysis, the NEPA Baseline for determining significance of impacts is defined by the "No Federal Action" condition, which is determined by examining the full range of construction and operational activities the applicant could implement and is likely to implement in the absence of permits from the Corps. Activities that require permits—those activities within the Corp's jurisdiction under Section 10 of the RHA and Section 404 of the CWA—are not part of the NEPA Baseline. Therefore, the NEPA Baseline includes all of the construction and operational impacts likely to occur without in-water construction activities (e.g., air emissions and traffic likely to occur without issuance of permits for dredge and fill or to modify wharves). The determination is based on direct statements and empirical data from the applicant, as well as the judgment and experience of the Corps.

The NEPA Baseline is not bound to a "no growth" scenario. Potential impacts are determined by comparing conditions with and without the federal components of the Project at given points in the future (in this case, 2013 and 2020, the opening year and the maximum activity year, respectively). The Corps evaluates the impacts of each alternative relative to the NEPA Baseline.

The NEPA Baseline for this Project assumes that the site would function as a multi-use storage facility, as described in Section 1.6.3.3. This use is deemed to be the most likely future use of the site, in the absence of federal permits, because it would fulfill a portion of the need for additional cargo handling facilities, meeting the forecasted increases in cargo throughput at POLB and the Port of Los Angeles (POLA) (see Section 1.3.1.2). The Port has made use of existing land for Port-related uses a priority, as specified in its Port Master Plan (PMP) (described more fully in Section 1.3.1). The Strategic Plan (POLB 2006, updated 2009) identified two key strategies to achieve the goal of providing an efficient and modern seaport complex: (1) "improve the efficiency of existing … lands and facilities to … support terminal operations," and (2) "promote responsible Port development that accommodates changes in trade volume and vessel size." There is little vacant or underused land remaining in the Port, meaning that a site such as Pier S, by accommodating new cargo-handling facilities, would be an important element of those strategies. In addition, there is no identified need for non-cargo-related facilities on a scale that would use the Pier S site.

For this EIS/EIR, the NEPA Baseline includes only construction of site improvements and subsequent operational activities that could occur without issuance of federal permits. Accordingly, under the NEPA Baseline, no wharf infrastructure would be constructed and no channel or berth deepening would occur. Therefore, this baseline would include development of container storage facilities and creation of backland area on the undeveloped site of Pier S, as more particularly described in Section 1.6.3.3.

CEQA Baseline

For purposes of this EIR, the CEQA Baseline is defined as the conditions that existed in January 2007, when the Notice of Preparation (NOP) for the Project was published. The CEQA Baseline analysis considers impacts from all changes that would occur by 2013 (Project completion and opening) and in 2020 (maximum activity year) compared to conditions in January 2007 for both in-water and upland Project components. The CEQA impact analysis is based on a comparison of the changes caused by the Project and alternatives from January 2007 through the year 2020. (Although the Project would likely continue operation beyond 2020, that year is chosen for analysis because it represents the maximum impact that would be expected; impacts in subsequent years would be similar or less in magnitude because throughput, and, therefore, activity levels, would not increase and control measures limiting impacts would become more effective.)

Because this is a Subsequent EIR, the use of the 2007 Baseline is conservative. Typically in

Subsequent EIRs where project construction has begun, the comparison is not to the condition that existed as of the NOP date, but to the fully developed and operational condition analyzed in the earlier EIR. By comparing the Project and the various alternatives to the 2007 condition, this EIS/EIR presents a "worst case" review. The Port chose to take this approach in recognition of the age of the original EIR, as a means of applying new control measures outlined in the San Pedro Bay Ports Clean Air Action Plan (CAAP) and Water Resources Action Plan, and to provide more conservative information to the public and decision makers.

ES.3 DESCRIPTION OF THE PROJECT AND ALTERNATIVES

Project Location

The Pier S Project site is located in the Northwest, Northeast, and Middle Harbor Planning Districts (Figure ES-1). The site is bounded on the north by Cerritos Channel and Piers A and B (Stevedoring Services of America [SSA] and Toyota Motor Sales); on the east by Piers C and D; on the south by Southern California Edison (SCE) property, the Long Beach Generating Station, Ocean Boulevard, and Pier T (BP Pipelines North America [crude oil], Pacific Coast Recycling [scrap metal], Total Terminals International [containerized cargo], and Weyerhaeuser Company [lumber]); and on the west by State Route 47 (SR-47), the Vopak Terminal, and the Southeast Resource Recovery Facility (SERRF). The Gerald Desmond Bridge, part of West Ocean Boulevard, spans the Back Channel and provides a link between San Pedro and downtown Long Beach. Marine access to Pier S is provided from the Outer Harbor via the Middle Harbor through the Back Channel and into the Inner Harbor Turning Basin.

Project Alternatives

NEPA (40 CFR 1502.14[a]) and CEQA Guidelines (15126.6) require that an EIS and an EIR examine a range of reasonable alternatives to a project that meet most of the basic project objectives while reducing the severity of potentially significant environmental impacts. This EIS/EIR compares the merits of the alternatives and identifies an environmentally superior alternative.

Seven alternatives were considered during preparation of this EIS/EIR, including alternative terminal configurations and locations. However, only three alternatives meet most of the Proposed Project's objectives and have been selected to be carried forward for detailed analysis (Section 1.6.3). Alternatives considered but not carried forward are addressed in Section 1.6.2.

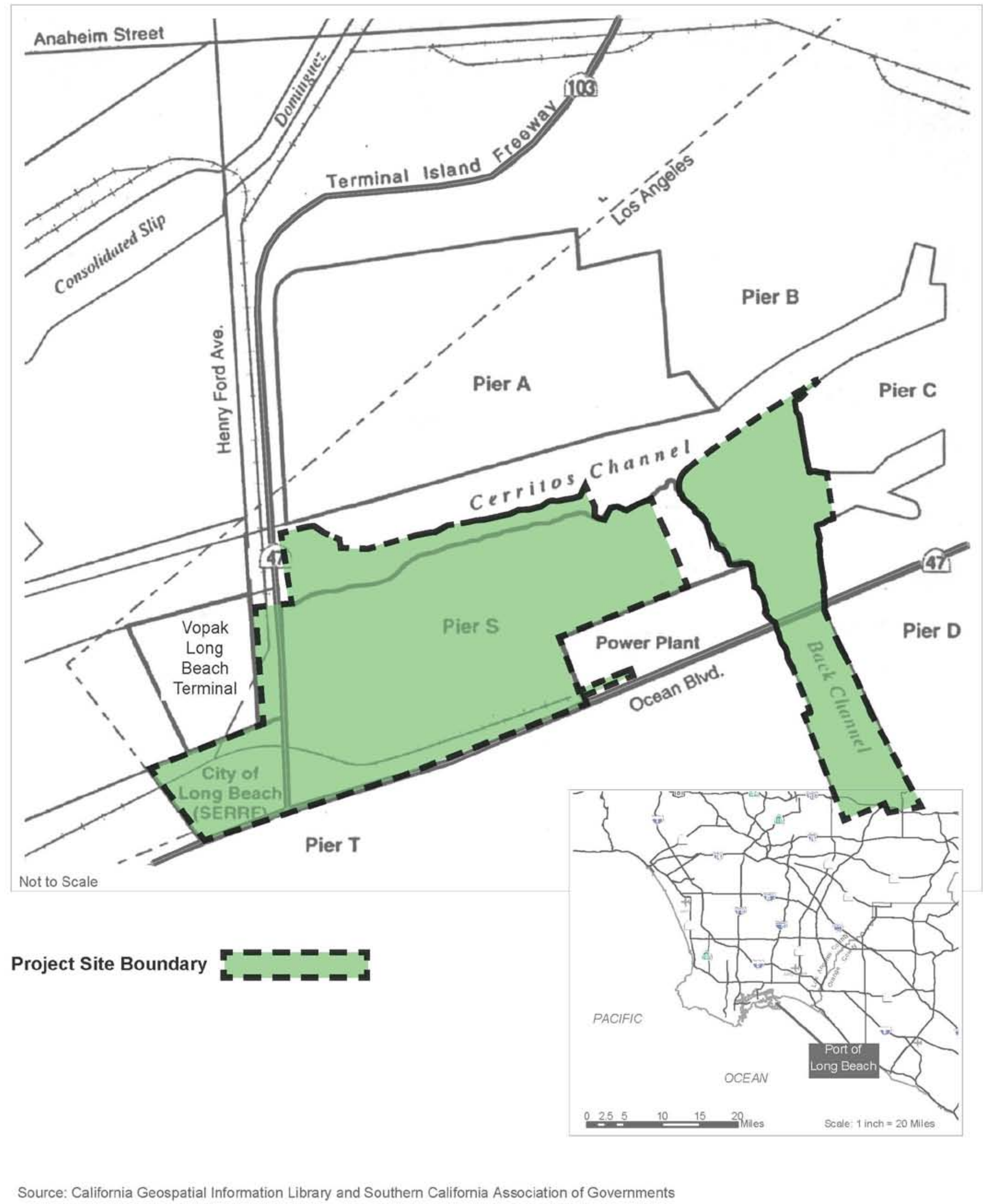
Following are the four alternatives considered but eliminated from further discussion:

- Sites outside the Port of Long Beach
- Alternative sites within the Port of Long Beach
- Rail Yard Alternative
- Auto Terminal Alternative

The following are the alternatives evaluated in this EIS/EIR:

- Three-Berth Alternative: Container Terminal with Rail Access, Full-Length Wharf, and Back Channel Improvements (Proposed Project)
- Two-Berth Alternative: Container Terminal with Rail Access, Reduced-Length Wharf, and Back Channel Improvements
- Multi-Use Storage Alternative (No Federal Action): Multi-Use Storage Facility without Wharf or Back Channel Improvements
- No Project Alternative

All except the No Project Alternative would meet at least some of the objectives of the Project, although the Multi-Use Storage Alternative would not meet the objectives of improving navigational safety or accommodating modern containerships.



Source: California Geospatial Information Library and Southern California Association of Governments

Figure ES-1
Project Location

Three-Berth Alternative (Proposed Project)

The Three-Berth Alternative would involve construction of a new 160-acre container terminal at Pier S with rail access, as well as Back Channel improvements. This alternative would include the following components: property transfer; dredging of the Cerritos Channel and Back Channel; construction of wharves, terminal buildings, truck gates, utilities, an intermodal rail yard, and supporting rail tracks; installation of container cranes and other cargo-handling equipment; oil facility relocation; and improvements to the Terminal Island Wye railroad tracks. At maximum capacity, the terminal would handle approximately 1.8 million TEU (twenty-foot equivalent units, the standard measure of containerized cargo volume) of cargo (approximately 1 million containers) per year, transported by 312 vessel calls (six per week), 1,728 annual train trips (549 on-dock train trips and 1,179 off-dock train trips), and 1.3 million annual truck trips. Construction would start in 2011 and end in 2013.

The Three-Berth Alternative would result in approximately 3,692 truck trips per day in the opening year, and approximately 7,168 per day at full operation in 2020.

Rail operations would result in 1.5 trains per day at the terminal's rail yard, and rail traffic at near-dock and off-dock rail yards would be increased by the equivalent of 3.2 trains per day.

Construction of the Pier S Terminal would require the transfer of two parcels owned by the City of Long Beach Department of Public Works to the Harbor Department. The first is an approximately 33,000-square-foot area that is part of the Southeast Resource Recovery Facility (SERRF). The parcel is bounded by New Dock Street on the north, SR-47 on the east, the rail line on the south, and Pier S Avenue to the west, and is currently devoid of major improvements. The second parcel is an approximately 5,000-square-foot railroad easement between SR-47 and Pier S Avenue. The acquisition of these properties would be required to enable the construction and operation of the proposed dual rail lead tracks. Property acquisition would not involve private property or require the use of eminent domain.

Approximately 3,200 feet of concrete pile-supported wharf would be constructed as part of the Project. As part of construction, the existing shoreline would be excavated to realign the existing dike and widen the Cerritos Channel to 808 feet between the Pier A and future Pier S pierhead lines. A total of 10.3 acres of upland would be converted to open water.

Wharf construction would consist of the following:

- Excavating approximately 1,500,000 cubic yards (cy) of material from upland areas, dredging 631,000 cy of materials from the Cerritos Channel, and dredging 250,000 cy of materials from the Back Channel to be disposed of, as described below (total of 881,000 cy of dredging for the Three-Berth Alternative with a total dredge footprint of 51.0 acres).
- Reconstructing the shoreline with approximately 551,000 tons of imported quarry run and rock.
- Dredging approximately 881,000 cy of material from the Cerritos and Back Channels to key in the toe of the rock dike and allow ships to safely berth. The minimum and maximum dredge depths would extend 80 feet north of the future Pier S pierhead line and would be -60 feet mean lower low water (MLLW) and -63 feet MLLW, respectively, which includes a 2-foot over-dredge allowance.
- Driving approximately 2,000 concrete piles (up to 110 feet in length) and constructing a steel-reinforced concrete wharf on top of the piles. The wharf would include 100-foot-gauge crane rails and electrical and telephone/fiber infrastructure to support container cranes and supply power to ships (i.e., cold-ironing) at berth.
- Installing a 3,500-foot-long groundwater barrier to replace the clay core in the dike

that will be removed during dredging. The groundwater barrier will be constructed using deep-soil-mixing (DSM) technologies, which use a mixing rig to inject a cement-bentonite grout into the subsurface soils and mix the grout with the soils to produce a relatively uniform soil-cement-bentonite wall. The wall would be approximately 3 feet thick and 60 to 65 feet deep.

Work would take approximately 270 days and would be both waterside and land-based. The dredging and dike realignment work would involve a barge-mounted, electrically powered dredge; two disposal scows, a flat rock delivery barge, and a dozer; two tugboats; several small workboats; and landside equipment for some of the dike work. Wharf construction would require a barge-mounted pile-driver crane; a tugboat and workboat; a truck-mounted crane; small earthmoving equipment; a variety of trucks delivering concrete, steel, asphalt, and other structural elements; generators and concrete saws; and support vehicles. The cranes would be delivered from the water by three or four oceangoing vessels assisted by tugboats.

Dredged material and excavated upland material would be deposited at the agency-approved Middle Harbor landfills (i.e., Piers D, E, and F). A small amount of chemically suitable dredged material could be disposed of at the Western Anchorage Disposal Site and the approved LA-2 ocean disposal site, if required by timing or capacity constraints at the Middle Harbor sites. Disposal at the Western Anchorage and LA-2 sites would only be undertaken with the approval of the Corps and the Regional Water Quality Control Board (RWQCB) following chemical, and possibly bioassay, testing of the material.

The safety and security features for this alternative would include radiation portal monitors, X-ray inspection areas, and security fencing.

The elements of the Back Channel dredging are as follows:

- Dredging the channel to a width of 323 feet and a depth of -52 feet (MLLW) plus up to 2 feet of over depth dredging.
- Dredging and depositing approximately 250,000 cy of material at an approved Middle Harbor landfill (i.e., Piers D, E, and F). A small amount of chemically suitable dredged material could be disposed of at the Western Anchorage Disposal Site and the approved LA-2 ocean disposal site, if required by timing or capacity constraints at the Middle Harbor sites. Disposal at the Western Anchorage and LA-2 sites would only be undertaken with the approval of USACE and RWQCB following chemical, and possibly bioassay, testing of material.
- Dredging the Turning Basin at piers C, D, and S to a depth of -52 feet (MLLW) and a diameter of 1,200 feet.
- Constructing embankment stabilization at both sides of the channel and at the turning basin if necessary to facilitate steepening of the channel side slopes. The stabilization is anticipated to consist of Cement Deep Soil Mixing (CDSM) of the embankment soils. CDSM consists of in-situ mixing of soil and cement slurry to strengthen and improve the geotechnical properties of the embankment soils.
- Disposing of the dredged material at the site mentioned above.
- Placing approximately 80,000 tons of riprap on the dredged slopes for erosion protection.
- Demolishing portions of the intake structure and potential modifications to the outfall structure at the adjacent power plant.
- Removing abandoned utilities and relocating utilities above an elevation of 56 feet that may be affected by the dredging.

The terminal would operate under a new lease between the terminal operator and the Port that would include environmental controls imposed pursuant to the Port's Green Port Policy and the CAAP. This EIS/EIR assumes the Three-Berth Alternative would include participation in the POLB/POLA Vessel Speed Reduction Program (CAAP measure OGV-1) and compliance with applicable Environmental Protection Agency (EPA), RWQCB, California Air Resources Board (ARB), and South Coast Air Quality Management District (SCAQMD) regulations.

Two-Berth Alternative

The Two-Berth Alternative is substantially the same as the Three-Berth Alternative, but would have a shorter wharf (Figure 1-7) with only two ship berths. As shown in Table 1-3, the Two-Berth Alternative would develop a slightly smaller terminal (approximately 150 acres) than the Three-Berth Alternative, because the shorter wharf would not support as large a container yard. In addition, instead of electric-powered rail-mounted gantry cranes (RMG) in the container yard, the Two-Berth Alternative would have 12 diesel-powered rubber-tired gantries (RTGs) that would operate along concrete runways.

Construction of this alternative would be similar to the Three-Berth Alternative. The dike work would be the same for both the Three- and Two-Berth Alternatives to facilitate Cerritos Channel widening. Therefore, dredge/excavation quantities would also be the same for both alternatives. Construction would take approximately 22 months, the same as for the Three-Berth Alternative. Up to 2,800 feet of concrete pile supported wharf and 3,500 feet of groundwater barrier would be constructed as part of the Two-Berth Alternative. Eight 100-foot-gauge electric-powered gantry cranes, with supporting electrical and telephone/fiber infrastructure, would be installed on the wharf.

As with the Three-Berth Alternative, wharf construction would consist of the following:

- Excavating approximately 1,300,000 cy from the existing shoreline to realign the Cerritos Channel Dike.
- Widening the Cerritos Channel to 808 feet between the Pier A and Pier S pierhead lines and creating approximately 9.4 acres of new water surface area.
- Dredging approximately 881,000 cy of material from 44.3 acres of the Cerritos and Back Channels.
- Constructing the Back Channel improvements, including reconstructing the outfall structure.
- Constructing up to 2,800 feet of concrete pile supported wharf.
- Installing eight 100-foot-gauge electric-powered gantry cranes, with supporting electrical and telephone/fiber infrastructure.

Similar to the Three-Berth Alternative, construction work would be both waterside and land-based. The dredging and dike realignment work and wharf construction would involve the same type of construction equipment (such as a barge-mounted, electrically powered dredge; two disposal scows; two tugboats) as the Three-Berth Alternative.

As with the Three-Berth Alternative, dredged material and excavated upland material would be deposited at the agency-approved Middle Harbor landfills (i.e., Piers D, E, and F). A small amount of chemically suitable dredged material could be disposed of at the Western Anchorage Disposal Site and the approved LA-2 ocean disposal site, if required by timing or capacity constraints at the Middle Harbor sites.

This alternative would consist of one consolidated container terminal, which would load and unload containerized cargo to and from vessels, trucks, and rail cars. This alternative would include the same safety and security features as the Three-Berth Alternative, including radiation portal monitors, X-ray inspection areas, and security fencing.

The element of the Back Channel dredging would be the same as with the Three-Berth Alternative.

The type of container terminal operations for the Two-Berth Alternative would be similar to those of the Three-Berth Alternative; however, the number of vessel calls and truck and train trips would be reduced; the grounded portion of the container yard operation would be handled by RTGs instead of RMGs; and the wheeled portion would be handled by approximately 50 hostlers and 30 sidepicks and toppicks. Under the Two-Berth Alternative, the container terminal would handle approximately 1.33 million TEUs (approximately 720,000 containers) per year when operating at maximum capacity in 2016. The lower throughout would be the result of the combination of less berthing space and a smaller container yard compared to the Three-Berth Alternative.

The terminal would operate under a new lease between the terminal operator and the Port that would include environmental controls imposed pursuant to the Port's Green Port Policy and the CAAP. Similar to the Three-Berth Alternative, this EIS/EIR assumes the Two-Berth Alternative would include participation in the CAAP measure OGV-1 and compliance with applicable EPA, RWQCB, California ARB, and SCAQMD regulations.

The Two-Berth Alternative container terminal would receive a maximum of 260 vessel calls per year (five per week). Vessels would follow the same operating procedures as for the Three-Berth Alternative.

The Two-Berth Alternative would result in 1,262 annual train trips (591 on-dock train trips and 671 off-dock train trips), and 1.3 million annual truck trips. Approximately 3,692 truck trips per day in the opening year would be expected, and approximately 4,861 per day at full operation in 2020. All other aspects of truck operations would be the same as for the Three-Berth Alternative.

Rail operations would be the same as those of the Three-Berth Alternative except that, in 2020, there will be 1.6 trains per day at the terminal's rail yard, and rail traffic at near-dock and off-dock rail yards would be increased by the equivalent of 1.8 trains per day.

The potential impacts of all Project trains departing from the Project site and from the near- and off-dock rail yards are analyzed within the Port and throughout Southern California.

Multi-Use Storage Alternative

The Multi-Use Storage Alternative (No Federal Action) would not involve wharf construction, dredging, dike excavation and realignment, or any other construction activities in the Cerritos Channel or Back Channel; therefore, USACE permits would not be required for this alternative (Figure 1-8). Under this alternative, no rail yard or secondary gate complex would be built. The 150-acre terminal would require the same utilities as the previous alternatives plus five administration, maintenance, and gate buildings. This alternative would include the same safety and security features as the Proposed Project, including radiation portal monitors, X-ray inspection areas, and security fencing.

This alternative is equivalent to the No Federal Action Alternative because it includes only those construction and operational activities that would not require issuance of federal permits.

Construction of this alternative would take approximately 15 months and would involve only land-based equipment. Site preparation would involve earthmoving equipment (backhoes, loaders, dump trucks, scrapers, an excavator, and a grader). Paving and utility construction would involve backhoes, loaders, concrete trucks, delivery trucks, asphalt spreaders, an auger, a roller, concrete cutting and laying equipment, and supporting equipment. Building construction would require essentially the same equipment as the two other build alternatives.

The Multi-Use Storage Alternative would serve two purposes: (1) provide additional backland for San Pedro Bay container terminals and (2) provide a storage site for empty containers. Although the two functions are similar, the distinction reflects the difference in the direction of the flow and the duration of time the containers would be expected to remain on a terminal.

The additional container yard area would provide additional throughput capacity for terminals in both POLB and POLA that are backland-limited and projected to reach capacity by 2025 (i.e., it would accommodate demand at other terminals). The additional space would reduce the expected dwell time of all in-bound local containers for those terminals and free up space in those terminals' container yards.

The empty container storage function would serve POLB/POLA terminals that are projected to be backland constrained by 2025, replacing more distant off-site empty storage areas and increasing terminal efficiency. The throughput associated with this alternative is estimated to be 1.27 million TEUs (approximately 686,000 containers) per year.

Operations would consist primarily of storing chassis-mounted containers on-site for varying periods (i.e., a wheeled operation). Container handling operations would not employ gantry cranes; instead, any containers needing to be loaded or unloaded from trucks would be handled by three diesel-powered mobile cranes supported by a small fleet of light-duty trucks.

The Multi-Use Storage Alternative would result in 1,243 annual train trips (only off-dock train trips), and 800,000 annual truck trips. It would handle approximately 2,219 truck trips per day during the opening year and approximately 4,731 trucks per day at full operation in 2030. The regional distribution of Project-generated truck traffic is assumed to be similar to the other two alternatives, since containers would be drayed to and from the same regional destinations (i.e., warehouses, freight handlers, container storage yards, and rail yards); those destinations were selected based on origin-destination surveys conducted by the Port in 2004. Roadways within the Harbor District would experience additional truck trips compared to the other alternatives because of the traffic between marine terminals and the Pier S facility.

No Project Alternative

Under the No Project Alternative, the wharf construction and Back Channel improvements would not occur, and Pier S would not be developed as a marine terminal (Figure 1-9). The site would continue to be operated as a partially paved lot. On-site activities would be limited to the on-going activities related to the maintenance of the remediation project and construction staging, and occasional general cargo storage and non-cargo-related activities such as filming and special events.

ES.4 ENVIRONMENTAL PLANS AND POLICIES

The Port has implemented a variety of plans and policies to reduce the environmental effects associated with Port operations.

Green Port Policy

The Green Port Policy, which was approved by the Board of Harbor Commissioners (BHC) in January 2005, serves as a guide for decision-making and a framework for reducing environmental impacts associated with Port operations. The policy contains specific environmental principles that govern all Port activities and established a series of goals for each element of the policy. The Green Port Policy includes specific metrics to measure progress toward meeting the policy's goals, and identifies new environmental programs that are designed to achieve progress toward the goals. Additionally, the policy identifies specific incentives to promote program participation among tenants.

The principles of the Green Port Policy are the following: (1) protect the community from harmful environmental impacts of Port operations, (2) distinguish the Port as a leader in environmental stewardship and compliance, (3) promote sustainability, (4) employ best available technology to avoid or reduce environmental impacts, and (5) engage and educate the community. The Green Port Policy includes six basic program elements, each with an overall goal:

- *Wildlife* – Protect, maintain, and restore aquatic ecosystems and marine habitats.

- *Air* – Reduce harmful air emissions from Port activities.
- *Water* – Improve the quality of Long Beach Harbor waters.
- *Soils/Sediments* – Remove, treat, or render suitable for beneficial reuse contaminated soils and sediments in the Harbor District.
- *Community Engagement* – Interact with and educate the community regarding Port operations and environmental programs.
- *Sustainability* – Implement sustainable practices in design, construction, operations, and administrative practices throughout the Port.

The Port uses a variety of mechanisms, including lease provisions, tariff language, incentives, and permit conditions arising from the NEPA/CEQA process, to implement the Green Port Program's principles and policies. For example, new leases incorporate environmental measures that exceed federal and state law requirements. As a landlord, leases are one of the primary mechanisms for the Port to implement its environmental initiatives. The Port will continue to incorporate environmental provisions into all new and renegotiated leases, including leases for Pier S facilities under all four alternatives.

Clean Air Action Plan

The Port, in conjunction with POLA and with guidance from SCAQMD, ARB, and EPA, adopted the San Pedro Bay Ports CAAP on November 20, 2006, and adopted the first update on November 22, 2010. The CAAP is a comprehensive strategy that is designed to develop mitigation measures and incentive programs necessary to reduce air pollution and health risks associated with Port activities. The CAAP focuses on reducing emissions with two main goals: (1) reduce Port-related air emissions in the interest of public health, and (2) accommodate growth in trade. The CAAP is based on the following principles:

- The ports will work cooperatively to implement these changes;
- The CAAP will be continually updated and improved;
- The ports will be open to new technologies and other advancements to accelerate meeting the CAAP's goals; and
- The ports will achieve an appropriate fair share of necessary pollutant emission reductions that are cost effective and feasible.

The CAAP includes control measures for all Port emission sources, including ocean-going cargo vessels (OGV), trains, trucks, terminal equipment, and harbor craft. The CAAP proposes to implement near-term measures largely through new lease agreements, the CEQA/NEPA process, and tariffs. This EIS/EIR analysis assumes that the Proposed Project would comply with the CAAP. Project mitigation measures applied to reduce air emissions and impacts are consistent with, and in some cases exceed, the emission-reduction strategies stipulated in the CAAP. Project mitigation measures would also extend beyond the 5-year CAAP time frame to the end of the lease period.

ES.5 ENVIRONMENTAL ISSUES

Geology, Groundwater, and Soils

Project construction would not result in significant impacts on geology, groundwater, or soils under CEQA or NEPA. The topography in the Project site is relatively flat, paved, and hydraulic and engineered filled land, and the remainder consists of constructed harbor channels and is not subject to landslides or mudflows. Alteration of the topography beyond that resulting from natural erosion and depositional processes would not occur. Similarly, no on-site prominent geologic or topographic features exist that would be destroyed, permanently covered, or materially or adversely modified during Project construction. Project runoff would be controlled by use of best management practices (BMPs) such that soil runoff and deposition in the harbor would be minimized. The Pier S site is underlain by the Wilmington Oil Field and was an active oil and gas production field until 1999; as petroleum reserves beneath the site could be accessed from the established oil set-aside locations, mineral resource impacts would be less than significant.

Project operations would result in less-than-significant impacts on geology, groundwater, and soils. There are no known active or potentially active faults crossing the Project area that might result in significant ground rupture and/or structural damage. Construction in accordance with the City of Long Beach Building Code requirements would limit the severity of consequences from severe seismically induced ground movement during operations. Because the site elevation ranges from about +3 to +18 feet above MLLW, there would be a minor risk of coastal flooding due to tsunamis and seiches. Regardless, the likelihood of such an occurrence is extremely low and operational impacts would be less than significant under CEQA and NEPA.

Air Quality and Health Risk

The Project design includes all applicable control measures identified in the CAAP and additional clean air technologies. Project-specific air emission control measures applied to reduce air emissions and public health impacts are largely consistent with, and in some cases exceed, the emission-reduction strategies of the CAAP. Project mitigations also would extend beyond the 5-year CAAP timeframe.

Under both CEQA and NEPA, Project construction would produce daily emissions that are above the emission significance criteria for all pollutants except sulfurous oxides (SOx). With mitigation, Project construction emissions would remain above the emission significance criteria for all pollutants except SOx and particulate matter ($PM_{2.5}$ and PM_{10}) under NEPA, and for all pollutants except SOx under CEQA.

During construction, air dispersion modeling indicates that Project impacts would exceed the 1-hour SCAQMD nitrogen dioxide (NO_2) ambient thresholds and the 24-hour PM_{10} and $PM_{2.5}$ thresholds and result in significant impacts under CEQA and NEPA. All other pollutant impacts would remain below significant levels. With implementation of construction mitigation measures, Project impacts would remain significant for the 1-hour SCAQMD NO_2 ambient thresholds and the 24-hour PM_{10} thresholds under CEQA and NEPA.

Under both CEQA and NEPA, Project operations, considering application of air emission control measures, would produce daily emissions that are above the emission significance criteria for all pollutants except PM_{10}.

During operations, considering application of air emission control measures, air dispersion modeling indicates that Project impacts would exceed the 1-hour and annual SCAQMD NO_2 ambient thresholds and the 24-hour PM_{10} and $PM_{2.5}$ thresholds, and result in significant impacts under CEQA and NEPA. All other pollutant impacts would remain below significant levels.

The Project would produce a significant incremental increase in cancer risk for residential receptors for CEQA but be less than significant under NEPA. The Project would produce a significant incremental increase in cancer risk to occupational receptors under CEQA and NEPA. The incremental increase in cancer risk to sensitive receptors would be less than significant under both CEQA and NEPA. There are no additional mitigation measures that would reduce this impact to less-than-significant levels.

Non-cancer chronic health impacts and the cancer burden incremental increase from the Project would not exceed significance thresholds and would be less than significant under CEQA and NEPA. However, impacts on health risk would be significant under CEQA and NEPA, because the incremental increase in cancer risk is above the significance threshold with mitigation.

The Proposed Project would not create objectionable odors to sensitive receptors, as the distance between Project emission sources and the nearest residents (approximately 1 mile) would allow for dispersion of these emissions to below objectionable odor levels. Therefore, odor-related impacts would be less than significant under CEQA and NEPA.

Project operations would not conflict with or obstruct implementation of the Air Quality Management Plan (AQMP); therefore, impacts would be less than significant under CEQA and NEPA.

Global Climate Change

Under CEQA, the Proposed Project would result in a significant CEQA impact if carbon dioxide-equivalent (CO_2e) emissions exceed the SCAQMD's draft threshold of significance for industrial projects of 10,000 metric tons per year.

Both Project construction and operation emissions of greenhouse gases (GHGs) would be above 10,000 metric tons of CO_2e; therefore, impacts would remain significant under CEQA.

Under NEPA, there are no science-based GHG significance thresholds, nor has the federal government or the state adopted any by regulation. Because no NEPA threshold has been established, no determination of significance has been made for the GHG impacts.

Sea-level rise is one of the major areas of concern for any property along the California Coast. POLB projects incorporate sea level rise into their designs. In addition, the Port is developing a Port-wide Climate Change Adaptation and Coastal Resiliency Strategic Plan (CRS Plan) that will enable the Port to begin preparing for climate change and associated coastal hazards by providing a framework for the Port to incorporate adaptive measures relating to projected climate change into its policymaking and planning processes, environmental documents, infrastructure design, construction practices, and community outreach and education efforts

Marine Water and Sediment Quality

No significant construction impacts to the existing water or sediment quality conditions would occur with Project implementation. Sediment re-suspension and the associated turbidity would be short term and localized around the site of dredging, excavation, and earthwork. Compliance with requirements specified in the RWQCB Waste Discharge Requirements (WDR) during operations would minimize impacts. The material from dredging and excavation would be disposed of at an approved Middle Harbor landfill (i.e. Piers D, E, and F). A small amount of chemically suitable dredged material could be disposed of at the Western Anchorage Disposal Site and the approved LA-2 ocean disposal site, if required by timing or capacity constraints at the Middle Harbor sites. Disposal at the Western Anchorage and LA-2 sites would only be undertaken with the approval of USACE and RWQCB following chemical, and possibly bioassay, testing of the material. Discharges of fill regulated under Section 404 of the CWA would require a 401 water quality certification from RWQCB. Compliance with the State General Permit for Storm Water Discharges Associated with Construction Activities would minimize potential water quality effects.

No significant operational impacts to the existing water or sediment quality conditions from the operation of the new terminal would occur. Back and Cerritos Channel widening and other localized modifications would result in less-than-significant impacts to changes in tidal prism and water storage. These changes are not likely to significantly alter the harbor-wide circulation or flushing conditions. Storm water discharges from the new terminal, upon completion, would be regulated under the storm water management plan of the Port. There is no potential for damage to biological resources as a result of on-site flooding.

Biota and Habitats

Construction of the Proposed Project, including dredging and filling as well as backland improvements and wharf construction activities, would be unlikely to affect any listed, candidate, sensitive, or special concern species due to temporary increases in noise or vibration. No endangered or threatened marine fish or invertebrate species of state or federal concern occur in the Project area. However, essential fish habitat (including recently discovered eelgrass) is present within the harbor, and marine mammals and turtles, as well as many marine birds, are species of state or federal concern. One listed bird species, the California least tern, may forage in the vicinity, but it does not nest near the Project area. Construction activities would result in no loss of individuals or habitat for rare, threatened, or endangered species. Sound pressure waves from construction activities in the water would not injure marine mammals or significantly reduce their foraging habitat.

The net direct impact of construction to the marine environment would be short-term losses to benthic epifaunal and infaunal communities, and rocky subtidal and intertidal biota during dredging activities. However, construction impacts would occur in a small portion of the harbor and, after dredging ceases and the replacement of riprap occurs, the benthic communities would rapidly re-colonize both soft bottom and new hard substrate habitats. All lost habitat would eventually be replaced and there would be the creation of about 10.3 acres of additional benthic and epibenthic habitat, a net gain. Impacts to bird species that use the Proposed Project area for nesting, resting, or foraging could occur if they are present during construction. However, bird species would be able to use other areas within the Project area or the harbor complex for such activities, causing them to temporarily avoid the area during construction. Marine mammals, such as seals and sea lions, would also likely temporarily leave the construction area due to sound pressure waves in the water caused by pile driving. No other protected or sensitive marine species normally occur in the Proposed Project area.

All lost habitat would eventually be replaced and there would be the creation of about 10.3 acres of additional benthic and epibenthic habitat, a net gain. Ship operations could have a potential to result in more collisions with whales as vessels transit coastal waters into and out of the harbor; however, whale strikes are relatively rare and the increased number of ship calls (3 percent more) over the baseline would be an insignificant change that would result in a very low potential for a significant impact on whales. Also, Project vessels would travel at 12 knots or less within 40 miles of the harbor entrance, in compliance with the Vessel Speed Reduction Program, which would appreciably lessen the chance of whale strikes in coastal waters, although not on the open sea.

Operations of the berth would involve shading an area of intertidal and subtidal habitat for a period of time while ships are in Port to be loaded or unloaded. This could have the effect of reducing primary productivity and thereby reducing the amount of invertebrates and fish that could potentially be supported by the area. This would not be a significant impact, as the period of time the ships are at dock will be kept to a minimum out of economic necessity.

Project operations have a very low potential to increase the introduction of nonnative species into the harbor that could substantially disrupt local biological communities, but such effects could still occur. The potential for introduction of additional exotic species via ballast water would be low from vessels entering from outside the Exclusive Economic Zone (EEZ). The potential for introduction of exotic species via vessel hulls would be increased in proportion to the increase in number of vessels. Therefore, impacts would be significant under CEQA and NEPA.

Ground Transportation

Construction-related traffic is not expected to have significant impacts on the study intersections; however, additional traffic generated by construction activities is expected to have significant impacts on certain study highway segments. Implementation of mitigation and environmental control measures would mitigate the Project's impact on the highway segments to a less-than-significant level under CEQA and NEPA.

In addition, it should be noted that the POLB is currently participating in on-going regional transportation programs that are intended to address future regional traffic growth and resulting congestion on area freeways. These programs include the I-710 Corridor EIS/EIR; the Advanced Transportation Management, Information, and Security System; and the SR-91 Corridor Study. Construction-related activities are not expected to affect public transit because there is no public transit in the vicinity of the Project site. In addition, construction-related activities are not expected to use or interfere with rail services, so there would be no impact on the regional rail network.

For Project operations, additional traffic generated by the Project would have significant impacts at certain study area intersections under CEQA and NEPA. The POLB does not own, control, or maintain all of the impacted intersections. Some of the impacted locations are within the POLA or City of Los Angeles' jurisdiction. Therefore, the POLB does not have authority to unilaterally implement any mitigation measures at these locations and can only recommend mitigation measures. Implementation of mitigation measures would mitigate Project-related impacts under the CEQA and NEPA analysis to less than significant. However, because the improvements listed in the mitigation measures are outside the POLB's jurisdiction, their implementation timing is uncertain and, therefore, the impacts on the identified intersections would be significant and unavoidable.

Additional operational traffic generated by the Project would have significant impacts on certain highway segments in the study area under CEQA and NEPA. Implementation of mitigation measures would mitigate the Project's impact to a less-than-significant level, in addition to the POLB's current participation in on-going regional transportation programs (see above). However, because the highway segments fall under the jurisdiction of Caltrans and are outside the POLB's jurisdiction, POLB does not have authority to unilaterally implement any mitigation measures on the highway segments; therefore, the impacts on the identified highway segments would be significant and unavoidable.

Although the Project would result in a staff increase during both construction and operation stages, this increase is not expected to affect public transit because there is no public transit in the vicinity of the Project site. Therefore, the Project is not expected to cause any increase in demand for transit services and, therefore, no impacts are anticipated under CEQA and NEPA.

Additional rail traffic will be generated as part of the Project on certain at-grade crossings in the Project study area. Because the impacts on rail service and at-grade crossings were found to be less than significant, no mitigation is required under CEQA and NEPA.

Vessel Transportation

Project construction-related marine traffic would have less-than-significant impacts on POLB marine vessel safety under CEQA and NEPA. Vessel transportation and marine terminals are regulated by many laws and regulations that are in place to ensure safety within the harbor. Various entities, including international, federal, state, and local agencies, are responsible for enforcing these regulations. Federal laws, the U.S. Coast Guard's Title 33 and Title 46 provisions, and USACE procedures would regulate navigation systems. Additional organization and programs in place are the Marine Exchange of Southern California, Harbor Safety Committee, Harbor Safety Plan, and Vessel Transportation Service. All in-water construction vessel traffic would be subject to USACE restrictions and requirements specified in the conditions of the USACE construction permit, as well as established regulatory conditions ensuring the safety of users in Long Beach Harbor waters. Activities would be scheduled to avoid significant effects to existing marine container terminal traffic.

During operations, the Proposed Project would increase the total number of vessels calling at

Pier S by 312 vessels per year, an approximately 11.6 percent increase over the current number of annual POLB vessel calls. This increase in vessel calls is expected to result in an increase of 0.26 allisions, collisions, and grounds (ACGs) per year, increasing the overall annual average accident rate within the POLB and POLA by only 3.9 percent. Therefore, impacts would be less than significant under CEQA and NEPA, and mitigation measures would not be required.

Public Services/Health and Safety

Project construction would not result in a significantly diminished level of public protection services provided by the Security Command and Control Center (SCCC), Long Beach Police Department (LBPD), Long Beach Fire Department (LBFD), or U.S. Coast Guard (USCG). Standard security measures would remain in place throughout the duration of Project construction, as required by the Maritime Transportation Security Act (MTSA).

Implementation of standard existing safety precautions governing POLB navigation on all support vessels in the Project area would maintain the existing level of safety for vessel navigation plus compliance with the Traffic Management Plan. During construction activities, adequate vehicular access to the site would be provided as part of an emergency response and evacuation plan. Therefore, construction-related impacts on public services/health and safety would be less than significant under CEQA and NEPA.

Standard security measures would help to prevent potential events that could jeopardize Port safety, and the Project would comply with City of Long Beach Fire Codes and state codes. The number of additional annual vessel calls at the POLB would increase slightly, resulting in a relatively small increase in accident potential. However, this increased demand on the U.S. Coast Guard (USCG) would be less than significant. Therefore, impacts to public services/health and safety from Project operations would be less than significant under CEQA and NEPA.

Noise

Impacts on noise were evaluated by determining the potential for the Proposed Project to increase ambient noise levels by three A-weighted decibels (dBA), exceed maximum noise levels allowed by the City of Long Beach Municipal Code (LBMC), exceed the ground vibration level acceptability limits prescribed by American National Standards Institute (ANSI) S2.71-1983, or result in the exposure of receptors to a substantially increased number of vibration events that exceed the acceptability limits prescribed by ANSI S2.71. It is anticipated that the highest Project-related noise levels would occur during pile driving for wharf construction. However, Project construction activities would not cause ambient noise levels to substantially increase (i.e., there would be a less than 3-dBA increase) at nearby sensitive receptors or result in exposure of nearby noise-sensitive receptors to significant short-term noise impacts. Similarly, Project operations would increase ambient noise levels less than 3 dBA. Therefore, construction and operation impacts would be less than significant and mitigation would not be required.

Project construction activities would not cause ambient noise levels to exceed LBMC maximum noise-level limits at any known noise sensitive receptor; therefore, construction of the Project would result in less-than-significant short-term impacts. Project operations would not exceed LBMC maximum noise levels. Therefore, impacts would be less than significant, and mitigation would not be required.

Project operations would not generate ground vibration levels that would exceed ANSI S2.71-1983 acceptability limits. Vibration measurements did not indicate a significant difference between ambient ground vibration and ground vibration during train movements on the Port mainline tracks. Measured vibration levels are well below the acceptability curve prescribed by ANSI S2.71-1983. Therefore, impacts would be less than significant, and mitigation would not be required.

Similarly, Project operations would not increase the number of vibration events that would exceed ANSI S2.71-1983 acceptability limits. Train movements on the Port mainline tracks associated with Project operations would have a less-than-significant vibration impact on sensitive receptors and would not exceed the limits prescribed by ANSI S2.71-1983. Therefore, impacts would be less than significant, and mitigation would not be required.

Hazards and Hazardous Materials

The Project would implement standard BMPs and proper use and storage of hazardous materials and petroleum products in accordance with applicable federal, state, and local regulations and the Risk Management Plan (RMP). The RMP would ensure compliance with state and federal laws, including internal compliance reviews, preparation of regulatory plans, and agency oversight. Therefore, impacts on hazardous and hazardous materials during Project construction would be less than significant under CEQA and NEPA.

During Project operations, there is potential for an accidental release or explosion of hazardous materials. However, the potential for risks associated with accidental release of a hazardous substance would be minimized by adherence to existing laws, regulations, and safety procedures. Operation of the Project would be required to comply with all existing hazardous waste laws and regulations, including the federal Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and CCR Title 22 and Title 26. The Project would comply with these laws and regulations to ensure that potential hazardous materials handling would occur in an acceptable manner. Therefore, operational impacts on hazards and hazardous materials would be less than significant under CEQA and NEPA.

Socioeconomics

Impacts on socioeconomics were evaluated by determining the potential for the Proposed Project to induce a substantial decrease in area employment, either directly or indirectly; induce substantial population growth in an area, either directly or indirectly; or induce a substantial increase in area housing, either directly or indirectly.

The construction jobs created by the Proposed Project would be a net increase for the region and would not induce a substantial decrease in area employment. New construction employment generated by the Project would not impact population in the region, since it is likely that the labor force from within the larger region would be sufficient to complete the construction without an influx of new workers and their families and that relocation within the region would be minimal. Since the Project would mainly draw from construction workers who already reside in the larger region, any change in housing demand would also be minimal. Therefore, construction impacts would be less than significant under CEQA and NEPA, and mitigation would not be required.

Employment projections were provided by the Port for the four different alternatives. The Project would result in approximately 28,020 jobs in 2013; 40,409 jobs in 2020; and 31,568 jobs in 2030. Operations-related jobs decline in later years due to a combination of gains in labor productivity and terminal throughput reaching capacity. The Project would create a rise in employment within the five-county region; this represents an increase in employment, and the Proposed Project would not induce a substantial decrease in area employment. For year 2020, when in-migration peaks, the number of in-migrants represents about 0.05 percent of the baseline population, or about one-tenth of the average annual increase in population in the Gateway Cities subregion. The additional households that would require housing units in the Gateway Cities subregion would comprise nearly 0.06 percent of the total number of households in the years 2008, 2013, and 2020, with rates less than 0.06 percent in 2030. This is considered a nominal increase. Additionally, the latest U.S. Census data suggest that ample vacant housing is available in the Gateway Cities subregion to absorb the need for additional housing. Therefore, operational impacts would be less than significant under CEQA and NEPA, and mitigation would not be required.

Utilities and Service Systems

The Project would result in less-than-significant impacts on utilities and service systems. Existing utility infrastructure and lines (i.e., water, wastewater, storm drains, oil lines, natural gas, and electricity) have been relocated or replaced as a component of Project site improvements and remediation. Construction of new infrastructure would be conducted in a manner designed to prevent service interruptions for adjacent tenants, and new construction would be in conformance with current design standards such that impacts would be less than significant. Therefore, construction of the Proposed Project would not result in significant demands on municipal utilities and service systems, including drinking water, wastewater treatment, and solid waste disposal.

Project operations would have less-than-significant impacts on utilities and service systems. Proposed container terminal employees would create minimal demands for water, wastewater, and natural gas compared with the system capacities of the providers (Long Beach Water Department [LBWD], Los Angeles County Sanitation District [LACSD], Long Beach Energy Department [LBED]). The new utility lines and infrastructure would be designed and constructed to accommodate these utility demands. The electrical facilities that serve Pier S would need to be upgraded as part of the Project. Additionally, the Project would comply with federal, state, and local regulations and codes pertaining to solid waste disposal.

Environmental Justice

Impacts on environmental justice were evaluated by identifying minority and low-income populations in the Project area and determining the potential for the Project to cause disproportionate public health and environmental effects on minority or low-income populations.

Significant unavoidable impacts from the Project would occur for air quality, and the study area would be associated with a significant increase in residential cancer risk (i.e., increased risk of 10 or more cases in 1 million based on lifetime exposure) as it relates to proportions of minorities and low-income residents.

Under the Proposed Project, the affected area contains all or parts of 22 Census block groups, ranging from 0 percent to 100 percent in total minority proportion, and 0 percent to 34.2 percent in the proportion of people of low-income status. Of the affected Census block groups within the elevated cancer risk area, 12 exceed one or both of the relevant thresholds (minority greater than 50 percent and low-income greater than 50 percent of the general population of Los Angeles County), out of 14 populated block groups. While the South Coast Air Basin includes many areas that do not constitute minority and low-income populations, in the Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, ARB estimated that elevated levels of cancer risks due to operational emissions from POLB and POLA occur within and in proximity to the two ports. Because the populations in closest proximity to the Port are predominantly minority and disproportionately low-income, this elevated cumulative risk would represent a disproportionately high and adverse impact on minority and low-income populations.

The transportation analysis includes an evaluation of the streets and intersections that would potentially be used by automobiles, trucks, and rail traffic to gain access to and from the Proposed Project, as well as those streets that would be used by construction traffic (i.e., equipment and commuting workers). The analysis determined that implementation of the Proposed Project would result in a significant and unavoidable cumulative impact Operations of the Proposed Project would create conditions at a number of study area intersections that would either result in a downgrade of LOS or would change V/C equal than or greater than 0.02., and would result in significant changes in LOS and/or V/C to a range of highway segments in 2013 and 2020. Construction and operation impacts to highway segments would not represent disproportionately high and adverse impacts on minority and low-income populations because, while in proximity to areas exceeding corresponding percentages for Los Angeles County, the highway segments represent major thoroughfares and impacts would be borne by regional commuters and commercial traffic in addition to residents of the neighborhoods immediately adjacent to these corridors.

For study intersections that would be significantly affected by operations of the Proposed Project, each intersection is relatively distant from residential areas, with many separated from residential areas by the Alameda Corridor, with the vast majority of intersections located on Terminal Island. While those residential areas in geographic proximity exhibit high proportions of minority and low-income individuals, it is unlikely that residents would be affected by LOS changes at these intersections as they primarily serve commercial and industrial traffic. Thus, operation of the Proposed Project does not represent a disproportionately high and adverse impact on minority and low-income populations.

ES.6 CUMULATIVE IMPACTS

Geology, Groundwater, and Soils

All related POLB and POLA projects would be subject to structural damage and risk of injury to those in the area due to seismically induced ground shaking. However, incorporation of modern construction engineering and safety standards would ensure that cumulative impacts would be less than significant. Similarly, structural damage and risk of injury is possible from coastal inundation as a result of a large tsunami; however, these events are extremely rare and cumulative impacts would be adverse but less than significant. Related projects involving grading, excavations, and construction/demolition could result in erosion-induced sedimentation of harbor waters and potential encounters with contaminated soil. However, implementation of a Storm Water Pollution Prevention Plan (SWPPP) and construction BMPs would ensure that cumulative impacts would remain less than significant. Further, potential impacts associated with encountering contaminated soil at probable future sites involving grading and construction would be less than significant because they would be generally localized and confined to the immediate area of contamination.

Air Quality and Health Risk

The South Coast Air Basin is not in attainment for the national and/or state ambient air quality standards for O_3, PM_{10}, and $PM_{2.5}$. This is due to the region's large population, number of emission sources, and geographical/ meteorological conditions that inhibit atmospheric dispersion. Therefore, impacts on air quality associated with construction and operation of reasonably foreseeable projects, including the Pier S Project, would be cumulatively significant. Similarly, the increase in airborne cancer and non-cancer risk levels resulting from operation of related projects would be cumulatively significant.

Increased emissions from Project construction and operation would produce cumulatively considerable and unavoidable contributions to volatile organic compound (VOC), carbon monoxide (CO), NO_2, PM_{10}, and $PM_{2.5}$ levels. Additionally, toxic air contaminant (TAC) emissions from Project operations would result in cumulatively considerable and unavoidable contributions to airborne cancer risks and chronic non-cancer health effects to residential, occupational, and sensitive receptors. Therefore, the Proposed Project's contribution to cumulative impacts would be significant.

Global Climate Change

Scientific evidence indicates a correlation between increasing global temperatures/climate change over the past century and human-induced levels of GHG. These and other environmental changes have potentially negative environmental, economic, and social consequences around the globe. Based on this information, past, current, and future global emissions of GHG are cumulatively significant.

Climate change as it relates to human-made GHG emissions is a global impact. Thus, the issue of global climate change is a cumulative impact, and an appreciable impact on global climate change would occur when GHG emissions from a project combine with GHG emissions from other human-induced activities on a global scale. Any concurrent emissions-generating activity that occurs worldwide would add additional air emission burdens to the GHG emission levels associated with the Proposed Project. It is unclear whether GHG emissions from the Project would make a significant contribution to the impact of global climate change when considered with GHG emissions generated by all natural and human activities. The Project GHG significance criterion states that any increase in GHG emissions above 10,000 metric tons of CO_2e is significant. The Project would result in an increase in GHG emissions of 282,173 metric tons of CO_2e. Therefore, emissions of GHG from construction and operation of the mitigated Project would produce cumulatively considerable and unavoidable contributions to global climate change under CEQA. Because no NEPA impact significance threshold has been established for GHG emissions, no determination of significance has been made for this impact under NEPA.

Marine Water and Sediment Quality

The region of influence for cumulative impacts on marine waters is the Long Beach/Los Angeles Harbor complex (inner and outer harbor areas). Cumulative projects would directly affect marine water quality and hydrology through fill (approximately 277 acres, of which about 105 acres are completed or under construction), dredging, wharf construction or reconstruction, rock dike construction, and other construction activities (e.g., boat slips and artificial reef). All of these projects would have the potential to affect harbor water quality through runoff of sediments and pollutants during construction and operational activities.

In-water construction activities for the Project would have less-than-significant impacts and would not make a cumulatively considerable contribution to effects on water quality. Temporary disturbances on land during construction of cumulative project facilities would add a small amount of soils in runoff to harbor waters. Runoff from these projects, however, would not occur simultaneously, but would be spread over time so that construction-related runoff to harbor waters would be dispersed in time and space. Cumulative impacts would be less than significant due, in part, to this dispersal, and also due to the small amount of land affected for each project and to implementation of runoff control measures required in project permits, such as SWPPPs. Runoff during operations of the cumulative projects could change as industrial uses and the amount of paving change, but such changes would be small, since most areas are already developed. The small increase in vessel traffic in the harbor caused by the Project would not make a cumulatively considerable contribution to effects on water quality. Thus, cumulative impacts to water quality would be less than significant. Project backland construction and rail yard construction and operation would have less-than-significant impacts on water quality, and the Project would not make a cumulatively considerable contribution to effects on water quality.

The Project would create up to 10.3 acres of new water surface area (i.e., reduce the acreage of current land area); therefore, the potential for flooding would be decreased and would not have the potential to add to impacts from cumulative surface runoff into the harbor. The Project would not increase the potential for flooding and, thus, would not make a cumulatively considerable contribution to effects of flooding.

Biota and Habitats

Project construction activities related to dredging, excavation, and wharf construction, in association with the cumulative projects, could result in significant direct impacts to Essential Fish Habitat (EFH) in the form of eelgrass (*Zostra marina*) beds that occur within the western portion of the Project dredge footprint. However, with the implementation of mitigation measures, unavoidable direct impacts to eelgrass would be reduced to below significance. Cumulative projects would also directly remove EFH in the form of soft-bottom and hard-substrate habitat; however, these areas would be expected to generate typical productivity and food sources for fish and other marine species within a relatively short time. The Project would ultimately result in the creation of an additional 10.3 acres of open water habitat, and would not contribute to cumulative losses of EFH.

Runoff from temporary disturbances on land during construction of cumulative project facilities would not occur simultaneously, but would be spread out over time so that total runoff to harbor waters, which could potentially impact EFH and marine habitat, would be dispersed, both in frequency and location. The Project's contribution to runoff from temporary disturbances on land during construction would be less than significant due, in part, to this dispersal and because runoff control measures, such as SWPPPs, would be implemented as required in project permits.

Construction of the cumulative projects has the potential to indirectly affect the California least tern, an endangered species. Those cumulative impacts would be significant but feasibly mitigated and, as a result, the Project would not contribute to cumulative effects on the least tern. Construction would also have no cumulative impacts on other covered species, or on the migration or movement of fish and wildlife.

With implementation of mitigation measures, construction of the cumulative projects would not make a considerable contribution to direct and indirect effects of noise (particularly during pile driving activities) on fish and marine mammals. Vessel sounds during construction and operation would also not directly or indirectly contribute to cumulative effects.

Many of the cumulative projects would have temporary impacts on terrestrial biota and habitats during construction. These effects would not result in significant direct or indirect cumulative impacts on local biological communities because these projects would only affect small areas at a time and would have minimal effects on the limited biological communities that exist in the industrial area in which these projects take place. The Project would not contribute to those impacts because it would not affect terrestrial habitats and would not substantially disrupt existing terrestrial biological communities.

The potential for a vessel collision with a blue or gray whale during construction of the cumulative projects is unlikely. Considering the small number of construction-related vessels relative to existing vessel traffic in the area, the low population densities of whales in the harbor, and the slow speeds of construction-related barges, collisions are not anticipated. An increase in vessel traffic during operation of the cumulative projects, particularly large vessels, would, however, increase the direct cumulative potential for vessel strikes of whales. Mitigation measures available to reduce the potential for whale strikes are unproven; however, it would be logical to assume that a reduction of speed would allow marine mammals more time for evasive maneuvers and thereby reduce the overall potential for a whale strike. Mortality of blue whale is of particular concern, and the occurrence of a blue whale strike would result in a significant and unavoidable impact for this species.

An increase in vessel traffic during operation of the cumulative projects would also increase the risk of invasive species introduction. Invasive aquatic species have become established in the waters of San Pedro, and, even with current ballast water regulations, a potential for introduction of invasive species exists. The potential consequences of invasive species introduction are considered serious, and, as there is no feasible proven mitigation, the cumulative impact of increased vessel traffic is significant. Although the Project would result in only a small increase in vessel traffic, the introduction of invasive species would result in a cumulatively significant unavoidable impact on local biological communities.

Ground Transportation

When considered cumulatively, the Project would have significant impacts at certain study intersections under CEQA and NEPA. The cumulative intersection impacts and the Project's fair share to mitigate the cumulative impacts are presented in Section 3.6 for all alternatives under CEQA and NEPA. The mitigated levels of service at the intersections with identified impacts are also presented in Section 3.6. Implementation of mitigation measures would alleviate the intersection impacts to a level of less than significant under the Three-Berth Alternative, except at the intersection of Henry Ford Avenue and Denni Street, which would be operating at LOS C in 2030 (which is significant under Los Angeles threshold because the V/C increases by more than 0.04), and where no feasible mitigation measures could be identified. In addition, the Proposed Project would result in potentially significant cumulative impacts at intersections outside of the City of Long Beach. The POLB does not own, control, or maintain all of the impacted intersections. Some of the impacted locations are within the POLA or City of Los Angeles' jurisdiction. Therefore, the POLB does not have authority to unilaterally implement any mitigation measures at these locations and can only recommend mitigation measures. The recommended mitigation measures would mitigate the impacts at the intersections outside of the POLB to a level of less than significant.

When considered cumulatively, the Project would have significant impacts at certain study highway segments under CEQA and NEPA. Although total highway traffic would increase substantially in the future, this Project contributes only a small portion of the anticipated future traffic. To mitigate the Project's impact at the potentially significantly affected locations outside of the City of Long Beach, POLB would provide a fair-share contribution to improvements aimed at reducing the significant impacts, as determined by the Board of Harbor Commissioners, if a fair-share funding program committed to specific improvements at the impacted locations exists at the time of the certification of the EIR. The funds would be held by POLB and transferred to the lead agency for the improvements once the future improvement project(s) have started construction (or earlier if necessary to implement the fair share program). It should be noted that the POLB is currently participating in the on-going regional transportation programs described under the Proposed Project, which would contribute toward mitigating any potential impacts of the Project.

Impacts would be less than significant with the implementation of the recommended mitigation measures. However, the highway segments are outside of POLB's jurisdiction. Until Caltrans implements improvements on the SR-91 highway segments, the Project would have significant impacts at these locations. Therefore, impacts on highway segments would be significant and unavoidable.

The Project would not contribute toward cumulative impacts on transit services. The Project is not expected to have a negative impact on vehicular delays at the Pier B Street/9th Street and New Dock Street grade crossings in the Port. Additionally, the Project would not have cumulative impacts in year 2030 at identified at-grade crossings in the regional rail network compared to the future baseline. The cumulative impacts are presented in Section 3.6 and would be less than significant. Therefore, no rail mitigation is necessary.

Vessel Transportation

Both the POLB and POLA have proposed or planned numerous projects (Table 2-1) to accommodate the anticipated cargo growth (see Chapter 1) that would result in a substantial increase in vessel traffic. This increase in traffic, estimated to double by 2020, has the potential to result in a substantial increase in allusions, collisions, and groundings (ACGs). Assuming that accident rates remain unchanged, the increase in Port shipping would result in an equivalent increase in the number of ACGs. This is considered a potentially significant cumulative impact. It should be noted that environmental control measure BIO-2 was incorporated into the Project to reduce potential impacts. Additionally, the Pier S Project would contribute a relatively small fraction of the potential cumulative increases in TEU, port calls, and potential ACGs. Therefore, the Pier S Project's contribution to potential cumulative impacts related to vessel transportation would be less than significant.

Public Services/Health and Safety

The related cumulative projects would result in an increase in the maximum throughput of containers in the POLB and POLA. The Project would not burden the U.S. Coast Guard (USCG), Long Beach Police Department (LBPD), Long Beach Fire Department (LBFD), or Security Command and Control Center (SCCC) such that they would not be able to maintain adequate levels of service. The Port reimburses the City of Long Beach for fire and police services within the Harbor District and contributes proportionally to the operation of the SCCC. Accordingly, the demand for public services attributable to the Project would be funded through the Port and city budgets. Furthermore, the Project and alternatives would implement standard security measures and comply with the Maritime Transportation and Security Act (MTSA). Therefore, the cumulative contribution of the Project would be less than significant under CEQA and would not be cumulatively significant under NEPA.

Similar to the Three-Berth Alternative, the related cumulative projects would comply with MTSA standards and implement standard security measures. However, several of the related projects (see Table 2-1) would result in regional growth that would use additional police, fire, and USCG services. That demand could result in cumulatively significant impacts to public services and safety. In light of the funding arrangements described above, however, the Project would not contribute to that impact and no mitigation would be required.

Noise

All of the projects listed in Table 2-1 would have some potential for construction noise impacts. Based on the calculated noise levels from Project construction and the great distance of the project from local noise sensitive receptors, noise levels from Project construction would not be distinguishable over existing ambient noise levels, as they would be at least 10 dBA below the ambient. Thus, the Project's contribution to cumulative construction noise impacts would be less than significant under both CEQA and NEPA.

All reasonably foreseeable projects listed in Table 2-1 (Chapter 2) would have the potential to generate operational noise impacts, such as increased noise from vehicular traffic. Based on the assessments under each alternative, the maximum forecasted cumulative noise level increase above existing conditions in 2030 would be 0.5 dBA or less due to Project traffic. Therefore, the Project's contribution to future cumulative traffic noise would not result in a cumulatively significant impact under CEQA or NEPA. The Project contribution would be inaudible and would be a less than cumulatively considerable increase under CEQA and a less than adverse increase in noise levels under NEPA.

As outlined in Section 3.9, reasonably foreseeable future projects that would increase rail traffic would result in potentially significant vibration impacts. The Project's cumulative contribution to train noise (1 dBA or less) along the Alameda Corridor and vibration would be well below perceptible levels and would be a less than cumulatively considerable increase under CEQA and a less than adverse increase in vibration levels under NEPA.

Hazards and Hazardous Materials

Because projected terminal operations at Pier S would accommodate a total of 312 annual vessel calls and 1.8 million TEUs compared to the CEQA Baseline, the potential for an accidental release or explosion of hazardous materials would be expected to increase by 0.8 per year, assuming a linear relationship. The projected number of increased spills would be the contribution of the Project to cumulative impacts in the POLB/POLA region. This spill frequency would be classified as "frequent" (0 to

1 per year). Based on past history of spills within POLB/POLA (1997–2007), a slight possibility exists for injury and/or property damage to occur during one of these infrequent accidents; therefore, the potential consequence of such accidents is classified as “slight,” equating to a Risk Code of 4 (i.e., “acceptable”).

To the extent that increased container throughput would occur through existing POLB and POLA terminals, there could be an increased risk of upset, compared to baseline conditions, from increased vessel/truck traffic and container throughput. In the absence of any quantitative details of such a scenario, however, it is not possible to definitively conclude that those impacts would occur or be significant.

Compliance with laws and regulations governing the transport of hazardous materials and emergency response to hazardous material spills would minimize the potential for adverse impacts associated with related POLB and POLA projects. The cumulative impact of these projects on hazards and hazardous materials would be less than significant.

The Pier S Project would contribute to cumulative impacts from hazards and hazardous materials from other projects. However, compliance with applicable federal, state, and local laws and regulations governing packing, labeling, and transporting and manifesting hazardous materials, along with emergency response to hazardous materials spills, would minimize the potential for adverse public safety impacts associated with the Pier S Project. In addition, as previously discussed, the potential consequence of accidental spills is classified as “slight,” equating to a Risk Code of 4 that is “acceptable.” Therefore, the Pier S Project’s cumulative contribution would be adverse, but less than significant under CEQA and NEPA.

Socioeconomics

Many of the current and foreseeable projects at the POLB and POLA involve construction or renovation of port facilities. These construction projects would increase the number of jobs in the construction industry. However, the effects of the additional construction jobs would be temporary and would last only during the term of the construction. Also, individual construction workers may be able to work on multiple construction projects at the Port. The incremental effect of the construction employment from Proposed Project construction activities would be minimal given the estimated number of jobs that would be created as a result of Project construction and the number of construction jobs in the five-county region.

Other current and foreseeable projects to occur at the POLB and the POLA have the potential to create new jobs in the region, particularly in the Gateway Cities subregion; however, specific information on the estimated number of jobs that would be created is not available. The incremental effects, however, of the operations from the Proposed Project would not be significant, given the minimal effects of the additional employment, population, and demand for housing on the five-county region and the Gateway Cities subregion. Therefore, the Proposed Project’s contribution to cumulative impacts on socioeconomics would be less than significant under CEQA and NEPA.

Utilities and Service Systems

Many of the related projects involve relocation of existing facilities from within the POLB and POLA or do not involve expansion of operation and would not, therefore, result in an increased demand on public resources. However, several of the related projects would generate additional temporary and permanent employees that would result in additional demand on utilities/service systems, including increased generation of solid waste and wastewater treatment, or through consumption of water, electricity, and natural gas. Due to the number of related projects that would place an additional demand on utilities/service systems, potentially significant cumulative impacts on utilities/service systems would result.

However, the Proposed Project’s contribution to these cumulative impacts would not be significant because it would not contribute to a substantial percentage increase in the demand for utilities/service systems associated with the reasonably foreseeable related projects. Furthermore, each cumulative project as part of the environmental review process must prove that adequate supplies exists for the various utilities or provide mitigation and or improvements to existing utility systems to ensure proper and adequate capacity. Therefore, the Project's contribution to cumulative impacts on utilities/service systems would be less than significant.

Environmental Justice

Construction and operation of related projects in the POLB and POLA region would increase the potential for cancer and chronic non-cancer health risks. Because the populations in closest proximity to the Port are predominantly minority and disproportionately low-income, this elevated cumulative risk would represent a disproportionately high and adverse impact on minority and low-income populations.

The Proposed Project would further increase the potential for developing cancer health risks within the POLB and POLA region. Therefore, the Proposed Project's contribution to cumulatively significant impacts on cancer health risk would represent a disproportionately high and adverse impact on minority and low-income populations.

The Proposed Project would provide additional jobs and economic benefits in the region and local area during construction and operations. In addition, by providing additional Port-related infrastructure, it would accommodate projected growth in goods movement consistent with Port cargo operations and enable proposed development consistent with Port plans while minimizing adverse impacts to human populations and the environment, improving the local economy and stimulating regional employment in a range of industries.

ES.7 PUBLIC INVOLVEMENT

USACE and POLB issued a Notice of Intent (NOI) and a Notice of Preparation and Initial Study (NOP/IS) on January 17, 2007. The NOP and NOI were published in the Federal Register on February 26, 2007. The NOI and NOP/IS described the Project and the joint environmental review process, solicited public input on environmental issues to be addressed in the EIS/EIR, and announced a joint NEPA/CEQA public scoping meeting. Two public scoping hearings for the Project were held on February 12 and February 22, 2007. Table ES-1 summarizes the environmental issues that were identified during the public scoping process and indicates the EIS/EIR sections in which these issues are addressed. Issues of concern that were identified for the Project are traffic/circulation, health impacts, air quality, global climate change, water quality, noise, cost-benefit analysis, and environmental justice.

This Draft EIS/EIR is being circulated for 45 days for public review and comment. The duration of the public review period is identified in the Notice of Availability attached to this Draft EIS/EIR. During this period, comments from the general public, organizations, and agencies regarding environmental issues in the Draft EIS/EIR and the Draft EIS/EIR's accuracy and completeness may be submitted to the lead agency at the following address:

Rick Cameron
Port of Long Beach
925 Harbor Plaza
Long Beach, CA 90802
Phone: (562) 590-4160
Email: Cameron@polb.com

General questions about this EIR/EIR and EIR/EIR process should also be directed to the phone number or email address above. The Port will prepare written responses to comments on the Draft EIS/EIR if they are (1) submitted as written letters and delivered to the address above by 5 p.m. of the last day of the public review period identified in the Notice of Availability, or (2) presented verbally at the public hearing on the Draft EIS/EIR that will be held during the public review period. Upon completion of the public review period, a Final EIS/EIR will be prepared that will include the comments on the Draft EIS/EIR received during the formal public review period and responses to those comments.

ES.8 IMPACTS AND MITIGATION MEASURES

Table ES-2 summarizes the environmental impacts and mitigation measures identified in this EIS/EIR.

Table ES-1. Comments Received During the Pier S Marine Terminal and Back Channel Improvements Project Public Scoping Process

Commenter	Comment Summary	Draft EIS/EIR Section Addressing Comment
Dave Hall, resident	The EIS/EIR should evaluate the effects of dredging on wildlife in San Pedro Bay, including all endangered, threatened species. The fish might be affected as well. Elaborate on the 10.3 acres of wildlife area that will be added with the Project.	Section 3.5 (Biota and Habitats)
John Cross, resident	The EIS/EIR needs to elaborate on the Project specifics, such as number of lifts, shore power, etc.	Chapter 1 (Introduction and Project Description)
	The EIS/EIR needs to evaluate the 710 freeway and the effects of the increased trucks.	Section 3.6 (Ground Transportation)
Elisa Trujillo, resident	Noise exposure impacts need to be assessed and analyzed.	Section 3.9 (Noise)
	The EIS/EIR should include ways to manage air quality impacts and analyze associated health risks.	Section 3.2 (Air Quality and Health Risk)
	The EIS/EIR needs to address global warming and how it relates to sea-level rise.	Section 3.3 (Global Climate Change)
Kathleen Woodfield, San Pedro Peninsula Homeowners Coalition	The purpose and objective of this Project needs to be in accordance with CEQA. The EIS/EIR needs to elaborate on the Project specifics, such as number of lifts, truck calls, etc.	Chapter 1 (Introduction and Project Description)
	Air quality impacts need to be analyzed and mitigation measures need to be provided in the EIS/EIR.	Section 3.2 (Air Quality and Health Risk)
	Global warming effects need to be evaluated, including tsunamis, greenhouse gases, and sea-level rise.	Section 3.3 (Global Climate Change)
Brian Jacobsen, Natural Resources Defense Council	The purpose and objective of this Project needs to be in accordance with CEQA. The EIS/EIR needs to elaborate on the Project specifics, such as number of lifts, shore power, truck calls, etc.	Chapter 1 (Introduction and Project Description)
	The alternative for the intermodal rail yard needs to be further evaluated.	Chapter 4 (Alternatives)
	Water quality impacts of dredging need to be analyzed further in the EIS/EIR.	Section 3.4 (Marine Water and Sediment Quality)
Roger Holman, Coolidge Triangle Neighborhood Association	Additional traffic associated with the Project needs to be analyzed further in the EIS/EIR.	Section 3.6 (Ground Transportation)
	Health risks associated with air quality impacts needs to be further analyzed since many children have lung issues that can be attributed to the Port's current air quality policies.	Section 3.2 (Air Quality and Health Risk)
Elina Green, Long Beach Alliance for Children with Asthma	Asthma amongst children in Long Beach is higher than other areas, so the health impacts and pollution associated with the Project need to be mitigated. The Project needs to go above and beyond the CAAP to minimize public health impacts.	Section 3.2 (Air Quality and Health Risk) and Section 3.3 (GHG Emissions)
Tom Politeo, resident	The EIS/EIR needs to elaborate on the utilities and communication technology associated with the Project.	Section 3.13 (Utilities and Service Systems)
	Global warming effects need to be evaluated, including tsunamis, greenhouse gases, and sea-level rise.	Section 3.3 (Global Climate Change)
	Electric rail options should be discussed in the EIS/EIR.	Chapter 1 (Introduction and Project Description)

Commenter	Comment Summary	Draft EIS/EIR Section Addressing Comment
Angelo Logan, East Yard Community Environmental Justice	Air quality impacts need to be analyzed and mitigation measures need to be provided in the EIS/EIR. Impacts of ultrafine particles to public health need to be looked at, as well as diesel-related emissions.	Section 3.2 (Air Quality and Health Risk)
	Innovative goods-movement technology should be considered for this Project as an alternative.	Chapter 4 (Alternatives)
Oty Nungaray, resident	Asthma and health risks associated with air quality impacts needs to be further analyzed, since many children have lung issues that can be attributed to the Port's current air quality policies.	Section 3.2 (Air Quality and Health Risk)
Marie Castle, Caltrans	Traffic issues associated with the Project need to be analyzed and mitigated.	Section 3.6 (Ground Transportation)
	Air quality impacts need to be analyzed and mitigation measures need to be provided in the EIS/EIR, especially how the longshoremen will be affected.	Section 3.2 (Air Quality and Health Risk)
Brigit De La Torre, Long Beach Council PTAs	Further elaboration on how the Project is supposed to reduce the overall pollution in the Port needs to be included in the EIS/EIR.	Section 3.2 (Air Quality and Health Risk)
	The Multi-Use Storage Alternative needs to be further explained in the EIS/EIR.	Chapter 4 (Alternatives)
	Health risks associated with air quality impacts need to be further analyzed, since many children have lung issues that can be attributed to the Port's current air quality policies.	Section 3.2 (Air Quality and Health Risk)
Gene Kininmonth, USC	Health risks associated with air quality needs to be analyzed to show how they affect recreational impacts such as rowing in the harbor.	Section 3.2 (Air Quality and Health Risk)

Table ES-2. Summary of Environmental Impacts and Mitigation Measures

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
GEOLOGY, GROUNDWATER, AND SOILS			
GEO-1: The Three-Berth Alternative would not substantially alter the topography beyond that resulting from natural erosion and depositional processes.	CEQA: Less than significant NEPA: No impact	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: No impact
GEO-2: The Three-Berth Alternative would not disturb or otherwise adversely affect unique geologic features (e.g., paleontological resources) or geologic features of unusual scientific value.	CEQA: No impact NEPA: No impact	CEQA: None necessary. NEPA: None necessary.	CEQA: No impact NEPA: No impact
GEO-3: The Three-Berth Alternative would not accelerate geologic processes, such as erosion.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
GEO-4: The Three-Berth Alternative would not render existing oil reserves beneath the site inaccessible from outside of Pier S site boundaries.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
GEO-5: Construction activities may encounter hazardous substances or other contaminants associated with historical uses of the Port, resulting in short-term exposure (duration of construction) to construction personnel.	CEQA: No impact NEPA: No impact	CEQA: None necessary. NEPA: None necessary.	CEQA: No impact NEPA: No impact
GEO-6: No active faults are located beneath the Pier S site; therefore, no ground rupture would occur.	CEQA: No impact NEPA: No impact	CEQA: None necessary. NEPA: None necessary.	CEQA: No impact NEPA: No impact
Impact GEO-7: Seismic activity along numerous regional faults could produce seismic ground shaking, liquefaction, differential settlement, or other seismically induced 7ground failure that would expose people and structures to greater than normal risk.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
Impact GEO-8: Construction and operation of the Three-Berth Alternative in the Pier S area would not likely expose people and structures to greater than normal risk involving tsunamis or seiches.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
AIR QUALITY			
AQ-1: Three-Berth Alternative construction would produce emissions that exceed SCAQMD emission significance thresholds.	CEQA: Significant NEPA: Significant	CEQA: **Mitigation Measure AQ-1: Additional Fugitive Dust Controls.** The calculation of unmitigated fugitive dust emissions from Project earth-moving activities assumes a 75 percent reduction from uncontrolled levels with rigorous watering of the site and use of other measures (listed below) to ensure Project compliance with SCAQMD Rule 403. This measure would further reduce fugitive dust emissions to achieve a 90 percent reduction from uncontrolled levels. The Project construction contractor shall develop and implement dust control methods that will achieve this control level in a SCAQMD Rule 403 dust control plan and designate personnel to monitor the dust control program and order increased watering, as necessary, to ensure a 90 percent control level. Their duties shall include holiday and weekend periods when work may not be in progress. Additional measures to reduce fugitive dust would include, but are not limited to, the following: ▪ Apply approved non-toxic chemical soil stabilizers according to manufacturers' specifications to all inactive construction areas or replace groundcover in disturbed areas. ▪ Provide temporary wind fencing around sites being graded or cleared. ▪ Cover truck loads that haul dirt, sand, or gravel, or maintain at least 2 feet of freeboard in accordance with Section 23114 of the California Vehicle Code. ▪ Install wheel washers where vehicles enter and exit unpaved roads onto paved roads, or wash off tires of vehicles and any equipment leaving the construction site. ▪ Suspend all soil disturbance activities when winds exceed 25 miles per hour (mph) or when visible dust plumes emanate from the site; stabilize all disturbed areas. ▪ Appoint a construction relations officer to act as a community liaison concerning on-site construction	CEQA: Significant and unavoidable NEPA: Significant and unavoidable

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		activity, including resolution of issues related to PM_{10} generation. ▪ Sweep all streets at least once a day using SCAQMD Rule 1186.1 certified street sweepers or roadway washing trucks if visible soil materials are carried to adjacent streets (recommend water sweepers with reclaimed water). ▪ Apply water three times daily, or non-toxic soil stabilizers according to manufacturers' specifications, to all unpaved parking or staging areas or unpaved road surfaces. ▪ Pave roads and road shoulders. ▪ Apply water three times daily or as needed to areas where soil is disturbed. **Mitigation Measure AQ-2: Emission Controls for Non-Road Construction Equipment.** Although they are not quantified in the analysis of mitigated emissions because the extent of achievable reductions is unknown at this time, the following measures are applied to further reduce combustion emissions. **Mitigation Measure AQ-2a: Best Management Practices (BMPs) for Construction Equipment Emissions Reduction**. The construction contractor shall implement the following BMPs on construction equipment, where feasible, to further reduce emissions from these sources: ▪ Use diesel oxidation catalysts and/or catalyzed diesel particulate traps, as feasible. ▪ Maintain equipment according to manufacturer specifications. ▪ Restrict idling of equipment and trucks to a maximum of 5 minutes (per ARB regulations). ▪ Use high-pressure fuel injectors on diesel-powered equipment. ▪ Use electricity from power poles rather than temporary diesel- or gasoline-powered generators.	

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		Mitigation Measure AQ-2b: Construction Traffic Emission Reductions. The construction contractor shall implement the following measures to further reduce emissions from construction: ▪ Trucks used for construction shall use engines certified to no less than 2007 NOx emission standards. ▪ Provide temporary traffic controls, such as a flag person, during all phases of construction to maintain smooth traffic flow. ▪ Schedule construction activities that affect traffic flow on arterial systems to off-peak hours where possible. ▪ Re-route construction trucks away from congested streets or sensitive receptor areas. ▪ Provide dedicated turn lanes for movement of construction trucks and equipment on- and off-site. ▪ Configure construction parking to minimize traffic interference. ▪ Improve traffic flow by signal synchronization. ▪ Properly tune and maintain all vehicles and equipment according to manufacturers' specifications. ▪ Reduce traffic speeds on all unpaved roads to 15 miles per hour (mph) or less. **Mitigation Measure AQ-2c: Tier 4 Standards for Construction Equipment**. While the construction scenario assumes that all equipment will meet USEPA Tier 3 standards, as a mitigation measure, construction equipment shall meet the USEPA Tier 4 non-road engine standards, where feasible. The first Tier 4 engines become available starting in year 2012. **Mitigation Measure AQ-3: Emission Controls for Construction Tug Boats.** The unmitigated Project analysis assumes partial implementation of Tier 2 engine standards on construction tug boats. Mitigation Measure AQ-3 requires use of Tier 2 engines in tugboats used during construction. Although they are not quantified in the analysis of mitigated emissions because the extent of achievable reductions is	

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		unknown at this time, the following measures are applied to further reduce combustion emissions: **Mitigation Measure AQ-3a: Construction Tugboat Home Fleeting.** The construction contractor shall require all construction tugboats that home fleet in the San Pedro Bay Port to shut down their main engines and refrain from using auxiliary engines while they are docked or to use electrical shore power, if need be. **Mitigation Measure AQ-3b: Tier 3 Engines in Construction Tugboats.** The construction contractor shall ensure that all tugboats used in construction shall meet the USEPA Tier 2 marine engine standards, and, if feasible, use construction tugs that meet the USEPA Tier 3 marine engine standards. The Tier 3 engines became available in 2009. Table 3.2-7b presents a summary of the emissions with implementation of quantifiable mitigation measures. NEPA: See **Mitigation Measures AQ-1** through **AQ-3b**.	
AQ-2: The Three-Berth Alternative construction would result in off-site ambient air pollutant concentrations that exceed a SCAQMD threshold of significance.	CEQA: Significant NEPA: Significant	CEQA: See **Mitigation Measure AQ-1** and **AQ-3b**. NEPA: See **Mitigation Measure AQ-1** and **AQ-3b**.	CEQA: Significant and unavoidable for 1-hour NO_2 and 24-hour PM_{10} NEPA: Significant and unavoidable for 1-hour NO_2 and 24-hour PM_{10}
AQ-3: The Three-Berth Alternative would result in operational emissions that exceed SCAQMD thresholds of significance.	CEQA: Significant NEPA: Significant	CEQA: **Environmental Control Measure AQ-1: Expanded Vessel Speed Reduction (VSR) Program.** All oceans-going vessels (OGV) that call at the Pier S container terminal shall comply with the expanded VSR Program of 12 knots from 40 nm from Point Fermin to the Precautionary Area. This measure equates to CAAP measure OGV1. Environmental **Control Measure AQ-2**: **Shore-to-Ship Power (“Cold Ironing”)**. OGV that call at the Pier S container terminal shall use shore-to-ship power while at berth. Lease stipulations shall include consideration of alternative technologies that achieve 90 percent of the emission reductions of cold-ironing. This measure equates to CAAP measure OGV2.	CEQA: Significant and unavoidable NEPA: Significant and unavoidable

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		Environmental Control Measure AQ-3: Low-Sulfur Fuels in OGV. All OGV shall comply with the more stringent of the ARB fuel sulfur regulations for OGV or use 0.2 percent or lower sulfur Marine Gas Oil (MGO) fuel in vessel auxiliary engines and in vessel main engines out to a distance of 40 nm from Point Fermin, or implement equivalent emission reductions. This measure equates to CAAP measures OGV3 and OGV4. **Environmental Control Measure AQ-4: Slide Valves on OGV Main Engines.** All OGV that call at the Project container terminal and that are capable of being so equipped shall have slide fuel valves installed on their main engines, or implement an equivalent emission reduction technology. This technology would reduce emissions of NOx and diesel particulate matter from OGV main engines. This mitigation measure equates to CAAP Measure OGV6. **Environmental Control Measure AQ-5: Container Handling Equipment (CHE).** All Project CHE shall meet USEPA non-road Tier 4 engine standards. This measure equates to CAAP measure CHE1. **Environmental Control Measure AQ-6: Heavy-Duty Trucks.** Container trucks that call at the Pier S container terminal shall meet USEPA 2007 Heavy-Duty Highway Rule emission standards. The measure equates to CAAP measure HDV1 (Clean Trucks Program). However, it is more stringent and would result in the ban of all trucks that do not meet the USEPA 2007 Heavy-Duty Highway Rule emission standards by January 1, 2012. Truck emissions for **Environmental Control Measure AQ-6** were calculated by assuming that 7 percent of trucks would use liquid natural gas (LNG), and all remaining engines would continue to burn diesel. Although not quantified in the analysis of Project operational emissions because quantification of emission reductions from these measures would be speculative, the following measures would result in reductions in criteria pollutant emissions from Project operations: **Environmental Control Measure AQ-7: Truck Idling Reduction Measures.** The Pier S container terminal	

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		operator shall minimize on-terminal truck idling and emissions. Potential methods to reduce idling include maximizing truck gate hours, including remaining open during off-peak hours, and implementing a container tracking and appointment-based truck delivery and pick-up system to minimize fuel consumption and resulting criteria pollutant emissions. The estimate of on-terminal trucking emissions considered the efficiencies of movement designed into the proposed Pier S container terminal and, therefore, assumed a low rate of on-terminal idling. Nevertheless, additional operational measures proposed in Environmental Control Measure AQ-7 would further reduce on-terminal truck activities and associated criteria pollutant emissions. However, this measure was not quantified due to the difficulties in determining the potential reduction in idling time because no specific design measures have been identified that would support calculations of potential idling time reductions. **Environmental Control Measure AQ-8: Periodic Technology Review.** To promote new emission control technologies, every 5 years following the effective date of the lease agreement, the tenant shall implement a review of new air quality technological advancements, subject to mutual agreement by the Port and tenant on operational feasibility, technical feasibility, and cost-effectiveness and financial feasibility, which agreement shall not be unreasonably withheld. If a technology is determined to be feasible in terms of cost and technical and operational feasibility, the tenant shall, in cooperation with the Port, implement such technology. No quantitative emissions reductions were assumed to be gained from this air quality control measure for the purposes of this document. NEPA: See **Environmental Control Measures AQ-1** through **AQ-8**.	
AQ-4: The Three-Berth Alternative operations would result in off-site ambient air pollutant concentrations that exceed a SCAQMD threshold of significance.	CEQA: Significant NEPA: Significant	CEQA: See **Environmental Control Measures AQ-1** through **AQ-8**. NEPA: See **Environmental Control Measures AQ-1** through **AQ-8**.	CEQA: Significant and unavoidable NEPA: Significant and unavoidable
AQ-5: The Three-Berth Alternative would not create objectionable odors to sensitive receptors.	CEQA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
	NEPA: Less than significant		NEPA: Less than significant
AQ-6: The Three-Berth Alternative would expose receptors to significant levels of Toxic Air Contaminants.	CEQA: Significant NEPA: Significant	CEQA: See **Environmental Control Measures AQ-1** through **AQ-8**. NEPA: See **Environmental Control Measures AQ-1** through **AQ-8**.	CEQA: Significant and unavoidable NEPA: Significant and unavoidable
AQ-7: The Three-Berth Alternative would not conflict with or obstruct implementation of the applicable AQMP and would conform to the most recent adopted SIP.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
GLOBAL CLIMATE CHANGE			
GCC-1: The Three-Berth Alternative would produce GHG emissions that would exceed the CEQA thresholds.	CEQA: Significant NEPA: Significant	CEQA (construction): See **Mitigation Measure AQ-2** under Air Quality. NEPA (construction): See **Mitigation Measure AQ-2** under Air Quality. CEQA (operation): See **Environmental Control Measure AQ-1, Environmental Control Measure AQ-2, Environmental Control Measure AQ-4, Environmental Control Measure AQ-7 and Environmental Control Measure AQ-8** under Air Quality. **Mitigation Measure GCC-1: Leadership in Energy and Environmental Design (LEED)**. The main terminal building shall obtain the LEED gold certification level. LEED certification is made at one of the following four levels, in ascending order of environmental sustainability: certified, silver, gold, and platinum. The certification level is determined on a point-scoring basis, where various points are given for design features that address the following areas (U.S. Green Building Council 2005): ▪ Sustainable sites ▪ Water efficiency ▪ Energy and atmosphere ▪ Materials and resources	CEQA (construction): Significant and unavoidable NEPA (construction): No determination of significance has been made due to lack of NEPA thresholds CEQA (operation): Significant and unavoidable NEPA (operation): No determination of significance has been made due to lack of NEPA thresholds

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		▪ Indoor environmental quality ▪ Innovation and design process As a result, a LEED-certified building would be more energy efficient, thereby reducing GHG emissions compared to a conventional building design. On-terminal electricity consumption would represent about 3 percent of the total Project GHG emissions. The effects of this measure are not quantified in this analysis. **Mitigation Measure GCC-2: Indirect GHG Emission Avoidance and Mitigation**. The applicant and terminal tenants shall minimize the use of indirect GHGs through measures that reduce or avoid electricity consumption at the terminal. Such measures may include the use of low-energy demand lightings (e.g., fluorescent or LED), installation of solar panels on the main terminal building, the construction of solar carports, the use of energy efficient boom flood lights on new dock cranes, and the use of regenerative systems on cargo-handling equipment and cranes. To identify future opportunities to reduce indirect GHG emissions, the tenant shall conduct a third-party energy audit every 5 years and install innovative power saving technologies where feasible, such as power factor correction systems and lighting power regulators. Such systems help to maximize usable electric current and eliminate wasted electricity, thereby lowering overall electricity use, particularly with large on-terminal electricity consumers such as on-terminal lighting and electric wharf gantry cranes. These sources consume the majority of on-terminal electricity and account for about 1 percent of overall Project GHG emissions. Therefore, implementation of power-saving technologies at the terminal could reduce overall Project GHG emissions by a fraction of 1 percent. For those on-terminal, indirect GHG emissions that are not avoided, the terminal tenant shall be required to use “green” commodities, such as those available from the California Climate Action Registry’s Climate Action Reserve, to offset carbon emissions associated with the terminal’s electricity consumption subject to the limitation specified below. This measure applies to all electricity consumed at the terminal, including shore-to-ship power usage (“cold ironing”). The	

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		terminal-related carbon emissions from electricity consumption will be calculated each year based on the local utility's carbon intensity for that year as recognized by the State of California. The tenant may adjust the carbon intensity value to wholly reflect any carbon offsets provided by the electricity deliverer (i.e., point of generation or point of importation) under applicable California and/or federal cap-and-trade regulations (i.e., no double offsetting). The Port is limiting the potential cost of this measure. The maximum expenditure for purchased offsets required under this measure shall not exceed 15 percent of the terminal electricity costs for any given year (i.e., cost of offsets shall not exceed 15 percent of terminal electricity costs). With respect to the use of green commodities, the reason the Port is limiting the potential cost of this measure is because the future implementation cost for this measure is not known. It could potentially be affected by several unknown factors: (a) the future carbon intensity of electricity delivered by the local utility; (b) the future price of green commodities (renewable energy certificates [RECs] and voluntary emission reductions [VERs]); (c) the price of electricity; and (d) the effects of future cap-and-trade regulations on (a), (b), and/or (c). **Mitigation Measure GCC-3: Recycling**. The terminal buildings shall implement a recycling program. In general, products made with recycled materials require less energy and raw materials to produce than products made with un-recycled or raw materials. This savings in energy and raw material use translates into GHG emission reductions. The effectiveness of this mitigation measure was not quantified due to the lack of a standard emission estimation approach. **Mitigation Measure GCC-4: Tree Planting**. The Port shall plant shade trees around the main terminal building. Trees act as insulators from weather, thereby decreasing energy requirements. On-site trees also provide carbon storage (AEP 2007). Although not quantified, implementation of this measure is expected to reduce the Project's GHG emissions by less than 0.1 percent.	

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		Mitigation Measure GCC-5: Tree Planting – Transportation Corridors. The Port shall plant new shade trees on Port-controlled lands adjacent to the roads into the Pier S container terminal to the extent practicable given safety and other land use considerations. **Mitigation Measure GCC-6: Employee Carpooling.** The construction contractor and terminal tenant shall encourage construction and terminal employees to carpool or to use public transportation. These employers shall provide incentives to promote the measure, such as preferential parking for carpoolers or vanpool subsidies, and they shall provide information to employees regarding the benefits of alternative transportation methods. As mentioned in Section 3.3.1.2, the Port is in the process of developing the Climate Change/Greenhouse Gas (CC/GHG) Strategic Plan. This Plan will outline the overall approach for mitigating potential project-specific and/or cumulative GHG impacts of projects through the modernization and/or upgrading of marine terminals and other facilities in the Long Beach Harbor District. The Greenhouse Gas Emission Reduction Program Guidelines (GHG Reduction Program) describe the procedure for the evaluation and prioritization of GHG emission reduction projects and practices that the Port may fund consistent with the Port's overall GHG reduction goals. Several types of projects are described in the GHG Guidelines, but other projects and practices may be defined as the GHG Plan evolves. The original GHG Guidelines were adopted by the Board of Commissioners on March 2, 2009, and may be revised accordingly. The GHG Reduction Program is incorporated into the Project as **Mitigation Measure GCC-7**. **Mitigation Measure GCC-7: Greenhouse Gas Emission Reduction Program (GHG Program).** To partially address the cumulative GHG impacts of the Project, the Port will require this Project to provide funding for the GHG Program. The Three-Berth Alternative is estimated to result in 126,444 metric tons of CO_2e emissions in 2013, 206,962 metric tons of CO_2e emissions in 2020, and 262,067 metric tons of CO_2e emissions in 2030, which represent increases over the CEQA Baseline. When compared with the NEPA Baseline condition, the estimated increases are smaller, namely	

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		87,635 metric tons of CO_2e emissions in 2013, 121,936 metric tons of CO_2e emissions in 2020, and 214,306 metric tons of CO_2e emissions in 2030. These increases are considered by the Port to be cumulatively considerable, and are above the SCAQMD's interim significance threshold of 10,000 metric tons of CO_2e emissions. NEPA: **Environmental Control Measures AQ-1** and **AQ-2**, **Environmental Control Measure AQ-4**, **Environmental Control Measures AQ-7** through **AQ-8**, and **Mitigation Measures GCC-1** through **GCC-7** would reduce operational GHG emissions.	
Impact GCC-2: The Three-Berth Alternative would expose people and structures to risk of flooding by bringing them into the affected area.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. POLB would implement adaptation mechanisms to ensure less-than-significant impacts. NEPA: None necessary. POLB would implement adaptation mechanisms to ensure less-than-significant impacts.	CEQA: Less than significant NEPA: Less than significant
MARINE WATER AND SEDIMENT QUALITY MASTER STORM WATER PROGRAM			
WQ-1: The Project would result in violation of regulatory standards or guidelines (e.g., California Water Code, Water Quality Control Plan, Clean Water Act, California Toxics Rule, and Enclosed Bays and Estuary Plan).	CEQA: Less than significant NEPA: Less than significant	CEQA: **Environmental Control Measures WQ-1** through WQ-4 would ensure less-than-significant impacts. **Environmental Control Measure WQ- 1: Construction Storm Water Pollution Prevention Plan (SWPPP).** The Project would conform to the requirements of the General Storm Water Permit for Construction Activities. A Storm Water Pollution Prevention Plan (SWPPP) would be prepared in conformance with the permit and include site inspections, employee training, and Best Management Practice (BMPs). BMPs would include but not be limited to the following features: • Erosion control • Inlet protection • Waste and material management • Equipment management and fueling **Environmental Control Measure WQ- 2: Dredge Monitoring.** Dredge operations would be conducted in accordance with a USACE Permit and RWQCB Waste Discharge Requirements (WDR) and Monitoring Program.	CEQA: Less than significant NEPA: Less than significant

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		WDR-specified water quality data would be collected during dredge operations to ensure conformance with these requirements. **Environmental Control Measure WQ- 3: Warf Face Drainage.** The wharf deck drainage would be directed landward to a trench drain and water collection area where it would undergo treatment by any one or a combination of settlement, filtration, clarification, and/or oil/water separation. **Environmental Control Measure WQ- 4: Standard Urban Storm Water Mitigation Plan (SUSMP).** Consistent with the Water Resource Action Plan Control Measure LU-2, Design Guidance Manual, the Project would prepare and implement a SUSMP. The SUSMP would contain required BMPs that would be implemented throughout the Project. The SUSMP would be designed to minimize storm water pollutants of concern, provide storm drain system signage, properly design outdoor material storage areas, properly design trash storage areas, provide proof of ongoing BMP maintenance, and include design standards for structural or treatment control BMPs. NEPA: None necessary besides required permits.	
WQ-2: The Project would substantially alter water circulation or currents (e.g., impacts from the Project would result in a long-term detrimental alteration of harbor circulation that would result in reduced water quality).	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary besides required permits. NEPA: None necessary besides required permits.	CEQA: Less than significant NEPA: Less than significant
WQ-3: The Project would result in flooding that could harm people, damage property, or adversely affect biological resources.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary besides required permits and site-specific BMPs. NEPA: None necessary besides required permits and site-specific BMPs.	CEQA: Less than significant NEPA: Less than significant
WQ-4: The Project would result in wind and water erosion that causes substantial sediment runoff or deposition not contained or controlled on-site.	CEQA: Less than significant NEPA: Less than significant	CEQA: **Environmental Control Measure WQ-5** would ensure less than significant impacts. **Environmental Control Measure WQ- 5: Operational (SWPPP).** The Project would be included in the Port-wide Master Storm Water Program. Under the program, the Project would develop a SWPPP that would include employee training, inspections, annual certifications, and BMPs. BMPs for operational activities would include the following features:	CEQA: Less than significant NEPA: Less than significant

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		• Storm water treatment • Erosion control • Spill prevention • Waste collection practices NEPA: None necessary besides required permits and site-specific BMPs.	
BIOTA AND HABITATS			
BIO-1: Construction activities would not substantially affect any rare, threatened, or endangered species or their habitat.	CEQA: Significant NEPA: Significant	CEQA: **Environmental Control Measure BIO-1** and **Mitigation Measure BIO-1** would ensure less-than-significant impacts. **Environmental Control Measure BIO-1: Sound Abatement Techniques.** The construction contractor would use sound abatement techniques to reduce both noise and vibrations from pile driving activities. Sound abatement techniques would include vibration or hydraulic insertion techniques, drilled or augured holes for cast-in-place piles, bubble curtain technologies, and sound aprons where feasible. At the initiation of each pile driving event, and after breaks of more than 15 minutes, the pile driving shall also employ a "soft-start" in which the hammer is operated at less than full capacity (i.e., approximately 40 to 60 percent energy levels) with no less than a 1-minute interval between each strike for a 5-minute period. **Mitigation Measure BIO-1: Replacement Eelgrass Habitat.** Potential significant impacts to eelgrass habitat would occur during construction from dredging. To determine impacts to eelgrass, the POLB acknowledges the need to perform a pre-construction survey to document the areal extent and density of eelgrass in the Project area. The POLB also acknowledges that a post-construction survey of the Project area would need to be initiated within 30 days of Project completion to determine the actual impact of the Project on eelgrass. At that time, a determination of appropriate mitigation would be made. The POLB intends to consult with the National Marine Fisheries Service (NMFS) and comply with mitigation protocols outlined in the Southern California Eelgrass Mitigation Policy (SCEMP) (NMFS and CDFG 1991). As presented in the SCEMP, it is expected	CEQA: Less than significant with mitigation NEPA: Less than significant with mitigation

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		that mitigation shall be implemented by creating new eelgrass habitat at a 1.2:1 ratio. This could likely include transplanting eelgrass from areas where dredging would have an impact on it to an appropriate mitigation site identified by POLB. NEPA: None necessary.	
BIO-2: Construction activities would not interfere with migration or movement of fish or wildlife.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
BIO-3: Construction activities would not result in a loss or substantial alteration of marine habitat or an existing wetland.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary NEPA: None necessary	CEQA: Less than significant NEPA: Less than significant
BIO-4: Construction activities would not substantially affect a natural habitat or plant community.	CEQA: Significant NEPA: Significant	CEQA: **Environmental Control Measure BIO-1** and **Mitigation Measure BIO-1** would ensure less-than-significant impacts. NEPA: **Environmental Control Measure BIO-1** and **Mitigation Measure BIO-1** would ensure less-than-significant impacts.	CEQA: Less than significant with mitigation NEPA: Less than significant with mitigation
BIO-5: Construction activities would not substantially interfere with ecological processes and/or species behaviors.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
BIO-6: Operational activities would not substantially affect any rare, threatened, or endangered species or their habitat.	CEQA: Less than significant NEPA: Less than significant	CEQA: **Environmental Control Measure BIO-2** would ensure less-than-significant impacts. **Environmental Control Measure BIO-2:** Vessel Speed Reduction Program (CAAP Measure OGV1). Vessels calling at the new terminal would be required to slow to 12 knots within 40 nm of Point Fermin. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
BIO-7: Operational activities would not interfere with migration or movement of fish or wildlife.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
BIO-8: Operational activities would not result in a loss or substantial alteration of marine habitat or an existing wetland.	CEQA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
	NEPA: Less than significant		NEPA: Less than significant
BIO-9: Operational activities would not substantially affect a natural habitat or plant community.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
BIO-10: Operational activities would not substantially interfere with ecological processes and/or species behaviors.	CEQA: Significant NEPA: Significant	CEQA: No feasible mitigation is currently available. NEPA: No feasible mitigation is currently available.	CEQA: Significant NEPA: Significant
GROUND TRANSPORTATION			
TRANS-1: Project construction would result in short-term, temporary increases in auto and truck traffic at the study intersections.	CEQA: Less than significant NEPA: Less than significant	CEQA: **Environmental Control Measure TRANS-1** would ensure less-than-significant impacts. **Environmental Control Measure TRANS-1: Traffic Management Plan.** The Port would prepare a Traffic Management Plan that requires construction contractors to coordinate with emergency service providers during construction of all roadway modifications to establish alternative response routes. The plan would be developed with input from all emergency response providers and would be submitted to the City of Long Beach for review and approval. Measures that would likely be part of the traffic plan include regular notifications and coordination with local and regional law enforcement and transportation entities, appropriate scheduling of road and ramp closures, dedicated on-site traffic management personnel, and signage and striping for detours and closures. NEPA: See **Environmental Control Measure TRANS-1**.	CEQA: Less than significant NEPA: Less than significant
TRANS-1: For Project operations, additional traffic generated by the Project would have significant impacts at certain study area intersections.	CEQA: Less than significant NEPA: Significant	CEQA: None necessary. NEPA: Implementation of **Mitigation Measures TRANS-2 to TRANS-7** would reduce impacts to less than significant. However, POLB does not own or control these locations and cannot unilaterally implement the suggested improvements. Therefore, these impacts remain significant and unavoidable. **Mitigation Measure TRANS-2:** Add a second southbound left-turn lane and a second westbound right-turn lane at the intersection of Alameda Street and O Street by year 2020.	CEQA: Less than significant NEPA: Significant and unavoidable

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		Mitigation Measure TRANS-3: Add a second eastbound left-turn lane and a third eastbound through-lane at the intersection of Alameda Street and Anaheim Street by year 2013. **Mitigation Measure TRANS-4:** Add a third eastbound through lane, restripe the shared northbound left through-lane to a second northbound through-lane, add protected phasing north/south, and add a second southbound and northbound left-turn lane at the intersection of Henry Ford Avenue and Anaheim Street by year 2020. **Mitigation Measure TRANS-5:** Add an exclusive eastbound right-turn lane at the intersection of Henry Ford Avenue and Terminal Island Freeway on/off ramps by year 2013. **Mitigation Measure TRANS-6:** Add a third northbound left-turn lane at the intersection of Seaside Avenue and Navy Way by year 2020. **Mitigation Measure TRANS-7:** Add a southbound right-turn overlap at the intersection of Pier S Avenue and Ocean Boulevard by year 2020.	
TRANS-2: Additional traffic generated by Project construction activities would have short-term significant impacts on highway locations in the study area.	CEQA: Significant NEPA: Significant	CEQA: **Environmental Control Measure TRANS-1** would reduce any adverse construction traffic effects from the Project. Implementation of **Mitigation Measure TRANS-1** would reduce impacts to less than significant. However, the POLB does not own, control, or maintain any of the impacted highway segments. These segments fall under the jurisdiction of Caltrans. Therefore, the POLB does not have authority to unilaterally implement any mitigation measures on the highway segments. Therefore, these impacts remain significant and unavoidable. **Mitigation Measure TRANS-1:** To mitigate the Project's impact at the potentially significantly affected locations outside of the City of Long Beach, POLB will provide a fair share contribution to improvements aimed at reducing the significant impacts, as determined by the Board of Harbor Commissioners, if a fair-share funding program committed to specific improvements at the impacted locations exists at the time of the certification of the EIR. The funds will be held by POLB and transferred to the lead agency for the	CEQA: Significant NEPA: Less than significant after mitigation

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		improvements once the future improvement project(s) have started construction (or earlier if necessary to implement the fair-share program). To maintain the lead agency's access to these funds, the improvements must be under contract for construction within 5 years of the certification of the EIR. If the improvements are not under contract for construction within 5 years of the certification of the EIR, the lead agency's access to the funds shall be maintained only if, for the fifth fiscal year following the certification of this EIR and for every 5 years thereafter until construction of the improvements has begun, the lead agency makes both of the following findings, supported by substantial evidence, with respect to the funding program: (i) Adequate funding will be procured from identified sources and in identified amounts so as to allow the lead agency to timely begin construction of the needed improvements; (ii) The approximate date on which the necessary funding is expected to be available to the lead agency to construct the necessary improvements will be given. Absent the lead agency's compliance with the above conditions, the fair share funds shall not be made available to the lead agency. In no circumstances will the funds be made available for more than 15 years. If there are other (existing or future) committed funding programs in place that provide equivalent mitigation at the affected locations (e.g., a container fee program), this mitigation measure will not be applied. Table 3.6-26 includes a summary of the operating conditions with mitigation at the highway segments with identified impacts for all scenarios. Table 3.6-26 also indicates the Project's share of the future traffic on these highway segments. The Project's maximum share of the traffic on each individual link ranges from approximately 1 to 7 percent. In addition, it should be noted that the POLB is currently participating in the following on-going regional transportation programs, which are intended to address future regional	

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		traffic growth and resulting congestion on area freeways: **I-710 Corridor EIS/EIR 2008** The Port is presently working with the California Department of Transportation (Caltrans), Los Angeles County Metropolitan Transit Authority (Metro), the Southern California Association of Governments (SCAG), and the Gateway Cities Council of Governments (COG) (of which the Port and City of Long Beach are member agencies) on the I-710 Corridor EIR/EIS and Caltrans Project Report. POLB has committed $5 million to this $34 million study, which began in early 2008 and is expected to be completed in 2012. This project entails analyzing potential impacts and advancing preliminary engineering of the Locally Preferred Strategy (LPS) adopted by the communities and participating agencies in 2004/2005. The LPS consists of dedicated truck lanes starting at Ocean Boulevard, additional mixed flows on I-710 between Ocean Boulevard and Washington Boulevard, and numerous freeway-to-freeway and arterial street interchange improvements. The POLB, City of Long Beach, and Gateway Cities COG are aggressively seeking federal, state, and Metro funds for the I-710 Corridor. **Advanced Transportation Management, Information, and Security (ATMIS)** The POLB/POLA will also be implementing an intelligent transportation systems project by 2011. This $11 million program will provide real-time information to travelers in the Port vicinity and on adjacent regional transportation facilities. The ATMIS system will monitor vehicle traffic conditions through the use of closed-circuit television cameras and vehicle detection devices at the terminal gates. The ATMIS system will distribute the traffic information to truck drivers, motorists, other agencies, and intermodal industry information systems through the use of strategically placed changeable message signs, internet video, and appropriate data sharing means. While the ATMIS system will assist in addressing recurring daily congestion, its major benefit will be providing information to inform drivers, including trucks exiting the Port gates, of non-recurring incidents and congestion and to allow them to choose, if possible, alternative routes to avoid congested areas.	

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		The ATMIS system will be a major component in an overall intelligent transportation systems program for the I-710 Corridor. **SR-91 Corridor Study** The Gateway Cities COG has begun an SR-91 Corridor Study to explore options that will improve traffic conditions on this freeway. POLB continues to work in concert with the COG, Caltrans, and other agencies to find solutions to improving operating conditions on SR-91. No additional feasible mitigation measures are available at this time. NEPA: See **Environmental Control Measure TRANS-1**.	
TRANS-2: Additional operational traffic generated by the Project will have significant impacts on certain highway segments in the study area.	CEQA: Significant NEPA: Significant	CEQA and NEPA: Implementation of **Mitigation Measure TRANS-1** would reduce impacts to less than significant. However, the POLB does not own, control, or maintain any of the impacted highway segments. These segments fall under the jurisdiction of Caltrans. Therefore, the POLB does not have authority to unilaterally implement any mitigation measures on the highway segments. Until Caltrans implements improvements on the SR-91 highway segments, the Project would have significant impacts at these locations. Therefore, these impacts remain significant and unavoidable.	CEQA Significant and unavoidable NEPA: Significant and unavoidable
TRANS-3: Project construction would not increase the demand for transit services.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
TRANS-3: Project operations would not increase the demand for transit services.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
TRANS-4: Project construction would not result in any increases in rail activity.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
TRANS-4: For Project operations, additional trains generated by the Project would have significant impacts on certain at-grade crossings in the study area.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
VESSEL TRANSPORTATION			
VT-1: Project construction-related marine traffic would not cause a change in vessel traffic patterns, including an increase in traffic volumes or a change in location that would result in substantial incremental changes to vessel safety.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
VT-2: Project operations would not cause a significant increase in vessel traffic or a change in patterns of vessel movements that would result in substantial incremental changes to vessel safety.	CEQA: Less than significant NEPA: Less than significant	CEQA: **Environmental Control Measure BIO-2** would ensure less-than-significant impacts. See **Environmental Control Measure BIO-2** Vessel Speed Reduction. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
PUBLIC SERVICES AND SAFETY			
PSS-1: Project construction activities would burden existing LBPD staff levels or facilities such that the LBPD would not be able to maintain an adequate level of service without additional facilities, the construction of which could cause significant environmental effects.	CEQA: Less than significant NEPA: Less than significant	CEQA: **Environmental Control Measure TRANS-1** would ensure less-than-significant impacts. See **Environmental Control Measure TRANS-1** Traffic Management Plan. NEPA: **Environmental Control Measure TRANS-1** would ensure less-than-significant impacts. See **Environmental Control Measure TRANS-1** Traffic Management Plan.	CEQA: Less than significant NEPA: Less than significant
PSS-2: Project construction activities would require the addition of a new fire station or the expansion, consolidation, or relocation of an existing facility to maintain acceptable emergency response times.	CEQA: Less than significant NEPA: Less than significant	CEQA: **Environmental Control Measure TRANS-1** would ensure less-than-significant impacts. See **Environmental Control Measure TRANS-1** Traffic Management Plan. NEPA: **Environmental Control Measure TRANS-1** would ensure less-than-significant impacts. See **Environmental Control Measure TRANS-1** Traffic Management Plan.	CEQA: Less than significant NEPA: Less than significant
PSS-3: Project construction would burden existing USCG staff levels and facilities such that the USCG would not be able to	CEQA: Less than significant NEPA: Less than	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
maintain an adequate level of service without the construction of additional facilities, the construction of which could cause significant environmental effects.	significant		significant
PSS-4: Project construction would substantially diminish the level of public protection services provided by the Security Command and Control Center (SCCC).	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
PSS-5: Construction activities would result in inconsistency with an existing emergency response plan or evacuation plan.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
PSS-6: Project operations would burden existing LBPD staff levels or facilities such that the LBPD would not be able to maintain an adequate level of service without additional facilities, the construction of which could cause significant environmental effects.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
PSS-7: Project operations would require the addition of a new fire station or the expansion, consolidation, or relocation of an existing facility to maintain acceptable emergency response times.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
PSS-8: Project operations would burden existing USCG staff levels and facilities such that the USCG would not be able to maintain an adequate level of service without the construction of additional facilities, the construction of which could cause significant environmental effects.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
PSS-9: Project operations would substantially diminish the level of public protection services provided by the SCCC.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
PSS-10: Project operations would result in inconsistency with an existing emergency response plan or evacuation plan.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
NOISE			
NOI-1: Project construction activities would increase ambient noise levels by 3 dBA or more from construction at any noise-sensitive receptor.	CEQA: Less than significant NEPA: Less than significant	CEQA: **Environmental Control Measures NOI-1** through **NOI-6** and **Environmental Control Measure BIO-1** would ensure less-than-significant impacts. **Environmental Control Measure NOI-1: Construction Equipment.** All construction equipment powered by internal combustion engines would be properly muffled and maintained. **Environmental Control Measure NOI-2: Idling Prohibitions.** The idling of internal combustion engines near noise-sensitive areas would be prohibited during Project construction. **Environmental Control Measure NOI-3: Equipment Location**. All stationary noise-generating construction equipment, such as air compressors and portable power generators, would be located as far as practical from existing noise-sensitive land uses. **Environmental Control Measure NOI-4: Quiet Equipment Selection.** Quiet construction equipment would be used during Project construction to the extent feasible. **Environmental Control Measure NOI-5: Construction Timing.** Limit construction to the hours of 7 a.m. to 7 p.m. on weekdays, between 9 a.m. and 6 p.m. on Saturdays, and prohibit construction equipment noise anytime on Sundays, as prescribed by section 8.80.202 of the Long Beach Municipal Code (LBMC). **Environmental Control Measure NOI-6: Notification.** The Port would publish notices in the Press Telegram, and all property managers adjacent to the Project site would be notified in advance of the construction schedule. The Port would coordinate with affected agencies, including schools, to ensure construction activities, would not substantially interfere with facility operations. NEPA: **Environmental Control Measures NOI-1** through **NOI-6** and **Environmental Control Measure BIO-1** would ensure less-than-significant impacts.	CEQA: Less than significant NEPA: Less than significant

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
		See **Environmental Control Measures NOI-1** through **NOI-6** and **Environmental Control Measure BIO-1**.	
NOI-2: Result in construction noise levels exceeding the limits established by the LBMC at any noise-sensitive receptor.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary. See **Environmental Control Measures NOI-1** through **NOI-6** and **Environmental Control Measure BIO-1**.	CEQA: Less than significant NEPA: Less than significant
NOI-3: Project operations would not generate noise levels that would permanently increase ambient noise levels by 3 dBA or more at any noise-sensitive receptor.	CEQA: Less than significant NEPA: No impact	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: No impact
NOI-4: Project operations would not exceed the maximum noise levels allowed by the LBMC.	CEQA: Less than significant NEPA: No impact	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: No impact
NOI-5: Ground vibration levels would not exceed the acceptability limits prescribed by the American National Standards Institute (ANSI) S2.71-1983, approximately 0.07 inches per second squared (in/sec^2).	CEQA: Less than significant NEPA: No impact	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: No impact
NOI-6: Project operations would result in exposure to a substantially increased number of vibration events that exceed the acceptability limits prescribed by ANSI S2.71.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
HAZARDS AND HAZARDOUS MATERIALS			
HAZ-1: The Project would not result in an accidental release of hazardous materials from onshore facilities or from vessels that would adversely affect the health and safety of the general public or workers.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
HAZ-2: The Project would not result in noncompliance with state guidelines associated with abandoned oil wells.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
HAZ-3: The Project would not substantially increase the probable frequency of consequences to people or property as a result of accidental spills of petroleum product or hazardous substance.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
HAZ-4: The Project would not result in inconsistency with the Port of Long Beach Risk Management Plan.	CEQA: No impact NEPA: No impact	CEQA: None necessary. NEPA: None necessary.	CEQA: No impact NEPA: No impact
SOCIOECONOMICS			
SOCIO-1: Project construction would not induce a substantial decrease in area employment, either directly or indirectly.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
SOCIO-2: Project construction would not induce substantial population growth in an area, either directly or indirectly.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
SOCIO-3: Project construction would not induce a substantial increase in area housing, either directly or indirectly.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
SOCIO-4: Project operations would not induce a substantial decrease in area employment, either directly or indirectly.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
SOCIO-5: Project operations would not induce substantial population growth in an area, either directly or indirectly.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
SOCIO-6: Project construction would not induce a substantial increase in area housing, either directly or indirectly.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
ENVIRONMENTAL JUSTICE			
AQ-1: Proposed Project construction would produce emissions of VOC, CO, or NO_x that would exceed SCAQMD thresholds of significance.	NEPA: Significant; Cumulatively Significant	NEPA: Impact AQ-1 would not represent disproportionately high and adverse impacts on minority and low-income populations because they relate to conflicts with a regulatory standard and would not be associated with a specific location or dependent on the presence of sensitive receptors or uses.	NEPA: Less than significant

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
AQ-2: Proposed Project construction would result in off-site ambient air pollutant concentrations that would exceed SCAQMD thresholds of significance. This impact would be significant under NEPA and would also contribute to a cumulatively significant impact.	NEPA: Significant; Cumulatively Significant	NEPA: This impact would not represent disproportionately high and adverse effects on minority and/or low-income populations.	NEPA: Less than significant
AQ-3: Proposed Project operation emissions would exceed the SCAQMD daily emission thresholds for all pollutants except PM_{10} for all milestone years. This impact would be significant under NEPA and would also contribute to a cumulatively significant impact.	NEPA: Significant; Cumulatively Significant	NEPA: Impact AQ-3 would not represent disproportionately high and adverse impacts on minority and low-income populations because they relate to conflicts with a regulatory standard and would not be associated with a specific location or dependent on the presence of sensitive receptors or uses.	NEPA: Less than significant
AQ-4: Proposed Project operations would result in off-site ambient concentrations of 1-hour and annual NO_2 that would exceed SCAQMD thresholds of significance for NEPA. These impacts would also contribute to cumulative impacts.	NEPA: Significant; Cumulatively Significant	NEPA: This impact would not represent disproportionately high and adverse effects on minority and/or low-income populations.	NEPA: Less than significant
AQ-6: The Proposed Project would expose receptors to significant levels of toxic air contaminants (TAC), resulting in significant increases in cancer risk to residential and occupational sensitive receptors.	NEPA: Significant; Cumulatively Significant	NEPA: Because the populations in closest proximity to the Port are predominantly minority and disproportionately low-income, this elevated cumulative risk would represent a disproportionately high and adverse impact on minority and low-income populations.	NEPA: Significant and Unavoidable
TRANS-1: Additional traffic generated by the Project would have significant cumulative impacts at certain study area intersections.	NEPA: Significant; Cumulatively Significant	NEPA: This impact would not represent disproportionately high and adverse effects on minority and/or low-income populations.	NEPA: Less than significant
UTILITIES AND SERVICE SYSTEMS			
UTIL-1: Project construction activities would require or result in the construction or expansion of water, wastewater, storm drains, natural gas, or electrical utility lines or infrastructure, the construction of which could cause significant environmental effects during Project construction.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant
UTIL-2: Project construction activities would exhaust or exceed existing water, wastewater, natural gas or electricity (energy supplies), or landfill supplies/capacities and/or conflict with	CEQA: Less than significant NEPA: Less than significant	CEQA: **Environmental Control Measure UTIL-1 through UTIl-4** and **AQ-2** would ensure less-than-significant impacts. **Environmental Control Measure UTIL-1: Beneficial Reuse and Recycling of Construction-Generated Materials**. To the extent feasible, the Project would reuse	CEQA: Less than significant NEPA: Less than significant

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
existing energy standards during project operations.		suitable demolition, dredged, and excavated materials from the Project site as fill material or in new construction. Reuse as fill material would be consistent with the Port's Import Soil-Material Quality Requirements (dated March 29, 2006). Pursuant to City of Long Beach ordinance, recyclable waste materials (i.e., concrete and asphalt) would be processed for reuse by the Project within the Harbor District. Asphalt and concrete would be recycled at the Port's crusher site and other recyclable waste would be taken to accredited recycling centers, thereby diverting waste from landfills. Materials would be separated on-site for reuse, recycling, or proper disposal. During construction, separate bins for recycling of construction materials would be provided. **Environmental Control Measure UTIL-2: LEED® Standards.** Marine terminal buildings would be designed and constructed to LEED® standards for high-performance, sustainable buildings. **Environmental Control Measure UTIL-3: Xeriscape Landscaping.** Water conservation features including drought-tolerant planting materials would be incorporated into the Project landscaping, consistent with the Master Landscape Plan for the Port of Long Beach (POLA/POLB 1994). **Environmental Control Measure UTIL-4: Lighting Control.** The Project would incorporate use of photo cells/timers, low energy fixtures, and light-spillover reduction features into new and existing terminal lighting and new electrical equipment. **Environmental Control Measure AQ-2:** Shore-to-Ship Power ("Cold Ironing") (CAAP Measure OGV2). NEPA: **Environmental Control Measure UTIL-1 through UTIl-4** and **AQ-2** would ensure less-than-significant impacts.	
UTIL-3: Project operations would require or result in the construction or expansion of water, wastewater, storm drains, natural gas, or electrical utility lines or infrastructure, the construction of which could cause significant environmental effects during Project operations.	CEQA: Less than significant NEPA: Less than significant	CEQA: None necessary. NEPA: None necessary.	CEQA: Less than significant NEPA: Less than significant

Impact	Significance Before Mitigation	Mitigation	Significance After Mitigation
UTIL-4: Project operations would exhaust or exceed existing water, wastewater, natural gas or electricity (energy supplies), or landfill supplies/capacities and/or conflict with existing energy standards during Project operations.	CEQA: Less than significant NEPA: Less than significant	CEQA: **Environmental Control Measure UTIL-1 through UTIl-4** and **AQ-2** would ensure less-than-significant impacts. NEPA: **Environmental Control Measure UTIL-1 through UTIl-4** and **AQ-2** would ensure less-than-significant impacts.	CEQA: Less than significant NEPA: Less than significant

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Pettit, David

From: Robert Curry [rcurry@calcartage.com]
Sent: Wednesday, October 26, 2011 10:23 AM
To: Pettit, David
Subject: RE: Request for gate move date from 2006

David regarding your request for our gate moves in 2006. Our IT people have been able to capture the information and we have the following ---- our annual combined total (entries plus exits) for container and trailer activity for the calendar year 2006 amounted to 304,000 moves
I hope this answers your question
Bob Curry

From: Pettit, David [mailto:dpettit@nrdc.org]
Sent: Tuesday, October 25, 2011 5:10 PM
To: Robert Curry
Subject: RE: Request for gate move date from 2006

Thank you.

David Pettit
Senior Attorney
Natural Resources Defense Council
1314 2nd Street
Santa Monica, CA 90401
(310) 434-2300
www.nrdc.org

From: Robert Curry [mailto:rcurry@calcartage.com]
Sent: Tuesday, October 25, 2011 5:10 PM
To: Pettit, David
Subject: RE: Request for gate move date from 2006

We will have our people go into the records and see if we can retrieve the records and if so we will forward the results to you
Bob

From: Pettit, David [mailto:dpettit@nrdc.org]
Sent: Tuesday, October 25, 2011 2:18 PM
To: Robert Curry
Subject: RE: Request for gate move date from 2006

Bob: Just 2006 at this point.

Thanks.

David Pettit
Senior Attorney
Natural Resources Defense Council
1314 2nd Street
Santa Monica, CA 90401
(310) 434-2300

www.nrdc.org

From: Robert Curry [mailto:rcurry@calcartage.com]
Sent: Tuesday, October 25, 2011 2:07 PM
To: Pettit, David
Subject: RE: Request for gate move date from 2006

David are you asking us to give you the year 2006 or the years from 2006 thru 2010 and or current months of 2011
Please let know and I will see if we can give you what you are requesting
Bob Curry

From: Pettit, David [mailto:dpettit@nrdc.org]
Sent: Tuesday, October 25, 2011 11:12 AM
To: Robert Curry
Cc: Pettit, David; Henao, Lizzeth
Subject: Request for gate move date from 2006

Bob: By this email, I am asking you to provide Cal Cartage's gate movement data from 2006.

Thank you.

David Pettit
Senior Attorney
Natural Resources Defense Council
1314 2nd Street
Santa Monica, CA 90401
(310) 434-2300
www.nrdc.org

FINAL 2007 AIR QUALITY MANAGEMENT PLAN

JUNE 2007

EXECUTIVE SUMMARY

PREFACE

On behalf of the 16.5 million residents of the South Coast Basin, the 2007 AQMP must rise to meet the following major challenges.

Stiff new Federal standards have been set in place for ozone and PM2.5.

- Slightly longer timeframe for attainment than was allowed under previous standards, but significantly more stringent than old (withdrawn) standards.
- Fast-approaching and very difficult PM2.5 deadline (2014).
- Even more challenging 8-hour ozone deadline by 2023 timeframe.
- Recently revised 24-hour PM2.5 standard more stringent than current standards. (attainment deadline expected to be around 2020)

Significant reductions are needed from all sources, but especially Mobile Sources, since the bulk of the remaining air quality problem stems from Mobile Source emissions.

- Need new ultra-low emission standards for both new and existing fleet, including on-road and off-road heavy-duty trucks, industrial & service equipment, locomotives, ships & other watercraft, and aircraft.
- Must dramatically accelerate fleet turnover to achieve benefits of cleaner engines.
- Significant reformulation of consumer products which collectively are a major source of pollutant emissions.
- Stationary sources must continue to do their fair share of the emission reduction effort including expedited equipment modernization and technology advancements.

Even today's improved smog conditions result in known public harm. New and additional health studies indicate urgent public health concerns, especially from fine particulate exposure.

- Impaired lung function in children growing up in Southern California.
- Increased episodes of respiratory disease symptoms.
- Increase in doctor visits for heart disease.
- Increase in death rates.

To have any reasonable expectation of meeting the 2014 PM2.5 deadline, the pace of improvement must intensify for Mobile Sources under state and federal jurisdiction.

- At current pace, South Coast would fail to reach attainment of old standards.
- Given the huge challenge and the public health threat involved, there is no margin for error in the overall Plan strategy, and there is no room for wavering or hesitation in the implementation of its control measures.
- Substantial public and private funding is needed to expedite the retirement of older, higher-polluting engines and vehicles.
- The time for all responsible authorities to expeditiously adopt and aggressively implement effective control strategies is **now.**

INTRODUCTION

The long-term trend of the quality of air we Southern Californians breathe shows continuous improvement, although recent leveling off in ozone improvement causes marked concern. The remarkable historical improvement in air quality since the 1970's is the direct result of Southern California's comprehensive, multiyear strategy of reducing air pollution from all sources as outlined in its Air Quality Management Plan (AQMP). Yet the air in Southern California is far from meeting all federal and state air quality standards and, in fact, is among the worst in the nation. Although the new federal fine particulates (PM2.5) and 8-hour surface level ozone standards provide a longer compliance schedule, the standards are much more stringent than the previous PM10 and 1-hour surface level ozone standards. To reach clean air goals in the next seven to sixteen years provided by the Clean Air Act deadlines, Southern California must not only continue its diligence but intensify its pollution reduction efforts.

Continuing the Basin's progress toward clean air is a challenging task, not only to recognize and understand complex interactions between emissions and resulting air quality, but also to pursue the most effective possible set of strategies to improve air quality while maintaining a healthy economy. To ensure continued progress toward clean air and comply with state and federal requirements, the South Coast Air Quality Management District (AQMD or District) in conjunction with the California Air Resources Board (CARB), the Southern California Association of Governments (SCAG) and the U.S. Environmental Protection Agency (U.S. EPA) is preparing the Final 2007 revision to its AQMP (2007 AQMP or 2007 Plan). This Final 2007 AQMP employs the most up-to-date science and analytical tools and incorporates a comprehensive strategy aimed at controlling pollution from all sources, including stationary sources, on-road and off-road mobile sources and area sources.

The Final Plan proposes attainment demonstration of the federal PM2.5 standards through a more focused control of sulfur oxides (SOx), directly-emitted PM2.5, and nitrogen oxides (NOx) supplemented with volatile organic compounds (VOC) by 2015. The 8-hour ozone control strategy builds upon the PM2.5 strategy, augmented with additional NOx and VOC reductions to meet the standard by 2024 assuming a bump-up is obtained.

The Final 2007 AQMP proposes policies and measures currently contemplated by responsible agencies to achieve federal standards for healthful air quality in the Basin and those portions of the Salton Sea Air Basin (formerly named the Southeast Desert Air Basin) that are under District jurisdiction (namely, Coachella Valley).

This Final Plan also addresses several federal planning requirements and incorporates significant new scientific data, primarily in the form of updated emissions inventories, ambient measurements, new meteorological episodes and new air quality modeling tools. This Final Plan builds upon the approaches taken in the 2003 AQMP for the South Coast

Air Basin for the attainment of the federal ozone air quality standard. However, this Final Plan highlights the significant amount of reductions needed and the urgent need to identify additional strategies, especially in the area of mobile sources, to meet all federal criteria pollutant standards within the timeframes allowed under federal Clean Air Act.

This Final Plan as well as other key supporting information are available electronically and can be downloaded from the District's home page on the Internet (http://www.aqmd.gov, "Inside AQMD" tab at top, and click on "Clean Air Plans").

WHY IS THIS FINAL PLAN BEING PREPARED?

The federal Clean Air Act requires an 8-hour ozone non-attainment area to prepare a SIP revision by June 2007 and a PM2.5 non-attainment area to submit by April 2008. However, since the attainment date for PM2.5 is earlier than that for 8-hour ozone and because of the interplay between precursor emissions, it is prudent to prepare a comprehensive and integrated plan to design the most effective path to attain both standards within the specified timeframe. In addition, U.S. EPA requires that transportation conformity budgets be established based on the most recent planning assumptions (i.e., within the last five years) and approved motor vehicle emission model. The Final Plan is based on assumptions provided by both CARB and SCAG reflecting their most recent computer model (EMFAC) for motor vehicle emissions and demographic updates.

IS AIR QUALITY IMPROVING?

Yes. Over the years, the air quality in the Basin has improved significantly, thanks to the comprehensive control strategies implemented to reduce pollution from mobile and stationary sources. For instance, the total number of days on which the Basin exceeds the federal 8-hour standard has decreased dramatically over the last two decades from about 150 days to less than 90 while Basin station-days [detail follows] decreased by approximately 80 percent. However, the Basin still exceeds the federal 8-hour standard more frequently than any other location in the U.S. Under federal law, the Basin is designated as a "severe-17" nonattainment area for the 8-hour ozone standard. Figure ES-1 shows the long-term trend in ambient ozone counts over the federal standard since 1990. The figure depicts two types of exceedance measurements: the number of Basin-days and Basin-station-days above the federal 8-hour ozone standard, which represent, respectively the number of days the standard was exceeded anywhere in the Basin or by any station.

Lack of significant progress in ozone air quality for the last several years has raised some concern regarding the present-day effectiveness of control programs. The District held is planning to hold a technical forum in October 2006 on ozone air quality, to examine the issue of why progress has slowed in detail, including accuracy of emissions inventory, effectiveness of control strategies, ambient photochemistry, etc. It was generally believed that VOC reductions in the last several years have not kept up the pace with NOx reductions, especially with the MTBE phase-out and the introduction of ethanol that caused higher VOC emissions. A key policy question explored at the technical forum was what could be done differently to more effectively reduce ozone levels, given the need to attain fine particulate standards that NOx reductions are needed not only to achieve the PM2.5 and ozone standards, but also to benefit downwind ozone levels. Since it is likely that the VOC emissions are underestimated in the inventory, concurrent VOC reductions are desirable to provide near-term ozone improvement.

Relative to the 1-hour ozone standard, which was recently revoked by the U.S. EPA in favor of the new 8-hour ozone standard, the past air pollution controls have had an overall positive impact. The number of days where the Basin exceeds the federal 1-hour ozone standard has continually declined over the years. However, while the number of days exceeding the federal 1-hour ozone standard has dropped since the 1990s, the rate of progress has slowed since the beginning of the decade. The Basin currently still experiences ozone levels over the federal standard on more than 20 days per year. By 2010, this plan shows that the Basin will still exceed the federal 1-hour ozone standard by more than 30 percent despite the implementation of the 2007 AQMP control measures. The District and a number of environmental organizations have litigated against U.S. EPA's revocation of the 1-hour standard; the case is still pending. In December 2006, the Court ruled that the U.S. EPA acted within its authority in revoking the 1-hour standard. However, the Court also decided that certain 1-hour control measures must stay in place including, New Source Review, conformity, and the Section 185 emission fee measure.

In 2005, the annual PM2.5 standard was exceeded at several locations throughout the Basin. However, the 24-hour PM2.5 standard (98^{th} percentile greater than 65 ug/m^3) was not exceeded during the year[1]. In 2005, the Basin did not exceed the standards for carbon monoxide, nitrogen dioxide, sulfur dioxide, sulfates or lead. Figure ES-2 shows the annual average PM2.5 concentrations in the Basin in 2005 and Figure ES-3 shows the trends in PM10 and PM2.5.

The Basin has met the PM10 standards at all stations except for western Riverside where the annual PM10 standard has not been met as of 2006. Additional efforts, through localized programs, are under way to ensure compliance with this standard. These efforts are also outlined in the Final 2007 AQMP.

[1] In September 2006, U.S. EPA issued revised PM2.5 NAAQs lowering the 24-hr standard to 35 ug/m^3. However, the present Plan is not required to address this standard.

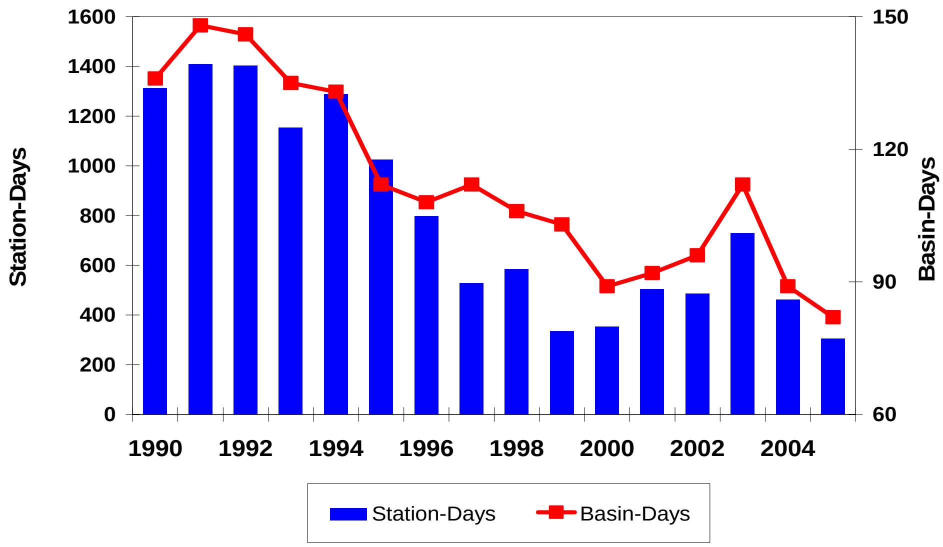


FIGURE ES-1

Total Basin-Days Above the Federal 8-Hour Ozone Standard from 1990-2005

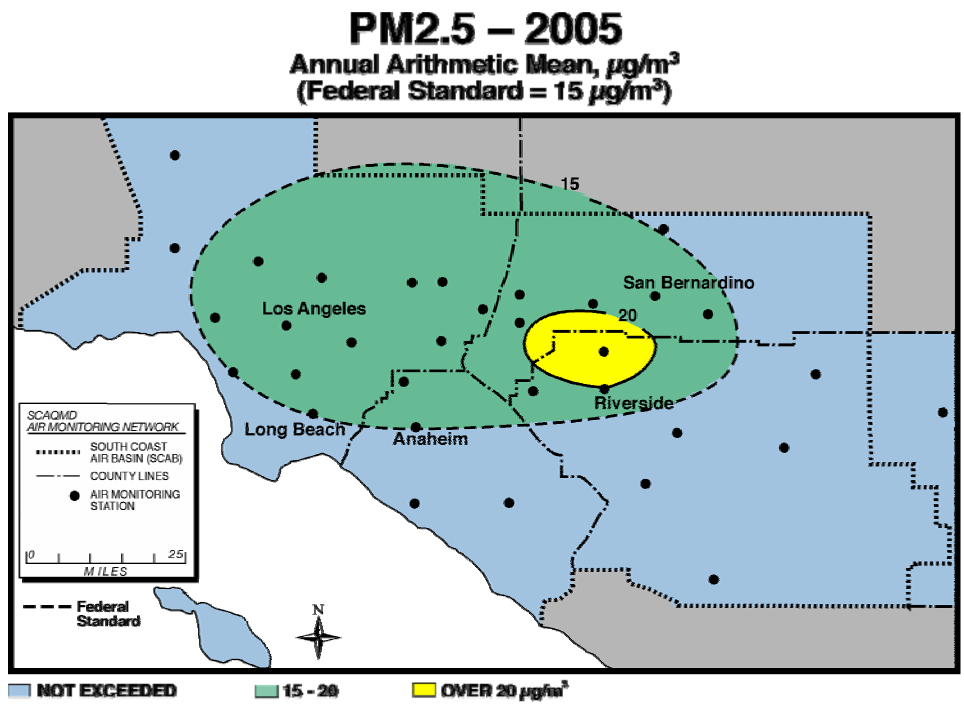


FIGURE ES-2
PM2.5 – 2005

Annual Average Concentration Compared to Federal Standard

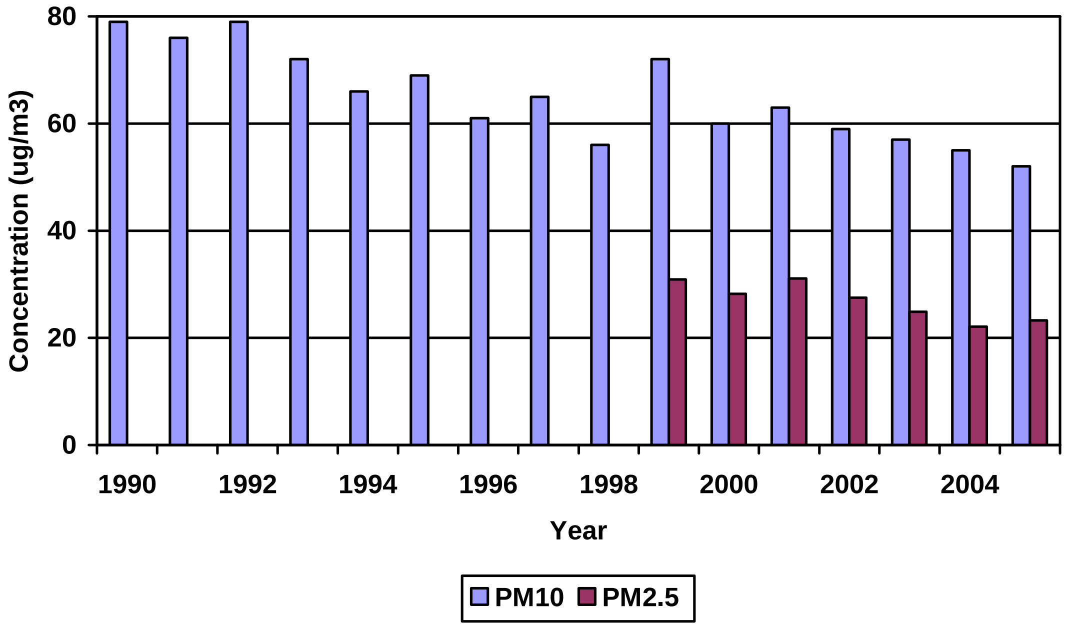


FIGURE ES-3

Trends in Basin Maximum Annual PM10 and PM2.5 Concentrations

WHAT ARE THE MAJOR SOURCES CONTRIBUTING TO AIR QUALITY PROBLEMS?

Figures ES-4 to ES-6 present the top ten categories for NOx, VOC, and SOx emissions.

FIGURE ES-4

Top Ten Categories for NOx Emissions

NOx Annual Average Emissions - 2002

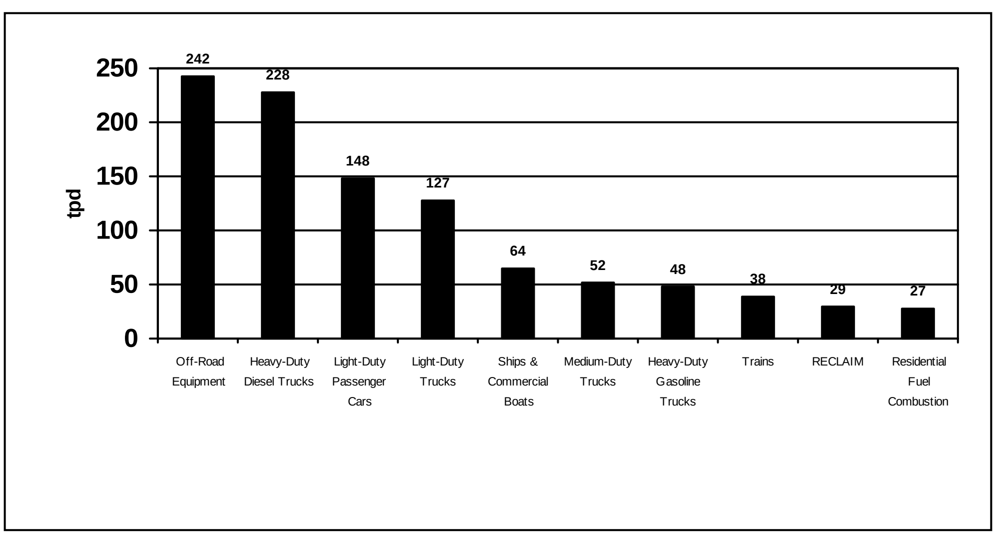


FIGURE ES-5

Top Ten Categories for VOC Emissions

VOC Annual Average Emissions - 2002

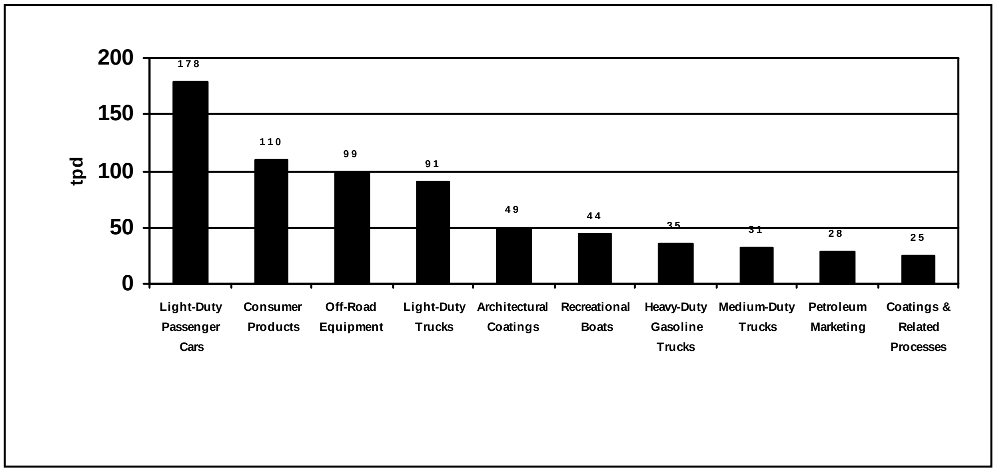
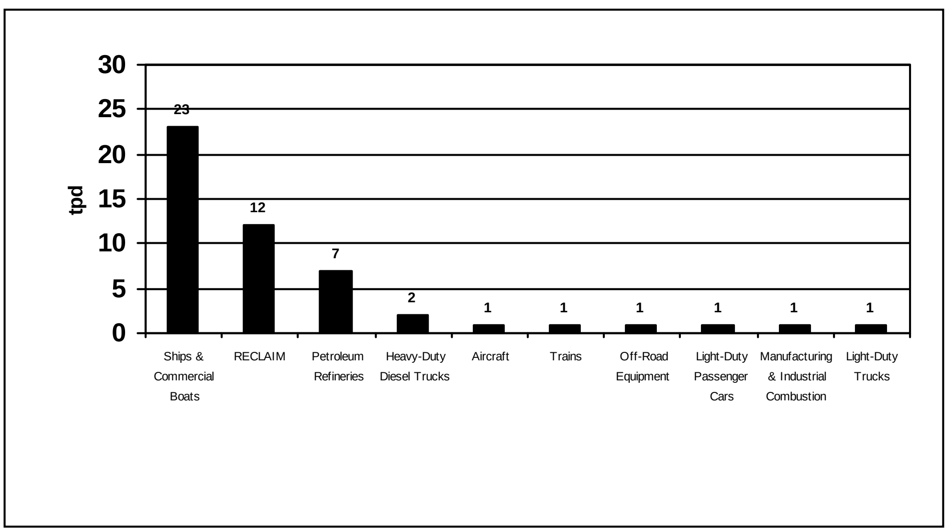


FIGURE ES-6

Top Ten Categories for SOx Emissions

SOx Annual Average Emissions - 2002



The combined Ports of Los Angeles and Long Beach including sources such as ocean-going vessels, harbor craft, trains, trucks, and cargo handling equipment represent the largest single source of emissions in the Basin, accounting for 60% of SOx, 27% of NOx, and 6% of PM2.5 in 2023.

SHOULD THE PM2.5 AND OZONE PLAN SUBMITTALS BE BIFURCATED?

The formal deadline for submission of the ozone attainment plan is June 15, 2007. The formal deadline for submission of the PM2.5 plan is April 15, 2008. Therefore, technically speaking, the PM2.5 plan is not due until 2008. However, the PM2.5 attainment date (i.e., 2015) is earlier than the 8-hour ozone of 2021 or 2024. In order to design the most efficient path to clean air, it is imperative that an integrated plan including both PM2.5 and ozone be developed. Furthermore, there are only seven years left to implement the necessary measures to attain the PM2.5 standard. The South Coast region needs a road map *now* to commit its resources for rule development, public and private funding, and technology deployment.

WHAT IS THE OVERALL CONTROL STRATEGY TO MEET THE CURRENT AIR QUALITY STANDARDS?

The Final 2007 AQMP builds upon improvements accomplished from the previous plans, and aims to incorporate all feasible control measures while balancing costs and socioeconomic impacts. The few years remaining to meet attainment deadlines afford little margin for error in implementing such a comprehensive control strategy. Further, the combined control strategies selected to attain the federal PM2.5 and 8-hour ozone standards must complement each other, representing the most effective route to achieve and maintain the standards.

The Final 2007 AQMP relies on a comprehensive and integrated control approach aimed at achieving the PM2.5 standard by 2015 through implementation of short-term and mid-term control measures and achieving the 8-hour ozone standard by 2024 based on implementation of additional long-term measures. Table ES-1 presents the overall reductions necessary for demonstrating attainment of the PM2.5 standard by 2015 and the 8-hour ozone standard by 2024. In order to demonstrate attainment by the prescribed deadlines, emission reductions needed for attainment must be in place by 2014 and 2023, respectively.

TABLE ES-1

Emission Reduction Targets for
PM2.5 and 8-Hour ozone Attainment
(tons per day, % reduction)

	2014	**2023**
NOx	**192 (29%)**	**383 (76%)**
VOC	**59 (11%)**	**116 (22%)**
SOx	**24 (56%)**	**----**
PM2.5	**15 (15%)**	**----**

Since PM2.5 in the Basin is overwhelmingly formed secondarily, the overall Final control strategy focuses on reducing precursor emission of SOx, directly-emitted PM2.5, NOx, and VOC instead of fugitive dust. Based on the District's modeling sensitivity analysis, SOx reductions, followed by directly-emitted PM2.5 and NOx reductions, provide the greatest benefits in terms of reducing the ambient PM2.5 concentrations. While VOC reductions are less critical to overall reductions in PM2.5 air quality (compared with equivalent SOx, directly-emitted PM2.5, and NOx reductions), they are relied upon for meeting the 8-hour ozone standard. It is further determined that SOx is the only pollutant that is projected to grow in the future, due to ship emissions at the ports, requiring significant controls. Directly-emitted PM2.5 emission reductions from on-going diesel toxic reduction programs and from the short-term and mid-term control measures are also incorporated into the Final 2007 AQMP. NOx reductions primarily based on mobile source control strategies (e.g., add-on control devices, alternative fuels, fleet modernization, repowers, retrofits) are essential for both PM2.5 and ozone attainment. Also, adequate VOC controls need to be in place in time for achieving significant VOC reductions needed for the 8-hour ozone standard by 2024. Reducing VOC emissions in early years would also ensure continued progress in reducing the ambient ozone concentrations. The 8-hour ozone control strategy builds upon the PM2.5 attainment strategy augmented with additional long-term VOC and NOx reductions for meeting the ozone standard by 2024. Based on the sheer magnitude of emission reductions needed for ozone attainment and the readiness of NOx control technologies, a NOx-heavy strategy is proposed for the Final AQMP which provides the most efficient path to clean air. With respect to PM10, since the Basin will not attain the annual standard by 2006 for one station, additional local programs are proposed to address the attainment issue in an expeditious manner.

The Final 2007 AQMP control measures consist of four components: 1) the District's Stationary and Mobile Source Control Measures; 2) CARB's Proposed State Strategy; 3) District Staff's Proposed Policy Options to Supplement CARB's Control Strategy; and 4) Regional Transportation Strategy and Control Measures provided by SCAG. These measures are outlined in Appendix IV-A (District's Stationary and Mobile Source Control Measures), Appendix IV-B-1 (CARB's Draft Proposed State Strategy for California's 2007 State Implementation Plan), Appendix IV-B-2 (District's Proposed Policy Options to Supplement CARB's Strategy), and IV-C (Regional Transportation Strategy and control Measures).

IS THE BUMP-UP REQUEST NECESSARY?

The South Coast Air Basin (Air Basin) is currently classified as a "Severe-17" non-attainment area for the federal ambient 8-hour ozone air quality standard with an attainment date of 2021. For any non-attainment area, the Clean Air Act (CAA) also provides for voluntary reclassification of such areas to a higher classification by submitting a request for "bump-up." The District is requesting a "bump-up" to "extreme" non-attainment classification for the Basin, which would extend the attainment date to 2024 and allow for the attainment demonstration to rely on emission reductions from measures that anticipate the development of new technologies or improving of existing control technologies (CAA Section 182(e)(5) measures). These measures are often referred to as "black box" measures and go beyond the short-term measures that are based on known and demonstrated technologies.

Under its current non-attainment classification, the District is prohibited from relying on "black-box" measures to demonstrate attainment. However, as shown in Table ES-2 approximately 43% of the ozone attainment strategy relies on "black-box" measures and 57% of reductions come from short-term measures.

TABLE ES-2

Emission Reductions Needed for Ozone Attainment
(2023, tons per day)

	VOC	NOx
Overall Reductions	116	383
Short-Term Reductions	89	193
Black Box Reductions	27	190

Converting these “black-box” reductions to short-term measures represents unique and complex challenges to this region and warrants additional time for development and implementation of more defined strategies, including in some cases sustainable funding.

If the region is unable to submit a SIP revision demonstrating attainment by the deadline, U.S. EPA must impose sanctions on the region. The first sanction, imposed after 18 months, is an offset ratio of 2 to 1 for major stationary sources (25 tpy or more). The second sanction (after 24 months) is withholding of all federal transportation funding for the region, except funding for transportation control measures and safety projects; in the South Coast, this amounts to billions of dollars. Finally, if the region cannot submit an approvable attainment demonstration, U.S. EPA must within 24 months adopt a “federal implementation plan” (FIP) demonstrating attainment by the severe-17 deadline. The FIP likewise could not rely on “black box” measures, and thus would likely impose draconian measures on mobile and stationary sources in the region.

Given the risk of becoming subject to sanctions and a FIP, and the benefits of a later attainment date and use of “black box” measures, AQMD staff recommends a voluntary bump-up request to “extreme” status as part of the 2007 AQMP submittal to the U.S. EPA. The bump-up would provide the basis for an approved plan for this region and implementation of short-term measures while providing an opportunity for a close collaboration among all agencies, industry, environmental organizations, and the public to define and implement these long-term measures as expeditiously as possible.

Despite the aggressive strategy proposed for the South Coast Air Basin, the Coachella Valley will not be able to meet the ozone standard by 2013, where the ozone problem is predominately a transport issue from the upwind South Coast Air Basin. Consequently, Ozone air quality will not meet the federal standard in the Coachella Valley until 2019 through the implementation of the Basin plan. Therefore, a “bump-up” request is also being made for Coachella Valley from a non-attainment classification of “serious” to “servere-15 with an extended attainment date of 2019.

WHAT ARE THE MAIN CHALLENGES OF ATTAINMENT?

Attainment of the new federal PM2.5 and 8-hour ozone standards poses yet another tremendous challenge for the South Coast Air Basin. The latest emissions inventory and air quality modeling analysis employed in the 2007 AQMP indicate that significant reductions above and beyond those already achieved are still needed for meeting these standards. The main challenges of attainment are described in this section.

PM2.5 ATTAINMENT BY 2015

Attainment of the federal health-based PM2.5 standard would demand significant emission reductions in PM2.5 components within the next seven years. Based on the District's recent air quality modeling analysis, these reductions are on the order of 192 tons per day of NOx, 59 tons per day of VOC, 24 tons per day of SOx, 15 tons per day of PM2.5 emissions. This range of reductions identifies the overall path to clean air and policy direction in designing the attainment strategy.

In 2014, sources primarily under the state and federal jurisdictions will account for 88% of NOx, 72% of VOC, and 63% of SOx emissions in the Basin in 2014. Therefore, in order to meet the federal PM2.5 standard by 2014, significant reductions are required from these sources. CARB has the overall responsibility of developing the State Element of the SIP outlining the state's specific short-term and long-term strategies for reducing emissions from mobile sources and consumer products. CARB has recently released its revised draft Proposed State Strategy for California's 2007 State Implementation Plan. By 2014, the proposed State measures are estimated to achieve 122 tons per day of NOx, 43 tons per day of VOC, 20 tons per day of SOx, and 9 tons per day of PM2.5 reductions.

District Staff's Proposal for PM2.5 Attainment Strategy

In the Proposed Modifications to the Draft Plan, released in March 2007, District staff identified a reduction gap of 71 tons per day of NOx for PM2.5 attainment by 2015 based on the estimated reductions from the draft proposed State strategy along with District's proposed control measures. Consequently, three policy options based on implementation of additional control measures and incentive funding were provided to close the gap (described in Appendix IV-B-2). In the revised draft state strategy, the reduction gap has increased to 74 tons per day of NOx due to foregone emission reductions for one of the state measures (i.e., off-road diesel equipment).

Based on further 3-agency (i.e., District, CARB, and SCAG) discussions to date, the District staff is proposing the following:

- The District is enhancing two of its proposed control measures (i.e., wood-burning fireplaces and wood stoves and commercial under-fired charbroilers) to obtain an additional 1.4 tons per day of directly-emitted PM2.5, which is equivalent to about 11 tons per day of NOx.

- CARB will commit to an additional 63 tons per day of NOx reductions to close the attainment gap, bringing the total commitment to 185 tons per day by 2014.

In its revised draft State strategy, CARB staff has suggested that the District consider additional local measures for directly-emitted PM sources to close the reduction gap. Specifically, CARB staff has suggested mandatory curtailment of the use of fireplaces and woodstoves during winter months, requiring additional controls on commercial cooking (i.e., charbroilers), and strengthening fugitive dust controls.

District staff has agreed to enhance its existing control measure on wood-burning fireplaces and woodstoves but has serious concerns over the feasibility and enforceability of the extent of mandatory curtailment suggested by CARB staff and the uncertainties in ambient concentrations from wood burning. Also, the District's control measure on commercial under-fired charbroilers has been strengthened to achieve additional PM2.5 reductions based on the installation of new and retrofit control equipment, similar to the proposed regulation currently being developed by the Bay Area Air Pollution Control District. However, despite these new reductions from measures proposed by the District, the PM2.5 standard can not be fully achieved by 2015 without additional reductions from mobile sources. In addition, inadequate initial steps would be made towards attainment of the new 24-hour PM2.5 standard and 8-hour ozone standard.

Therefore, since not fully attaining the PM2.5 standard by 2015 is not an acceptable or legally allowed public policy, the District staff is proposing that CARB commit to the additional 63 tons per day of NOx reductions from mobile sources to close the reduction gap for PM2.5 attainment by 2015. These NOx reductions will also be critically needed for achieving the 8-hour ozone and the 24-hour PM2.5 standards and making expeditious progress to implement all feasible measures. The District staff's proposed policy options identify a combination possible regulatory actions and public funding programs to achieve the additional NOx reductions. District staff believes these measures are feasible.

8-HOUR OZONE ATTAINMENT BY 2024

Attainment of the 8-hr ozone standard by 2024 will require significant additional reductions above and beyond those necessary for PM2.5 attainment. These reductions are expected to be achieved through implementation of new and advanced control technologies as well as improvement of existing control technologies. Control techniques requiring substantial levels of committed funding for implementation would also fall under this category of long-term emission reductions.

Based on District staff's air quality modeling analysis, the additional "black box" reductions needed for ozone attainment are estimated to be 190 tpd of NOx and 27 tpd of VOC reductions between 2015 and 2023 timeframe. These reductions are equally, if not more, challenging as the reduction gap for PM2.5, in that significant reductions are needed in a short timeframe. Actions are needed in the next couple of years to ensure technical readiness and significant quantity of product supply.

Table ES-3 provides a listing of some of the advanced technologies and innovative control approaches which could be relied upon to achieve the long-term reductions needed for ozone attainment, highlighting the level of stringency and aggressiveness of controls required.

TABLE ES-3

Possible Approaches for Long-Term Control Measures

Light Duty Vehicles	▪ Extensive retirement of high-emitting vehicles and accelerated penetration of PZEVs and ZEVs
On-Road Heavy Duty Vehicles	▪ Expanded modernization and retrofit of heavy-duty trucks and buses ▪ Expanded Inspection and Maintenance Program ▪ Advanced Near-Zero and Zero Emitting Cargo Transportation Technologies
Off-Road Vehicles	▪ Expanded modernization and retrofit of off-road equipment
Fuels	▪ More stringent gasoline and diesel specifications; Extensive use of diesel alternatives
Marine Vessels	▪ More stringent emission standards and programs for new and existing ocean-going vessels and harbor craft
Locomotives	▪ Advanced Near-Zero and Zero Emitting Cargo Transportation Technologies
Pleasure Craft	▪ Accelerated replacement and retrofit of high-emitting engines
Aircraft	▪ More stringent emission standards for jet aircraft (engine standards, clean fuels, retrofit controls), Airport Bubble
Consumer Products	▪ Ultra Low-VOC formulations; Reactivity-based controls
Renewable Enegry	▪ Accelerated use of renewable energy and development of hydrogen technology and infrastructure
AB32 Implementation	▪ Concurrent criteria pollutant reduction technologies

For light-duty vehicles, extensive retirement and replacement of high-emitting vehicles would be required through either mandatory or incentive-based programs. Furthermore, achieving further reductions from this source category will require an even more accelerated penetration of ATPZEVs and ZEVs beyond the 1 million target in 2020 currently proposed under short-term measures and could be as high as 4 to 5 million in 2023.

For heavy duty vehicles, a more extensive modernization program could be instituted to require the replacement of the remaining trucks not meeting the 2010 model year standard in 2020 after implementation of short-term measures. For off-road heavy diesel equipment, opportunities may also exist to achieve additional reductions by requiring that all of these equipment meet Tier 4 off-road engine standards or better through replacements or retrofits by 2020/2023. Reformulation of gasoline and diesel fuels coupled with requirements for using diesel alternatives (e.g., CNG, LNG, gas-to-liquid) would also provide an opportunity for additional long-term NOx, VOC, and PM reductions from on-road and off-road mobile sources.

Advanced cargo transportation technologies such as Maglev and other types of linear induction motor technologies could also be used to transport containers to and from ports thereby significantly reducing emissions from locomotives and heavy-duty trucks. Such alternative electric propulsion systems would have the added benefit of reducing congestion and reliance on fossil fuels. Accelerated development and implementation of these advanced technologies would provide a tremendous opportunity for achieving the emission reductions needed for ozone attainment

Further emission reductions from ocean-going vessels beyond those considered under CARB's goods movement plan could also be achieved through a more expanded main engine retrofit program which would target all vessels calling on the San Pedro Bay ports (i.e., including those making non-frequent or less frequent calls) to achieve higher levels of NOx reductions from existing vessels. CARB or the Ports have the ability to adopt and implement such programs, but may require authorization from U.S. EPA

Accelerated replacement of existing pleasure craft with new models meeting the most stringent engine standards and application of potential retrofit technologies provides another strategy for achieving long-term reductions. In addition, aircraft emissions could be further reduced through strategies such as lower engine emission standards, reformulation of jet fuel, and installation of retrofit kits which would require extensive technology development.

Finally, additional VOC reductions from consumer products could be achieved based on the application of low-VOC technologies and formulations developed for industrial coatings and solvents categories. Also, reformulation based on lower reactive compounds could offer an additional alternative for achieving equivalent reductions.

UNCERTAINTIES IN MOBILE SOURCE EMISISONS INVENTORY

Although the emissions inventory and projections in the 2007 AQMP represent the latest available methodologies, emission factors, and growth projections, there are uncertainties in the mobile source emissions inventory which need to be addressed in the final AQMP or, if necessary, immediately following the AQMP adoption. The mobile source inventory for this Final 2007 AQMP represents an increase over the previous AQMP primarily because of ethanol permeation, heavy-duty vehicle in-use emissions, increased evaporative emissions for pleasure craft, and other adjustments.

As part of the on-road mobile source inventory evaluation, it became clear that the EMFAC VMT estimates portrayed a 2005 "blip" as a result of CARB's methodology to adjust the 2005 VMT (provided by SCAG) based on Department of Motor Vehicle

(DMV) vehicle registrations and Bureau of Automotive Repair (BAR) odometer readings collected through the Smog Check program.

AQMD staff examination of the EMFAC VMT indicated that for 2005 the difference in CARB's VMT estimates and SCAG's was on the order of 10 percent for light- and medium-duty vehicles (or 30 million more VMT per day in CARB's estimates) and 20 percent for heavy duty vehicles (or about 5 million more VMT per day). The AQMD's consultants reviewed CARB's assumptions and to the extent possible some of the DMV and BAR data used to produce the 2005 VMT estimates. They concluded that there is no independent evidence to support a decline in VMT between 2005 and 2010, and recommended conducting sensitivity analysis in the near-term (given the need to develop an AQMP Revision) to determine the magnitude of the differences.

A sensitivity analysis was conducted to estimate the emissions impact of projecting the SCAG linear VMT trend using the 2005 CARB estimate as the anchor. The analysis indicates that should the revised VMT projections be a more accurate representation of future estimates, the ozone attainment strategy would need additional 30 to 40 tons per day of NOx reductions.

While the technical work to improve the inventory is on-going, the past plan revisions have shown continuous upward adjustment of the mobile source inventory. The control strategy for attainment demonstration should provide a certain level of safety margin to address this potential underestimation of emissions with only seven years remaining for PM2.5 attainment.

FAIR SHARE AGENCY RESPONSIBILITY

In order to achieve necessary reductions for meeting air quality standards, all four agencies (i.e., AQMD, CARB, U.S. EPA, and SCAG) would have to aggressively develop and implement control strategies through their respective plans, regulations, and alternative approaches for pollution sources within their primary jurisdiction. Even though SCAG does not have direct authority over mobile source emissions, it will commit to the emission reductions associated with implementation of the 2004 Regional Transportation Plan and 2006 Regional Transportation Improvement Program which are imbedded in the emission projections. Similarly, the Ports of Los Angeles and Long Beach have authority they must utilize to assist in the implementation of various strategies if the region is to attain clean air by federal deadlines.

The following figures (ES-7 and ES-8) represent the projected emission contributions by agency primary authority for major pollutants in 2014 and 2023 for key pollutants.

Although the District has completely met its obligations under the 2003 AQMP and stationary sources subject to the District's jurisdiction account for only 12% of NOx and 37% of SOx emissions in the Basin in 2014, the Final 2007 AQMP contains several short-term and mid-term control measures aimed at achieving further NOx and SOx reductions (as well as VOC and PM2.5 reductions) from these already regulated sources. These strategies are based on facility modernization, energy conservation measures and more stringent requirements for existing equipment (e.g., space heaters, ovens, dryers, furnaces).

Clean air for this region requires CARB to aggressively pursue reductions and strategies for on-road and off-road mobile sources and consumer products. In addition, considering the significant contribution of federal sources such as marine vessels, locomotives, and aircraft in the Basin (i.e., 56% of SOx in 2014 and 37% of NOx in 2023), it is imperative that the U.S. EPA pursue and develop regulations for new and existing federal sources to ensure that these sources contribute their fair share of reductions toward attainment of the federal standards. Unfortunately, regulation of these emission sources has not kept pace with other source categories and as a result, these sources are projected to represent a significant and growing portion of emissions in the Basin. Without a collaborative and serious effort among all agencies, attainment of the federal standards will be seriously jeopardized.

FIGURE ES-7

Emissions Contribution by Primary Agency Responsibility
(2014, Annual Average Inventory)

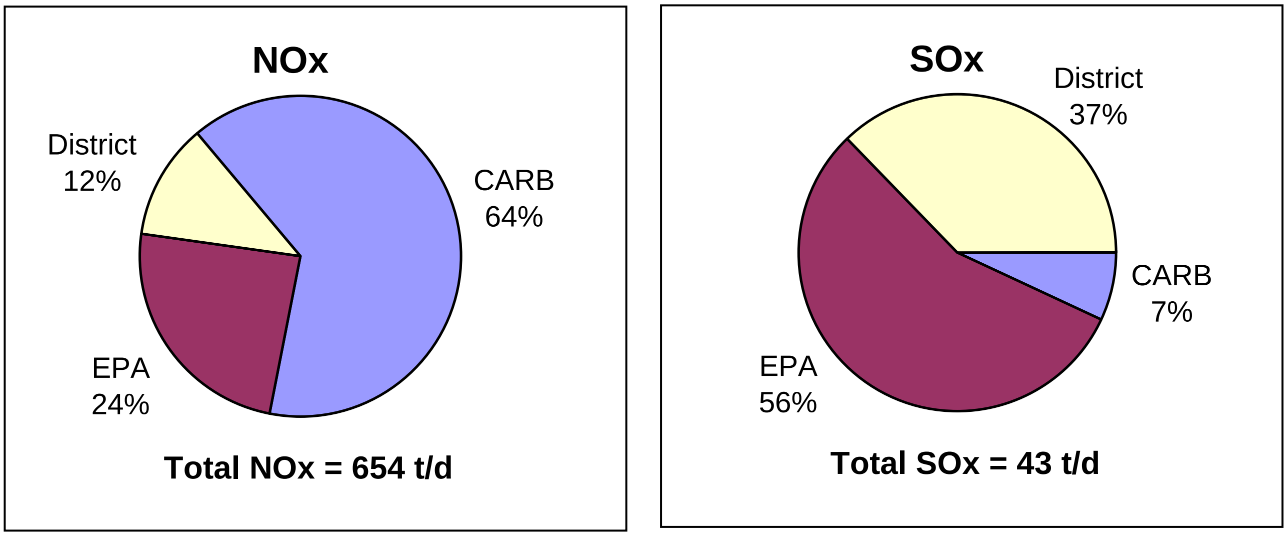
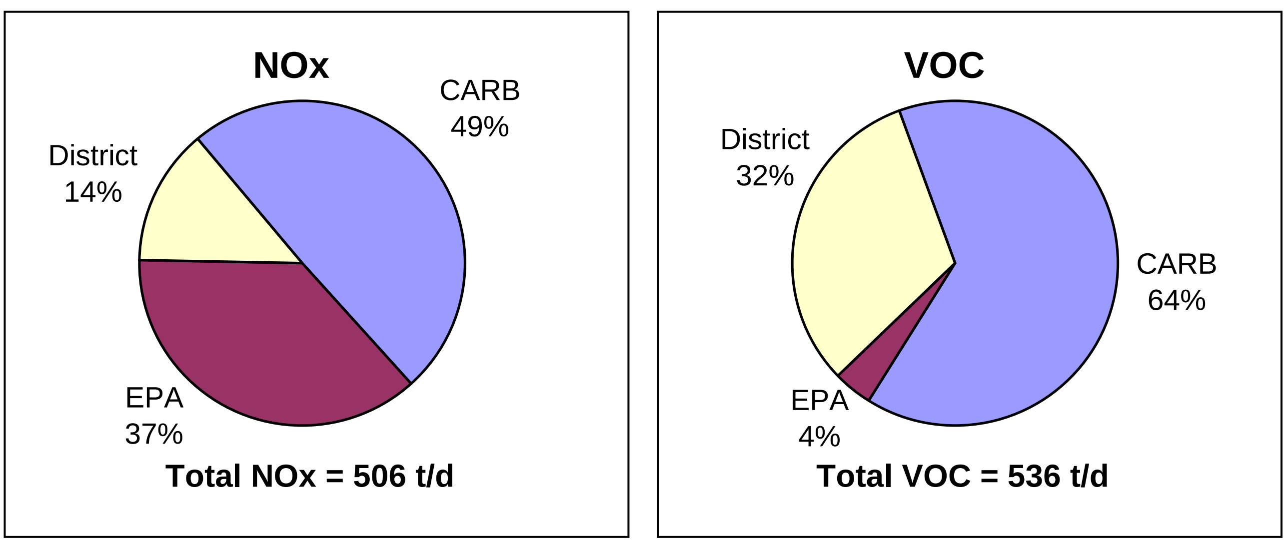


FIGURE ES-8

Emissions Contribution by Primary Agency Responsibility
(2023, Planning Inventory)



FUNDING AVAIABILITY

The overall costs of implementing the control measures proposed in the Final 2007 AQMP are in the billions of dollars. In-use mobile source fleet modernizations, accelerated retirement of high-emitting vehicles and equipment, alternative fuels and their infrastructure, advanced retrofits, facility modernization, and product reformulations and replacements are among strategies which require significant levels of funding. For illustration purposes, the estimated costs associated with the recently released San Pedro Bay Port's Draft Clean Air Action Plan and CARB's Goods Movement Plan targeting ports and goods movement sectors alone are approximately $2 billion dollars and $10 billion dollars, respectively. The costs of implementing the AQMP control measures affecting virtually all source categories in the Basin will add to these estimates. However, the economic values of avoiding adverse health effects are projected to be many times higher than the implementation cost of clean air strategies.

In order to meet the federal PM2.5 and 8-hour ozone ambient air quality standards, a significant amount of public and private funding will be required to implement some measures. A close collaboration among all stakeholders, government agencies, businesses, and residents would be critical to identify and secure adequate funding sources for implementing the AQMP control measures.

In addition to public funding for mobile sources, financial assistance to stationary sources should be explored in light of the need to further reduce emissions from local businesses. The Plan discussed the desire to seek tax incentives for early deployment of clean air technologies as part of plant modernization or to establish "Carl Moyer" type programs for stationary sources for pollution prevention, such as process changes to apply near-zero pollution technologies.

CHAPTER 1

INTRODUCTION

Purpose

Constraints in Achieving Standards

Control Efforts

Progress in Implementing the 2003 AQMP

2007 AQMP

Format of This Document

PURPOSE

The purpose of the 2007 Air Quality Management Plan (AQMP or Plan) for the South Coast Air Basin (Basin) is to set forth a comprehensive program that will lead the region into compliance with federal 8-hour ozone and PM2.5 air quality standards. The Plan will be submitted to U.S. EPA as a SIP revision once it is approved by the District's Governing Board and the California Air Resources Board (CARB). The key federal planning requirements are summarized briefly later in this chapter. Additional technical refinements are still underway to improve the planning assumptions, proposals, pollution control strategy, and attainment demonstration. Nonetheless, AQMD staff believes it is time to initiate broad public dialogue, to inform the public regarding the challenge ahead, and to solicit public input.

This Final 2007 AQMP sets forth programs which require the cooperation of all levels of government: local, regional, state, and federal. Each level is represented in the Plan by the appropriate agency or jurisdiction that has the authority over specific emissions sources. Accordingly, each agency or jurisdiction commit to specific planning and implementation responsibilities.

At the federal level, the U.S. Environmental Protection Agency (U.S. EPA) is charged with establishing emission standards of 49-state on-road motor vehicle standards; train, airplane, and ship pollutant exhaust and fuel standards; and regulation of non-road engines less than 175 horsepower. The CARB, representing the state level, also oversees on-road vehicle emission standards, fuel specifications, some off-road source requirements and consumer product standards. At the regional level, the District is responsible for stationary sources and some mobile sources, including operational limitations. In addition, the District has lead responsibility for the development and adoption of the Plan. Lastly, at the local level, the cities and counties and their various departments (e.g., harbors and airports) have a dual role related to transportation and land use. Their efforts are coordinated through the regional metropolitan planning organization; for the South Coast Air Basin, the Southern California Association of Governments (SCAG) is the District's major partner in the preparation of the AQMP. Interagency commitment and cooperation are the keys to success of the AQMP.

Since air pollution physically transcends city and county boundaries, it is a regional problem. No one agency can design or implement the Plan alone and the strategies in the Plan reflect this fact.

CONSTRAINTS IN ACHIEVING STANDARDS

The District is faced with a number of constraints or confounding circumstances that make achieving clean air standards difficult. These include the physical and meteorological setting, the large pollutant emissions burden of the Basin (including pollution from international goods movement), and the rapid population growth of the area.

Setting

The District has jurisdiction over an area of approximately 10,743 square miles, consisting of the four-county South Coast Air Basin (Basin), and the Riverside County portions of the Salton Sea Air Basin (SSAB) and Mojave Desert Air Basin (MDAB). The Basin, which is a subregion of the SCAQMD's jurisdiction, is bounded by the Pacific Ocean to the west and the San Gabriel, San Bernardino, and San Jacinto mountains to the north and east. It includes all of Orange county and the nondesert portions of Los Angeles, Riverside, and San Bernardino counties. The Riverside county portion of the SSAB is bounded by the San Jacinto Mountains in the west and spans eastward up to the Palo Verde Valley. The federal nonattainment area (known as the Coachella Valley Planning Area) is a subregion of Riverside county and the SSAB that is bounded by the San Jacinto Mountains to the west and the eastern boundary of the Coachella Valley to the east. The Los Angeles county portion of the MDAB (known as north county or Antelope Valley) is bounded by the San Gabriel Mountains to the south and west, the Los Angeles/Kern county border to the north, and the Los Angeles/San Bernardino county border to the east. The SSAB and MDAB were previously included in a single large Basin called the Southeast Desert Air Basin (SEDAB). On May 30, 1996, the California Air Resources Board replaced the SEDAB with the SSAB and MDAB. In July 1997, the Antelope Valley area of MDAB was separated from the District and incorporated into a new air district under the jurisdiction of the newly formed Antelope Valley Air Pollution Control District (AVAPCD). The entire region is shown in Figure 1-1.

The Coachella Valley Planning Area is impacted by pollutant transport from the South Coast Air Basin. In addition, pollutant transport occurs to the Antelope Valley, Mojave Desert, Ventura county, and San Diego county. As part of this AQMP revision, transport issues relative to the Coachella Valley Planning Area are specifically addressed in Chapter 8 – Future Air Quality – Desert Nonattainment Areas.

CHAPTER 4

AQMP CONTROL STRATEGY

Retrofit with Cleaner Technologies Retrofitting trucks, CHE, locomotives, and marine vessels with diesel particulate filters (DPF), selective catalytic reduction (SCR), diesel oxidation catalyst (DOC), and emulsified fuel offer significant emission reduction opportunities. In Europe, DPFs are being used on locomotives and NOx reductions are achieved on ocean-going vessels through the use of SCR and water emulsification technologies. Water emulsification and slide valves are cost effective approaches to reduce oxides of nitrogen and particulate matter from ocean-going vessels.

Another alternative is to use SCR and DPF in stationary units and direct the emissions of the idling locomotives and marine vessels into the cleanup apparatus through a “bonnet” system. Advanced Cleanup Technologies, Inc. has developed this technology and successfully demonstrated the system at the Roseville Railyard in partnership with CARB, the District, and Union Pacific. This technology will also be applied at the Port of Long Beach in 2007. Both the on-road and stationary SCR systems offer the potential for greatly reducing NOx and PM by up to 90%.

Use of Alternative Fuels and Other Cleaner Fuels

Significant oxides of nitrogen and particulate matter emission reductions have been associated with the use of alternative fuels such as natural gas, liquid petroleum gas (LPG), emulsified diesel, or biodiesel (as long as any associated oxides of nitrogen emission increases are mitigated) wherever possible in on-road heavy-duty vehicles, CHE, locomotives, and marine vessels. Alternatives to diesel such as gas to liquids (Fisher-Tropsch Diesel) and Di-Methyl Ether (DME) can also reduce NOx and PM emissions. The use of biodiesel can also have beneficial impacts relative to PM reductions. Depending upon the biodiesel blends, increased NOx emissions may be mitigated through fuel borne additives. CARB recently adopted a regulation requiring the use of 0.5% sulfur marine distillate fuels in auxiliary engines when marine vessels are within 24 miles of the California coastline. Maersk, one of the largest cargo shipping lines, announced in 2006 that they will be using a 0.2% marine distillate fuel immediately.

For light-duty vehicles, greater attention has been given to E-85 fuel to reduce dependency on petroleum fuel. Presently, auto manufacturers only manufacture flexible fuel vehicles that operate on either gasoline or E85. However, encouraging greater use of E85 fuel would result in additional emission benefits.

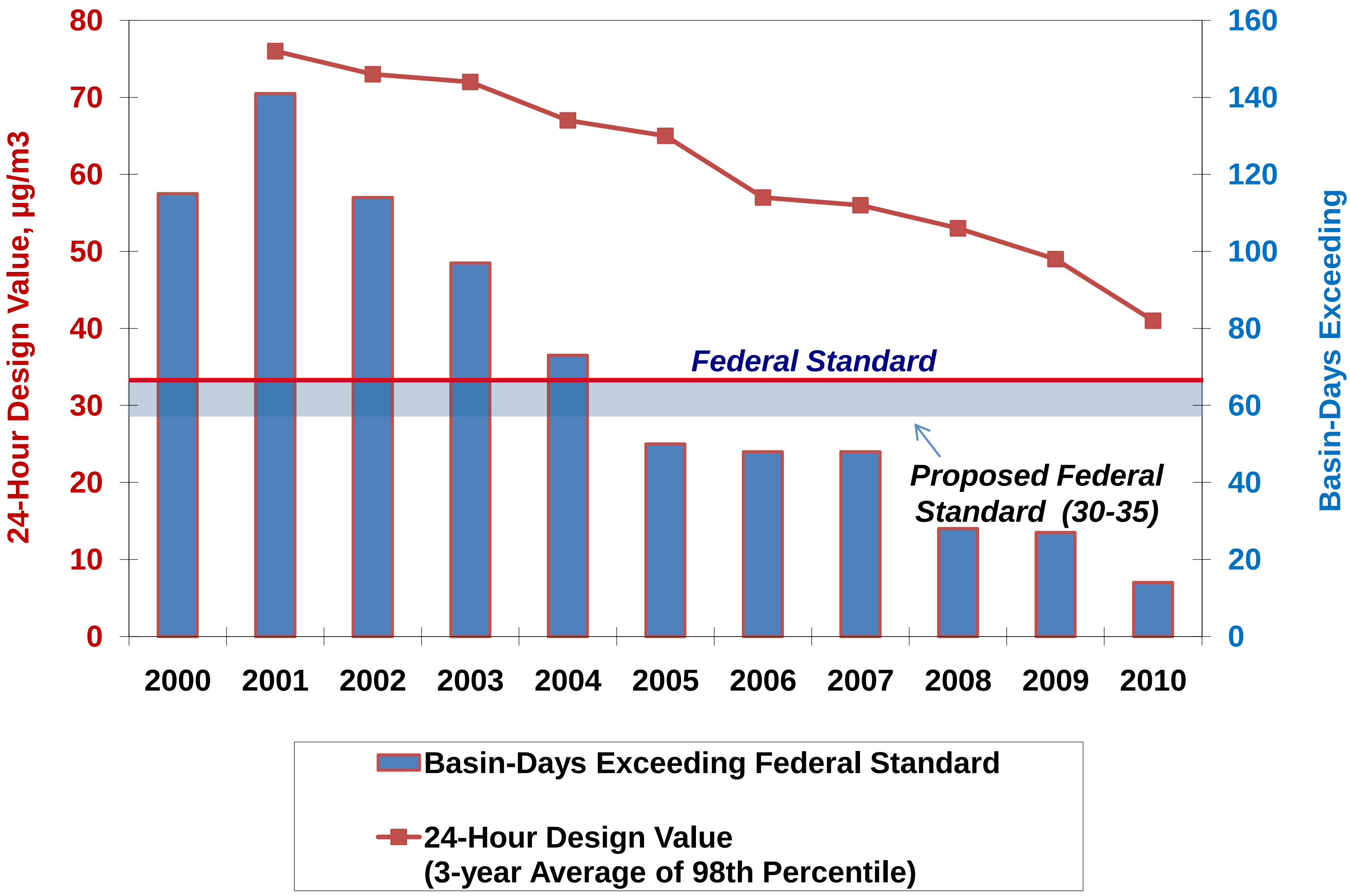
Electrification of goods movement related vehicles and equipment should also be considered. Electrification of the infrastructure at the ports and the Alameda Corridor can significantly reduce emissions from on-road trucks and locomotives. Providing shore-side power for marine vessels while at berth will also greatly reduce the emissions that would otherwise result from hotelling.

2012 Air Quality Management Plan

2012 AQMP
Word Association

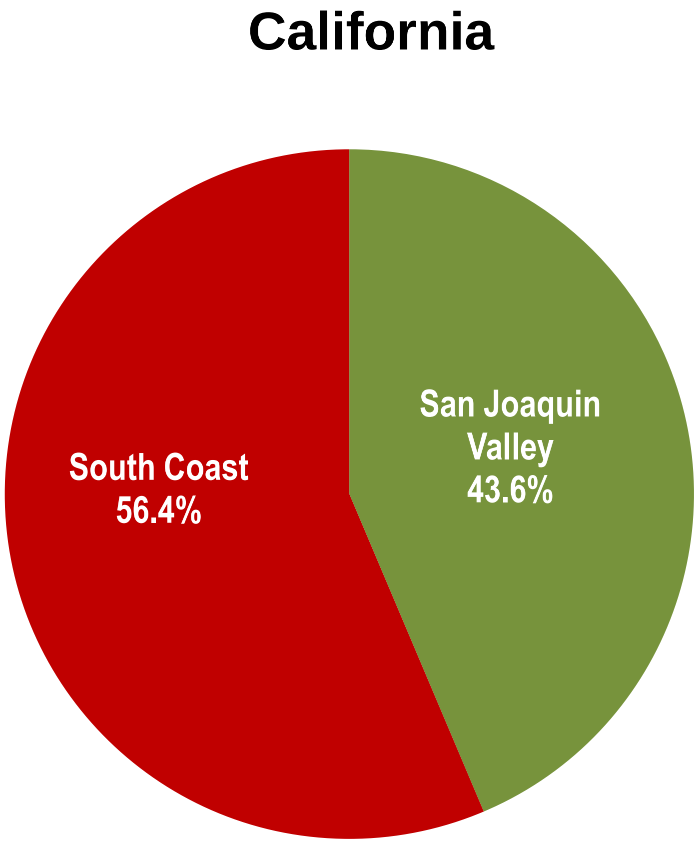
- Clean air and public health
- Jobs and economy
- Mobility and infrastructure
- Zero- and near-zero emissions technology/fuel
- Energy and climate change

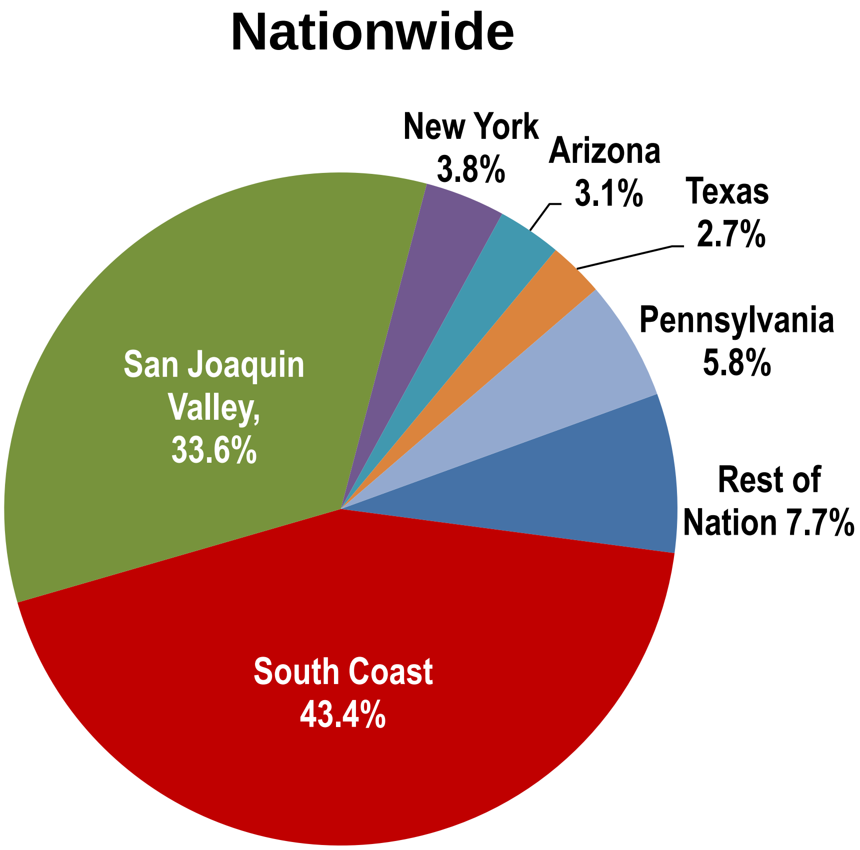
South Coast Air Basin 24-Hour PM2.5



PM2.5 Exposure*

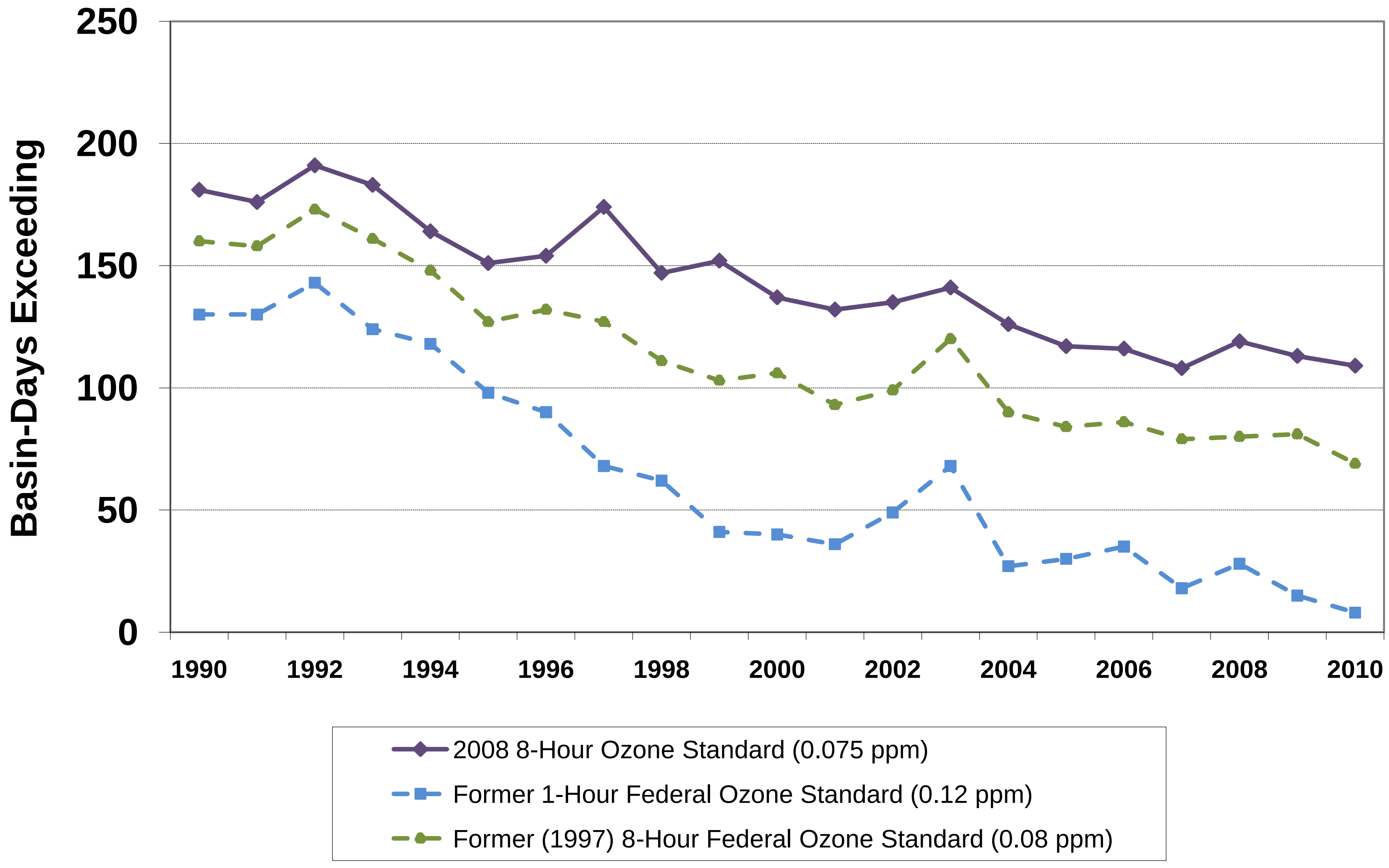
Annual Average NAAQS = 15 μg/m3





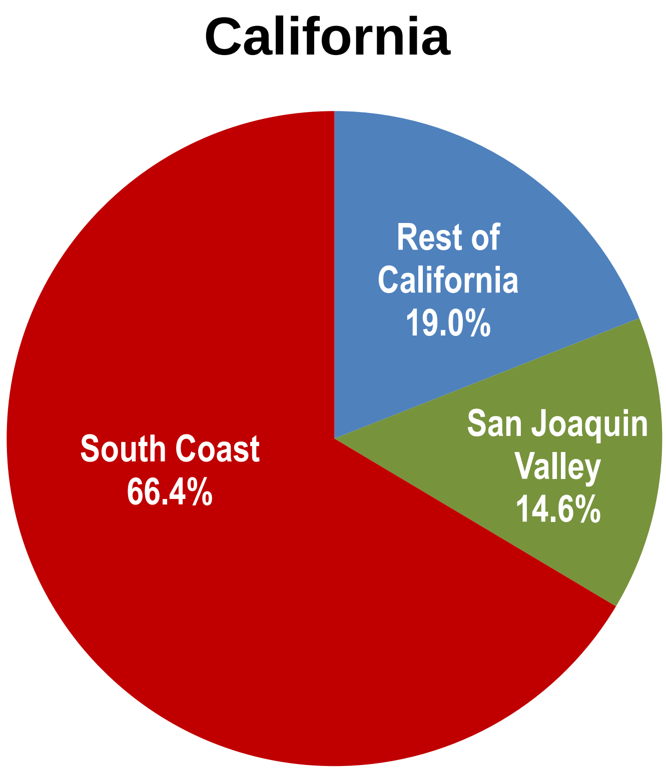
* Population-weighted incremental exposure to PM2.5 above the NAAQS annual standard, based on 2007-2009 data

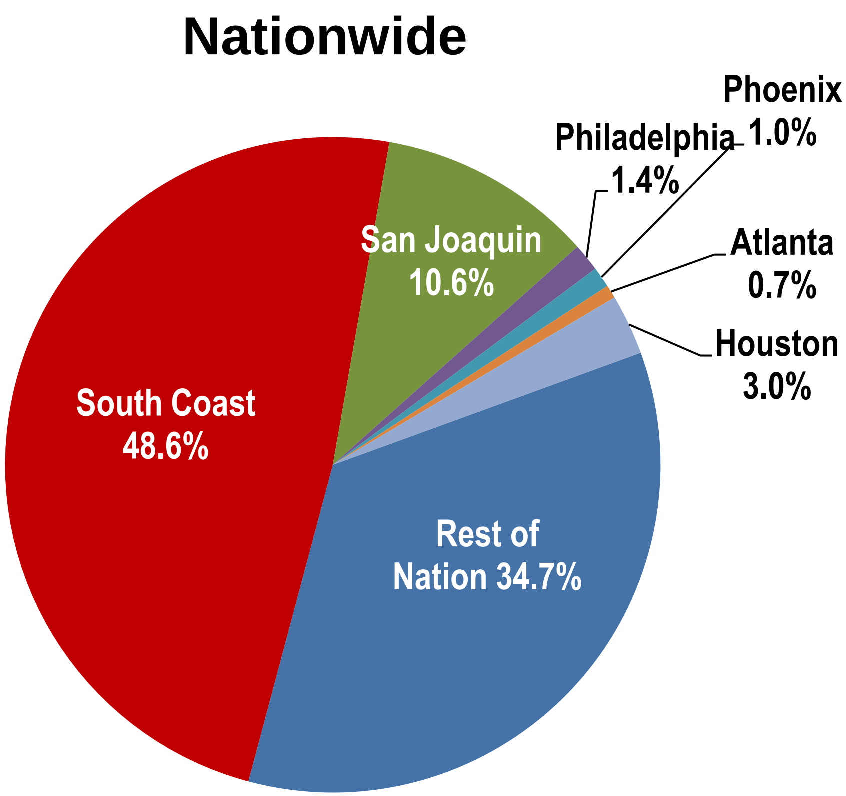
South Coast Air Basin Days Exceeding Federal Ozone Standards



Ozone Exposure*

8-Hour NAAQS = 75 ppb

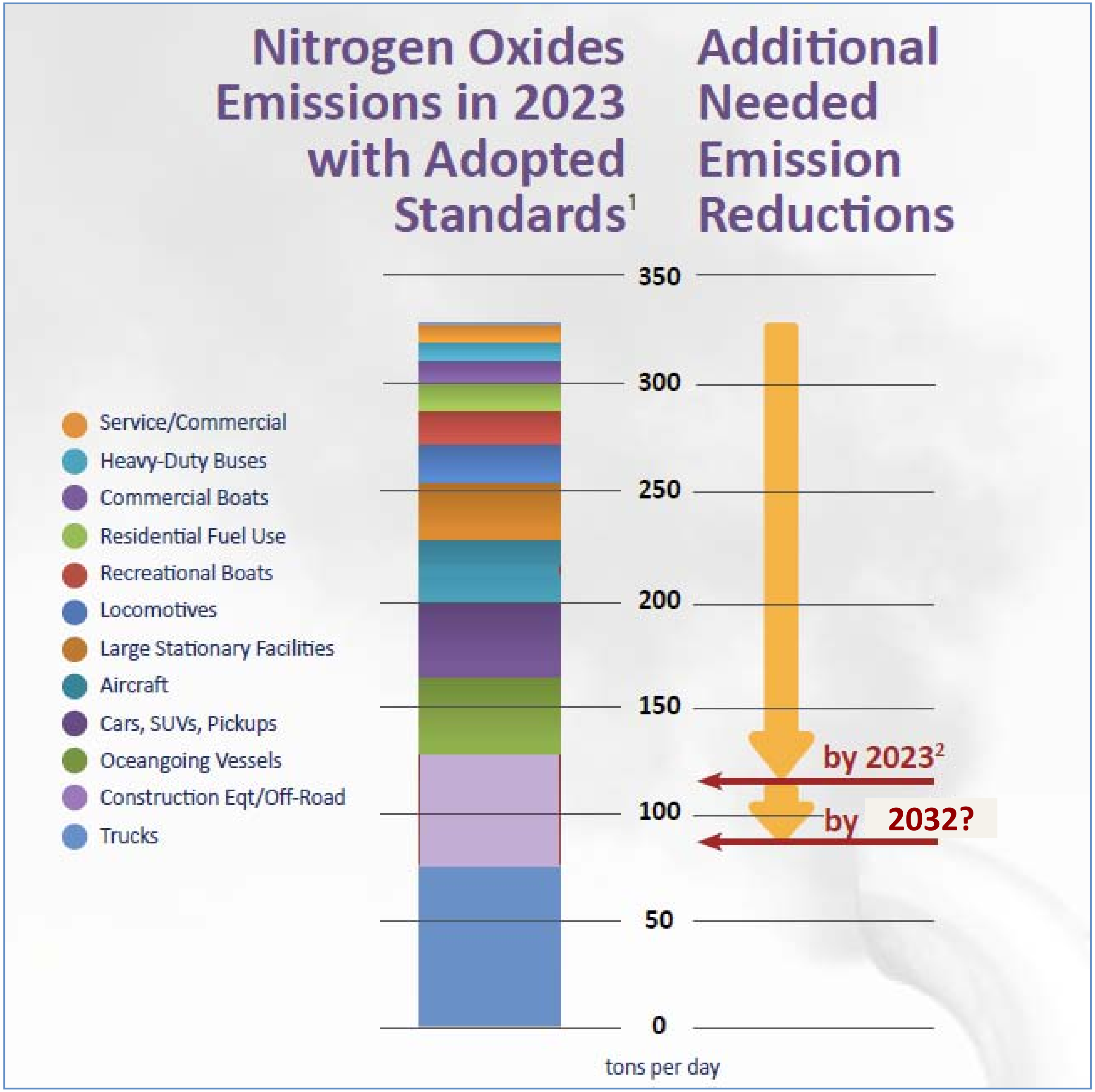




* Population-weighted incremental exposure to ozone above the 8-Hour NAAQS (> 75 ppb), based on 2008-2010 design values

Scope of 2012 AQMP

- Integrated multi-pollutant plan (efficient path)
  - 24-hr PM2.5 standard (35 μg/m3 by 2014-2019)
  - Updates to 8-hour ozone SIP (80 ppb by 2023)
    - Update on "black box" measures
  - Projections for new 8-hour ozone std (75 ppb by 2032?)
- Review of proposed new standards
- Energy and climate
- Ultrafine particles and near-roadway exposures



Nitrogen Oxides Emissions in 2023 with Adopted Standards[1]
Additional Needed Emission Reductions
350
300
250
200
150
100
50
0
tons per day
Service/Commercial
Heavy-Duty Buses
Commercial Boats
Residential Fuel Use
Recreational Boats
Locomotives
Large Stationary Facilities
Aircraft
Cars, SUVs, Pickups
Oceangoing Vessels
Construction Eqt/Off-Road
Trucks
by 2023[2]
by 2032?

2012 AQMP Challenges

- Balancing public health and economy through strategy selection
- Elimination of “Black Box”
- Fair share emission reductions
- Integrated solutions (AQ, climate, energy, mobility)
- Building consensus

Mobility. Environment. Community. Economy. Technology.

INTERSTATE CALIFORNIA 710

I-710 Corridor Project EIR/EIS

metro.net

Public Scoping Meeting

September 2008

Metro Caltrans GATEWAY CITIES The Port of LONG BEACH THE PORT OF LOS ANGELES SOUTHERN CALIFORNIA ASSOCIATION of GOVERNMENTS

Welcome/Introductions

Purpose of Scoping

Obtain public feedback on

- Project's purpose
- Potential options for improvements
- Environmental issues
- Other projects in area and issues

Project Overview

I-710 Corridor

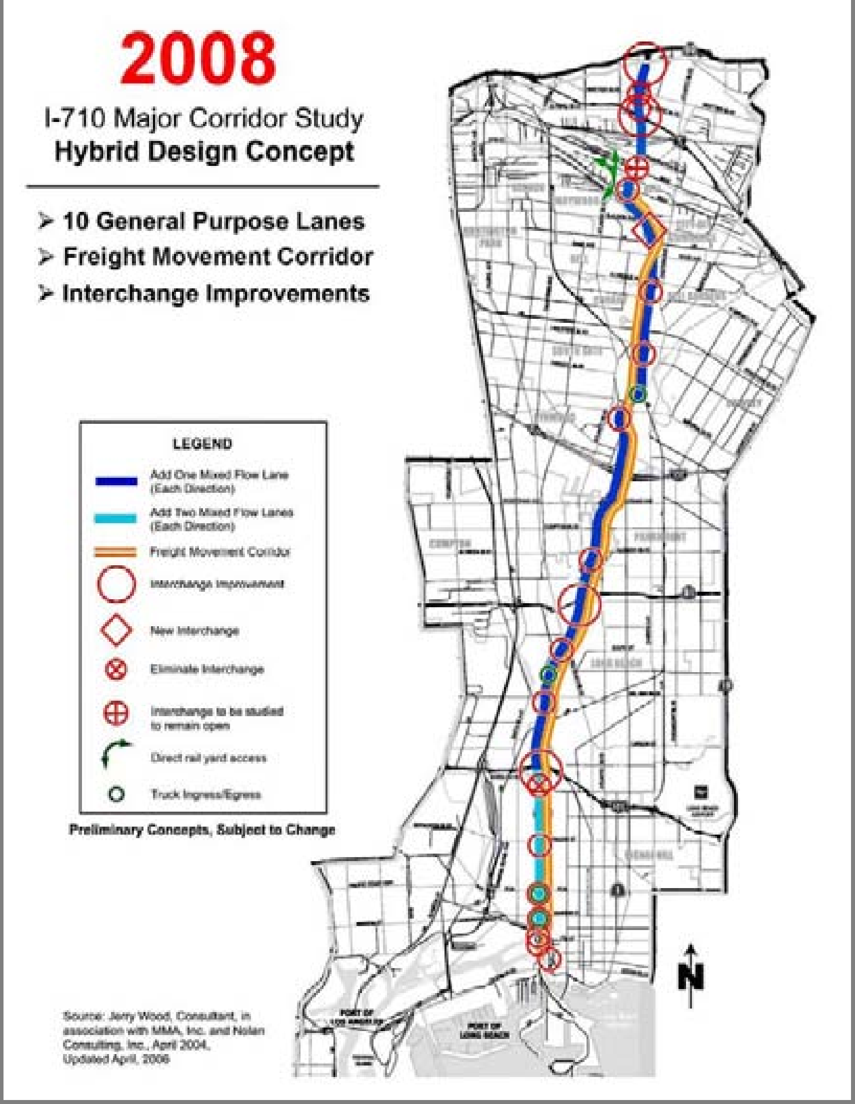
2005 Major Corridor Study (MCS)

- **Extensive technical and community participation process**
- **Analyzed congestion and mobility**

2005 Major Corridor Study (MCS)

- Developed solutions to improve air quality and mobility along the corridor
- Formed a multi-agency partnership to fund and conduct EIR/EIS

Locally Preferred Strategy



Objectives Emerging from MCS

- Improve air quality and reduce public health risks
- Improve mobility
  - Safety
  - Congestion
  - Outdated infrastructure

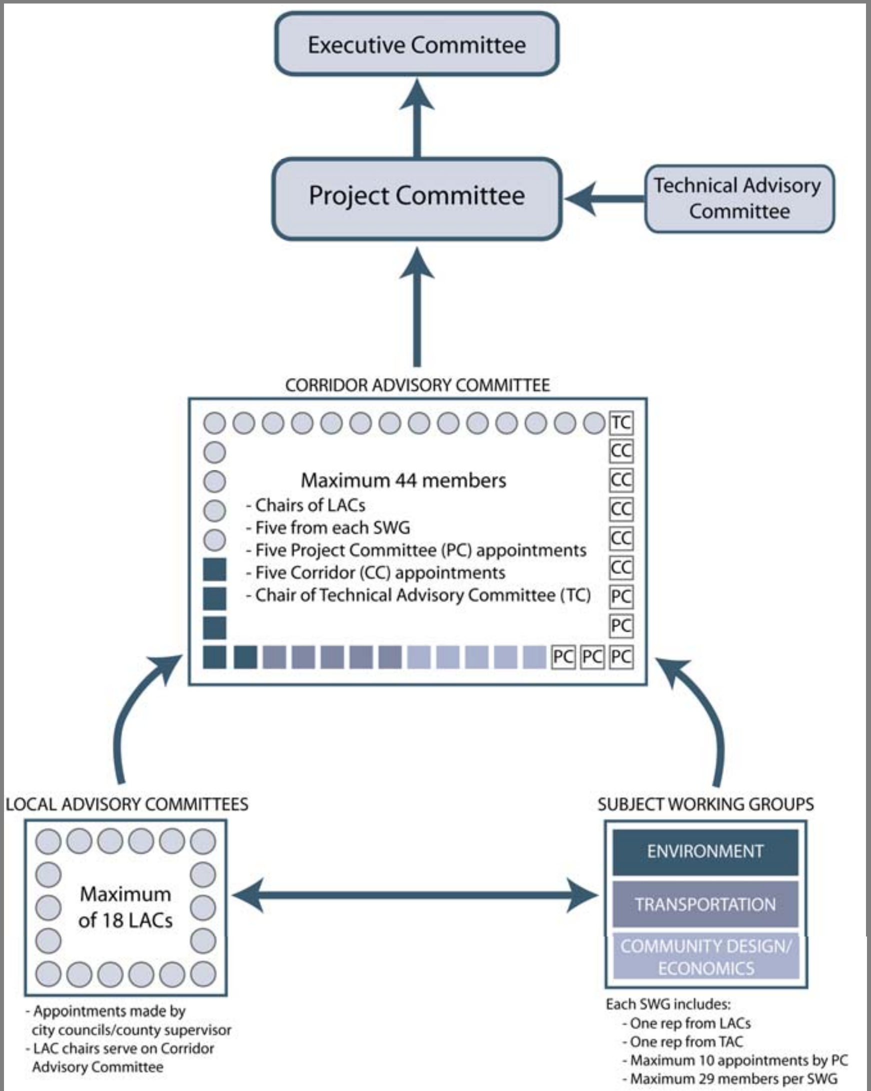
Objectives Emerging from MCS

- Assess alternative goods movement technologies
  - “Green” technologies for a freight movement corridor

Current Community Participation Approach

- Ensure participation at all levels
  - Local community interests
  - Corridor-wide interests
  - Technical
  - Policymakers/Elected Officials
  - Agencies
- Build on success of I-710 Major Corridor Study
- Customized for each community

Community Participation Framework



Technical Approach

Environmental and Engineering Scope of Work:

- **Develop baseline studies**
- **Prepare draft and final technical studies**
- **Develop preliminary engineering designs**

Technical Approach

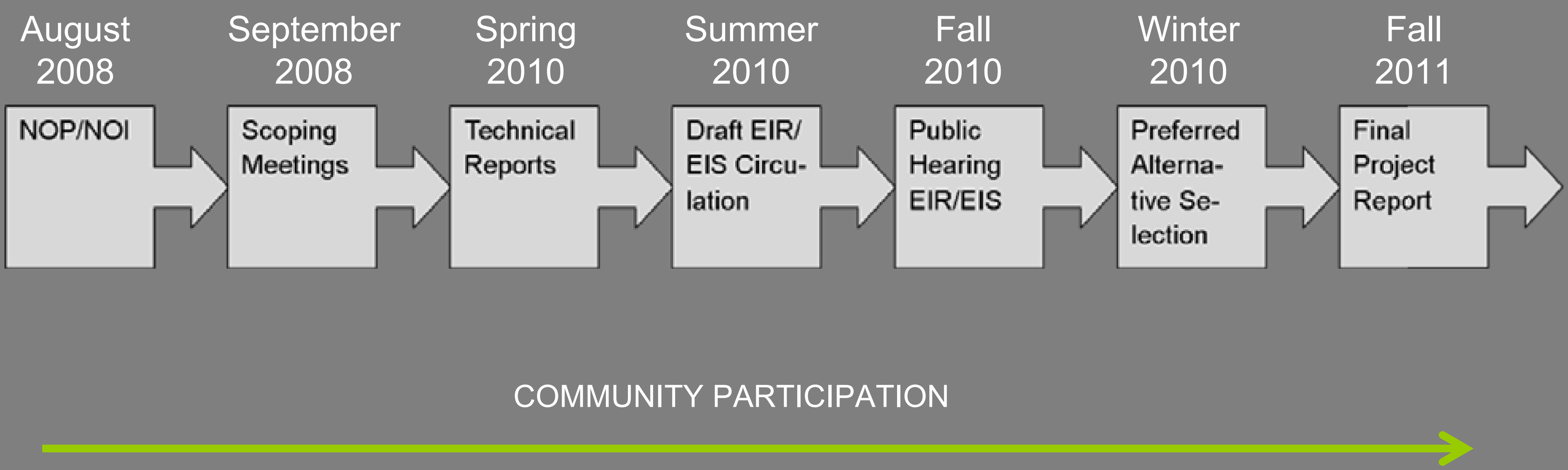
Scope of Work continued:

- Prepare EIR/EIS
  - Administrative Draft
  - Draft
  - Final

Technical Work Underway

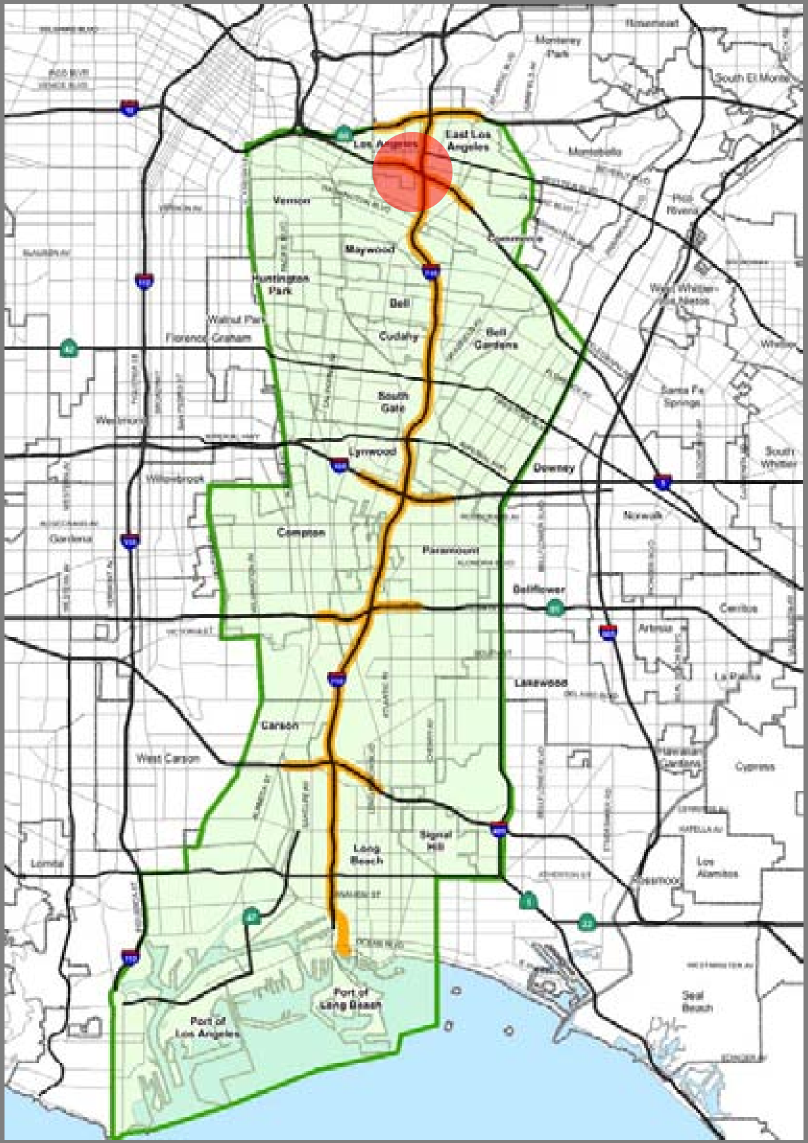
- Developing "Need and Purpose" statement
- Aerial mapping
- Evaluation of Locally Preferred Strategy
- Traffic counts and forecasting
- Goods movement study
- Alternative technology study

Project Schedule



Study Area

I-710 Corridor Project EIR/EIS



Coordination between I-710 and I-5 Projects

Community Participation Coordination

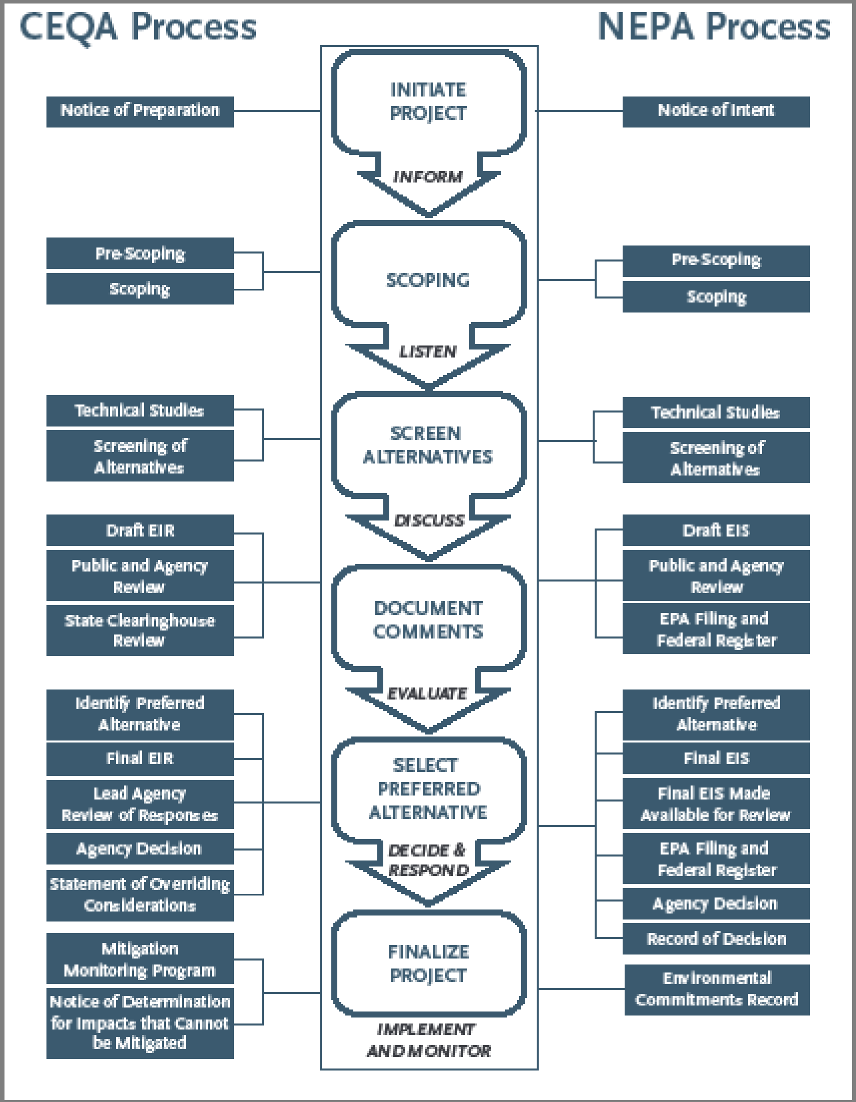
- Seamless integration of outreach
- Facilitated meetings

Technical Coordination

- Integrated engineering and environmental studies
- Same project management team

Environmental

CEQA and NEPA Process



Need and Purpose

Need and Purpose

- Air Quality and Health
- Traffic Safety
- Highway Design Deficiencies
- Future Traffic Conditions
- Growth in population, employment and goods movement activities

Alternatives

Alternatives Identified to Date

- No Build
- Transportation Systems Management/Transportation Demand Management (TSM/TDM) and Transit

Alternatives Identified to Date

- Goods Movement Enhancement by Rail and/or Advanced Technology
- Arterial Highway and I-710 Congestion Relief Improvements

Alternatives Identified to Date

- Mainline I-710 Improvements
  - Option A – 10 general-purpose lanes with no carpool lanes
  - Option B – eight general-purpose lanes with one carpool lane in each direction (total of 10)
- Locally Preferred Strategy Hybrid Design

Key Issues for Scoping

Key Environmental Issues

- Air Quality and Public Health
- Traffic Safety
- Jobs and Economic Development
- Environmental Justice
- Noise
- Congestion
- Community Enhancement
- Design Concepts

Please give us your thoughts

Ways to Provide Comments:

Mail to:

Mr. Ron Kosinski
Caltrans District 7
100 S. Main Street, MS 16A
Los Angeles, CA 90012

Please note: Deadline for comments is September 30, 2008

Please give us your thoughts

Ways to Provide Comments:

- Fill-out Comment Card provided and drop it in designated "Comment Card" boxes
- Email: 710eir@metro.net
- Project Website: www.metro.net/710eir
- Phone line: 213-922-4710
- Fax: 213-922-8868

FINAL REPORT

SCOPING SUMMARY REPORT
WBS ID:165.05.10-100

Prepared for

Metro

Los Angeles County
Metropolitan Transportation Authority

December 22, 2008

Prepared by:

URS

2020 East First Street, Suite 400
Santa Ana, California 92705

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EXECUTIVE SUMMARY

INTRODUCTION

The California Department of Transportation (Caltrans) is working to study alternatives for constructing freeway improvements to Interstate 710 (I-710) from Ocean Boulevard in the City of Long Beach to State Route 60 (SR-60) in Los Angeles County, California. Figure ES-1 depicts the I-710 Corridor Project study area. Alternatives initially under study include: (1) the No Build Alternative; (2) Transportation Systems Management/Transportation Demand Management; (3) Goods Movement Enhancement by Rail and/or Advanced Technology; (4) Arterial Highway and I-710 Congestion Relief Improvements; (5) Mainline I-710 Improvements with 10 general-purpose lanes and no carpool lanes; (6) Mainline I-710 Improvements with 8 general-purpose lanes and 1 carpool lane in each direction; and (7) the Locally Preferred Strategy (LPS) Hybrid Design (I-710 Mainline Improvements with the addition of a 4-lane separated freight movement facility).

The purpose of the I-710 Corridor Project is to (1) improve air quality and public health, (2) improve traffic safety, (3) address design deficiencies of the existing I-710 freeway, (4) address projected traffic volumes, and (5) address projected growth in population, employment, and economic activities related to goods movement.

A Draft Environmental Impact Report/Environmental Impact Statement (EIR/EIS) is being prepared for the I-710 Corridor Project. The first step in preparing the Draft EIR/EIS is conducting scoping in order to describe the proposed project and to solicit input from the general public and public agencies regarding the project purpose and need, the proposed alternatives, and the scope of the analysis to be included in the Draft EIR/EIS.

The California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA) both allow for and encourage public participation during the environmental evaluation phase of any transportation project. The initial step in this public process is called “scoping.” Scoping focuses on defining the environmental issues and alternatives that should be examined in the CEQA/NEPA process. Identification of other related projects is also important. This report summarizes the scoping outreach activities, distribution of notices and their responses, and the comments received during the I-710 Corridor Project scoping period from August 15 to September 30, 2008.

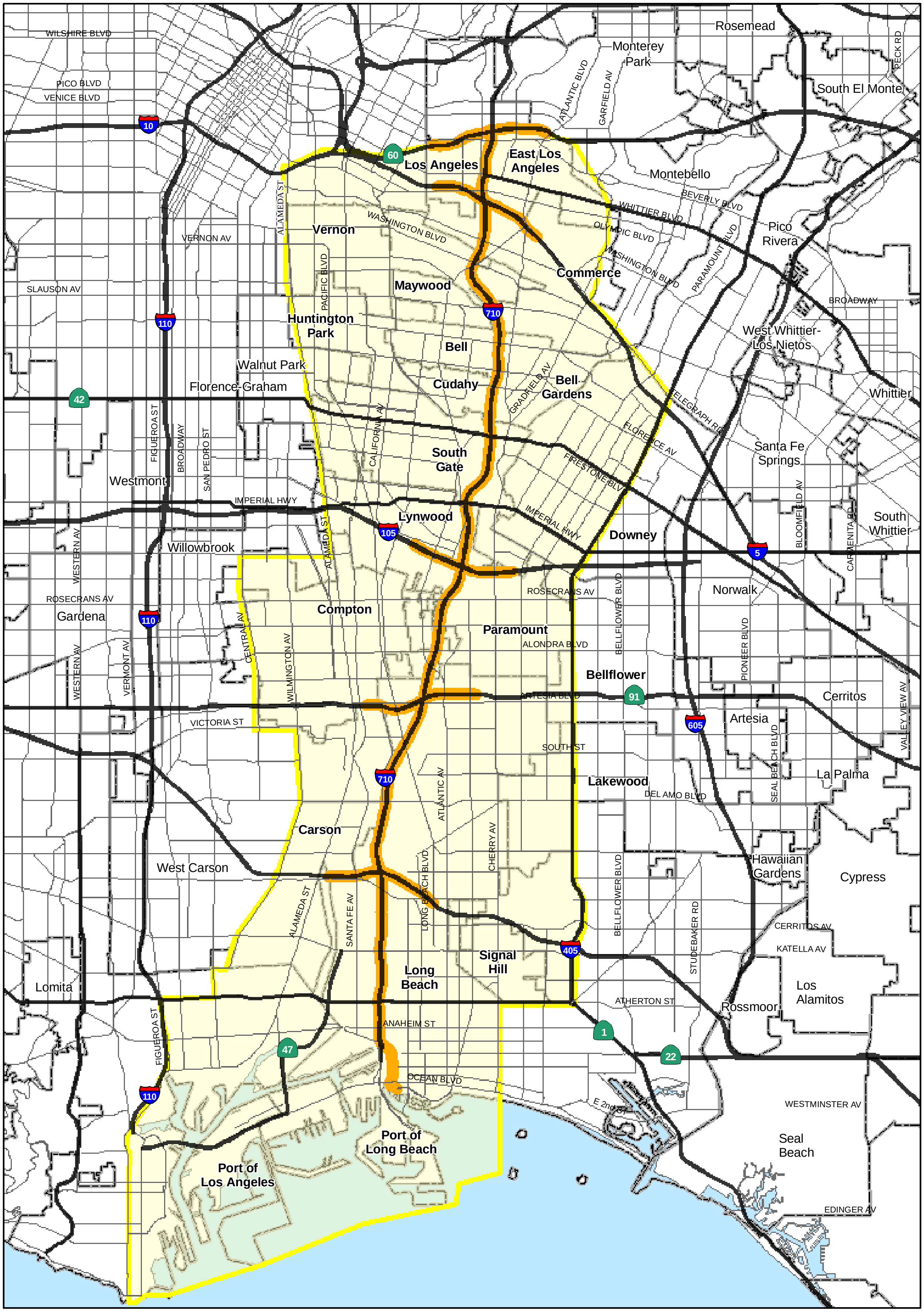

FIGURE ES-1

0 2.75
Miles

SOURCE: ESRI (2005); TBM (2007)

I-710 Corridor Project

Study Area

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NOTICE OF PREPARATION/NOTICE OF INTENT

The scoping process for the I-710 Corridor Project was initiated with the preparation and distribution of a Notice of Preparation (NOP) and the publication of a Notice of Intent (NOI) in the Federal Register.

The NOP was posted at the State Clearinghouse (SCH #2008081042) and circulated to public agencies and other interested parties in compliance with Section 15082 of the CEQA Guidelines on August 15, 2008. The NOP notified the public of the EIR/EIS being prepared along with the scoping meeting locations and how to provide comments on the project.

The NOI was published on August 20, 2008, in the Office of the Federal Register in compliance with federal regulation 40 CFR 1508.28. The NOI included background of the project, purpose and need, brief description of the proposed alternatives, information regarding the scoping meeting locations, and how to provide comments on the project.

Twenty-five comments were received from federal, State, and regional/County agencies, as well as members of the public in response to the NOP and/or NOI. Key issues included but are not limited to: alternatives; air quality and public health impacts; biological resources; noise; traffic impacts; environmental justice; and mitigation.

NOTICE OF SCOPING/INITIATION OF STUDIES LETTERS

Caltrans also distributed Notice of Scoping/Initiation of Studies letters to officially inform agencies, groups, organizations, and other interested parties of the initiation of studies for improvements to I-710 and that Caltrans will prepare a Draft EIR/EIS to evaluate the anticipated environmental effects and recommend measures to mitigate those effects pursuant to CEQA and NEPA. A total of 288 notices were sent to elected officials, agencies, and interested parties.

COOPERATING AND PARTICIPATING AGENCY LETTERS

Effective July 1, 2007, the Federal Highway Administration (FHWA) assigned, and Caltrans assumed, all the United States Department of Transportation (USDOT) Secretary's responsibilities under NEPA pursuant to Section 6005 of SAFETEA-LU. Caltrans assumed all of FHWA's responsibilities under NEPA for projects on California's State Highway System (SHS) and for federal-aid local streets and roads projects under FHWA's Surface Transportation Project Delivery Pilot Program pursuant to 23 CFR 773, including the I-710 Corridor Project. Caltrans also assumed all of FHWA's responsibilities for environmental coordination and consultation under other federal environmental laws pertaining to the review or approval of projects under the Pilot Program.

Pursuant to this NEPA assumption of responsibilities, Caltrans sent letters to federal agencies, inviting them to be Cooperating and/or Participating Agencies for the EIR/EIS for the proposed project, and also sent letters to nonfederal agencies that may have an interest in the project inviting them to be Participating Agencies. A total of 67 agencies (7 federal, 17 State, and 43 regional/County) were asked to accept or decline Caltrans' invitation to become a Cooperating and/or Participating Agency. The United States Environmental Protection Agency (USEPA) and United States Army Corps of Engineers (USACE) accepted the invitation to become a Cooperating Agency and Participating Agency. The County of Los Angeles Department of Public Works, Los Angeles County Department of Regional Planning, County of Sanitation Districts of Los Angles County, City of Lynwood, City of Vernon, and the Alameda Corridor Transportation Authority all accepted their invitation to become a Participating Agency. Both the United States Fish and Wildlife Service (USFWS) and United States Department of Homeland Security-Federal Emergency Management Agency (FEMA) declined their invitations to be Cooperating Agencies; however, USFWS accepted the invitation to be a Participating Agency. No other responses were received. An agency's nonresponse is considered an acceptance to the invitation.

PRESCOPING AND SCOPING MEETINGS

Prior to the review period of the NOP, 30 public participation meetings were held with Local Advisory Committees (LACs) from March 2008 to August 2008, separate from the I-710 scoping meetings, to review the project with the affected communities. The LACs are part of an extensive Community Participation Framework being managed by the Los Angeles County Metropolitan Transportation Authority (Metro) and the Gateway Cities Council of Governments (GCCOG) for the I-710 Corridor Project. The LACs for the I-710 Corridor Project were appointed by the local city council/county supervisor and provide an ongoing forum for citizen involvement in the project at the community level. The chairs of the LACs also serve on the Corridor Advisory Committee (CAC) for the I-710 Corridor Project, which reports to the Project Committee, which includes an elevated official from each local agency.

During September 2008, scoping meetings were held in the communities of Paramount, East Los Angeles, and Long Beach to provide an overview of the project and a summary of the environmental process and issues identified to date. Several methods of notification were used in addition to the publication of the NOP and NOI to notify the public of the scoping period and meetings: a newsletter, e-mail, public notices (Los Angeles Times, Long Beach Press Telegram, Mundo LA, Los Angeles Eastside Sun, and Los Angeles Watts Times), and the project Web site at http://www.metro.net/projects_studies/I710/default.htm.

Thirty-two verbal comments were received at the scoping meetings, as well as 10 written comments. Key issues submitted by individuals included, but are not limited to, the following: air quality impacts, noise impacts, aesthetics, community impacts, environmental justice, alternatives, and public transportation.

COMMENT SUMMARY

Comments received during the scoping period focused on three main issues: environmental impacts, alternatives, and coordination with related projects. Several comments also requested previous studies and reports for the project area be considered during the planning stages.

Environmental Impacts

Air Quality Impacts – The majority of comments received included concerns regarding air quality and public health. Requests were made to complete a Health Risk Assessment, dispersion modeling, Mobile Source Air Toxics analysis, and a diesel particulate matter analysis, and to develop feasible mitigation measures.

Noise Impacts – Comments included concerns regarding noise impacts, and requests were made for sound barrier construction near homes and schools.

Property Impacts – Comments included concerns regarding purchasing properties and what the process would be should a property owner have a loan for more money than the value of the property at the time of purchase.

Biological Resources – Comments from the USFWS and CDFG included requests to consider alternatives that could avoid and/or reduce impacts to listed species, sensitive species, and vegetation types. Comments requested discussion of impacts to significant ecological areas and environmental sensitive areas be included in the Draft EIR/EIS. Comments were also received regarding the replanting of trees in the corridor.

Land Use Impacts – Comments included concerns regarding impacts to residential buildings, community facilities, and businesses.

Traffic – The majority of comments received included concerns with traffic congestion on the freeway and local streets, the use of trucks on the freeway contributing to traffic congestion, and the need for additional on- and off-ramps. Several comments opposed implementation of double decking to relieve traffic congestion.

Floodplains – USACE requested further coordination and involvement in the project to work toward reducing potential impacts to the Los Angeles River flood control levees and/or channel. FEMA identified the requirement to comply with the National Flood Insurance Program and floodplain management building requirements.

Construction Impacts – Several comments included requests for notification of construction schedules and that construction impacts be analyzed for the project.

Cumulative Impacts – Comments requested cumulative impacts, as well as direct and indirect impacts, be considered as a result of the project.

Alternatives

Alternative Technology – Several comments included requests for considerations of alternative technology and expansion of public transportation. Several comments recommended implementation of a light rail system and use of a fuel-saver transit system called Citicar.

Alameda Corridor – Several comments requested the Alameda Corridor be considered for improvements instead of implementation of the I-710 Corridor Project.

Related Projects

I-5 Corridor Improvement Project (I-605 to I-710) – Comments included concern about coordination between the I-710 Corridor Project and the Interstate 5 (I-5) Corridor Improvement Project, including scoping and the configuration of the interchange for the two freeways.

Southern California International Gateway – Several comments referenced the Southern California International Gateway (SCIG) project, a near-dock intermodal facility proposed by Burlington Northern Santa Fe (BNSF), and how this project would impact the local area.

Riverlink – Comments included concern with how the project would impact implementation of the Riverlink project.

I-710 Tunnel/Valley Boulevard Project and Alhambra Avenue Connection Road project – Comments included concern with how the I-710 Corridor Project would impact implementation of the I-710 Tunnel/Valley Boulevard Project and the Alhambra Avenue Connection Road project.

COORDINATION WITH THE I-5 PROJECT

The LAC representing the East Los Angeles community requested the I-710 Corridor Project to coordinate with the I-5 improvement project between Interstate 605 (I-605) and I-710 since I-710 and I-5 project study areas overlap and both projects will be following similar environmental planning timelines. Coordination has begun between the two projects and will continue as the environmental process continues for both projects.

1.0 INTRODUCTION

Caltrans is working to study alternatives for constructing freeway improvements to I-710 from Ocean Boulevard in the City of Long Beach to SR-60 in Los Angeles County, California. Figure 1 depicts the I-710 Corridor Project study area. Alternatives initially under study include: (1) the No Build Alternative; (2) Transportation Systems Management/Transportation Demand Management; (3) Goods Movement Enhancement by Rail and/or Advanced Technology; (4) Arterial Highway and I-710 Congestion Relief Improvements; (5) Mainline I-710 Improvements with 10 general-purpose lanes and no carpool lanes; (6) Mainline I-710 Improvements with 8 general-purpose lanes and 1 carpool lane in each direction; and (7) the Locally Preferred Strategy (LPS) Hybrid Design (I-710 Mainline Improvements with the addition of a 4-lane separated freight movement facility).

The purpose of the I-710 Corridor Project is to (1) improve air quality and public health, (2) improve traffic safety, (3) address design deficiencies, (4) address projected traffic volumes, and (5) address projected growth in population, employment, and economic activities related to goods movement. The I-710 Corridor Project is a continuation of the study of project issues identified in the Major Corridor Study (MCS) completed in March 2005. The MCS identified 10 general-purpose lanes next to a 4-lane separated freight movement facility as the LPS.

A Draft Environmental Impact Report/Environmental Impact Statement (EIR/EIS) is being prepared for the I-710 Corridor Project. The first step in preparing the Draft EIR/EIS is conducting scoping in accordance with the Council on Environmental Quality Guidelines for implementing NEPA (40 Code of Federal Regulations [CFR] 1500–1508) and FHWA's guidelines for implementing NEPA (23 CFR 771). The purpose of the scoping process is to describe the proposed project and to solicit input from the general public and public agencies regarding the project purpose and need, the proposed alternatives, and the scope of the analysis to be included in the Draft EIR/EIS.

In addition to requirements under NEPA, Section 15082(c) of CEQA Guidelines (2005) states the following:

> (1) For projects of statewide, regional or areawide significance pursuant to Section 15206, the lead agency shall conduct at least one scoping meeting. The lead agency shall provide notice of the scoping meeting to all of the following:

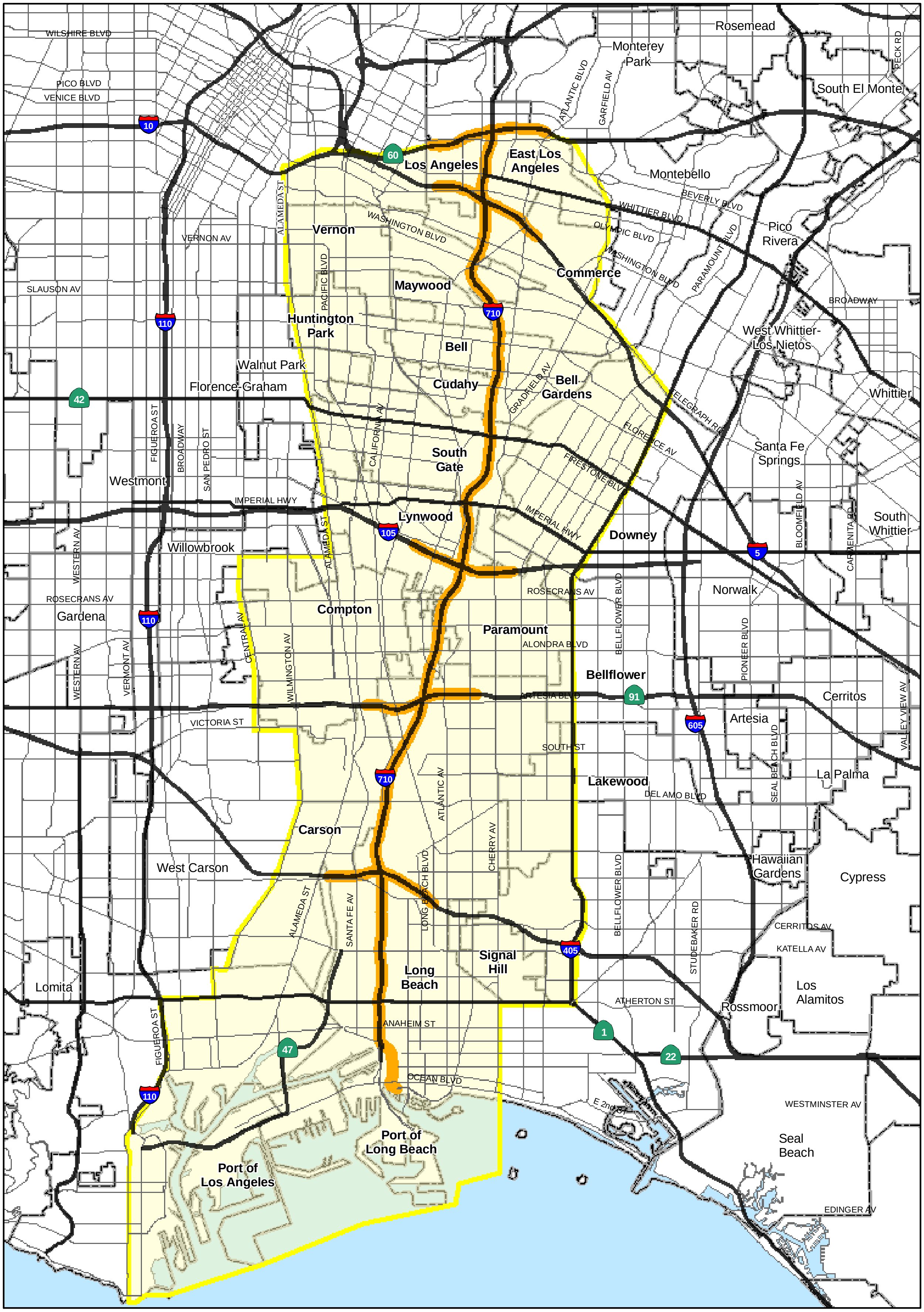

FIGURE 1

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0 2.75

Miles

SOURCE: ESRI (2005); TBM (2007)

I-710 Corridor Project

Study Area

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(A) any county or city that borders on a county or city within which the project is located, unless otherwise designated annually by agreement between the lead agency and the county or city;

(B) any responsible agency;

(C) any public agency that has jurisdiction by law with respect to the project; and

(D) any organization or individual who has filed a written request for the notice.

This Scoping Summary Report describes the process undertaken by Caltrans as the Lead Agency, as well as Metro and the other agency funding partners (Southern California Association of Governments [SCAG], Gateway Cities Council of Governments [GCCOG], Port of Los Angels [POLA], Port of Long Beach [POLB], and I-5 Joints Powers Authority [JPA]), to involve the public, to obtain comments on the purpose and need of the proposed project, proposed alternatives, potential environmental impacts and issues, and the scope of the environmental document. In addition, this report summarizes the issues and comments raised during the formal scoping period (August 15, 2008, to September 30, 2008) and also contains the actual comments received.

2.0 NOTICE OF PREPARATION AND NOTICE OF INTENT

The scoping process for the I-710 Corridor Project was initiated with the preparation and distribution of an NOP and the publication of an NOI in the Federal Register. Both the NOI and NOP are intended to inform public agencies and the general public about the project and the environmental review process. Comments and suggestions were invited from all interested parties in order to ensure that the full range of issues related to the proposed project, including reasonable alternatives and mitigation measures, are identified in the Draft EIR/EIS.

2.1 NOTICE OF PREPARATION

The NOP (posted at SCH #2008081042) was circulated to public agencies and other interested parties in compliance with Section 15082 of the CEQA Guidelines on August 15, 2008. Copies of the NOP are provided in Attachment A and a copy of the master distribution list, which shows recipients of the NOP is provided in Attachment B.

2.2 NOTICE OF INTENT

The NOI was published on August 20, 2008, in the Office of the Federal Register in compliance with federal regulation 40 CFR 1508.28. The NOI and Federal Register publication are provided in Attachment C.

2.3 NOP/NOI RESPONSES

Letters in response to the NOP/NOI were received by Caltrans and Metro and will be considered in developing the alternatives and issues to be analyzed in the Draft EIR/EIS. Many of the comments received provided valuable insights into the issues and concerns of potentially affected agencies, groups, communities, and individuals, and identified areas of concern that Caltrans expects to analyze in the Draft EIR/EIS. A summary of all substantive comments and key issues raised in the letters are listed below in Table A. The actual NOP/NOI response letters are provided in Attachment D.

Table A NOP/NOI Comment Summary

Agency Name	
Federal Agencies	
United State Environmental Protection Agency	Recommendations regarding project scope and purpose; Alternatives Analysis process recommendations; DEIS should provide detailed discussion and measurements of Mobile Source Air Toxins. Also included recommendations for a Construction Emissions Mitigation Plan. The EPA also commented on its concerns regarding the following topics: Transportation Conformity, Greenhouse Gas Emissions, Environmental Justice, Health Impact Assessment Cumulative Impact Analysis, and Water and Wetlands Resources.
Federal Emergency Management Agency (FEMA)	Identified concerns with compliance with the National Flood Insurance Program requirements and minimum floodplain management building requirements. Requested appropriate hydrologic and hydraulic data be submitted to FEMA for a Federal Insurance Rate Map (FIRM) revision if there any changes to the existing Special Flood Hazard Areas.
United States Fish and Wildlife Service	Recommendations to include protection of public fish and wildlife resources and habitat, and analysis of impacts to migratory birds. Requested that project include all practicable alternatives that have been considered to avoid and/or reduce project impacts to federally listed and other sensitive species and vegetation types. Also commented on concerns regarding the following topics: Cumulative Effects, Riparian habitat at DeForest Park, and habitat creation areas along the Los Angeles River for runoff treatment.
United States Army Corps of Engineers	Noted several proposed alternatives would require approval by the USACE that must comply with NEPA. Accepted invitation to become Cooperating and Participating Agency and requested to be involved in the review, screening, and analysis of alternatives. Encouraged development of alternatives that reduce or eliminate impact or redesign of Los Angeles River flood control levees and/or channel. Disclosed that due to the large nature of the project, the USACE may request additional funds to handle the necessary actions under the environmental review process.
State Agencies	
California Department of Fish and Game	Requested a description of the following be included in the Draft EIR: purpose and need; staging areas; access routes; utility relocations; impacts to biological resources, including any modifications to the Los Angeles River, Rio Hondo

Table A NOP/NOI Comment Summary

Agency Name	
	River, Compton Creek, and Ports of Long Beach and Los Angeles drainages; impacts to rare natural communities on site and within the area of impact; addressing of any significant ecological areas or environmental sensitive areas; discussion of listed and sensitive species and their habitats; direct, indirect, and cumulative impacts; mitigation measures; alternatives that avoid or substantially lessen impacts; a California Endangered Species Act (CESA) permit; identification of any locations of State Fully Protected Species in the project corridor; watercourses; edge effects; and best management practices (BMPs).
Native American Heritage Commission	Outlines the process to adequately assess the project-related impacts as well as the preservation of California's Native American cultural resources. Also attached the Native American contact list.
Regional Agencies	
Southern California Regional Rail Authority – Metrolink	Identified the need to protect and preserve the current BNSF and Union Pacific (UP) rights-of-way and to accommodate future rail improvements and rail expansion projects. Requested coordination with Caltrans during the project planning and construction phases to minimize service disruptions during construction.
South Coast Air Quality Management District (SCAQMD)	Recommendations to perform health risk assessment (HRA) that includes air dispersion modeling, the quantified health risk, and a significance determination in the Draft EIR. Offered SCAQMD data sources for project use while conducting the HRA, dispersion modeling, air quality analysis, and development of mitigation measures.
County Agencies	
Los Angeles County Department of Regional Planning	Pleased the document will include Air Quality and HRA and stated concerns with the future highway projects not increasing traffic, air quality, and health impacts. Requested that land use impacts be minimized and any impacts to residential buildings, community facilities, businesses, and other community structures be analyzed. Requested the EIR/EIS also examine whether there is additional capacity on the Alameda Corridor.
County Sanitation Districts of Los Angeles County	Requested a map of the proposed project alignment be submitted so the district can forward plans of existing and planned for facilities (i.e., trunk sewers) that would be impacted by the project.

Table A NOP/NOI Comment Summary

Agency Name	
City Agencies	
City of Commerce	Recommended that communication be maintained with the I-710 LAC regarding all aspects of the proposed project. Requested the following be completed: an HRA and a socioeconomic impact study. Requested the following be identified and studied: air pollution impacts; global warming impacts; noise standards and noise impacts; growth impacts; construction-related impacts; aesthetic impacts; traffic impacts; maintenance and operation impacts; and impacts to the storm water runoff and discharge. Requested that both public and private reasonably foreseeable future projects be included in the analysis and that there be continued coordination with other projects in the area. Requested details on the proposed alternatives, including the high-occupancy vehicle (HOV) lanes, and that improvements be proposed for all arterial intersections between I-5 and I-710. Requested the project be designed with architectural and aesthetic sensibility. Requested the assumptions for growth in containerized cargo volume at the Ports of Long Beach and Los Angeles be provided and fully analyzed.
City of Los Angeles – Department of Water and Power	Requested the feasibility of the preferred alternative with respect to continued operation of the transmission lines be resolved.
City of Maywood	Requested an on- and off-ramp at Slauson Avenue on I-710.
City of Signal Hill	Requested the traffic impacts to the Cherry Avenue and I-405 Freeway interchange be analyzed as part of the Draft EIR.
Interested Groups and Organizations	
Aline Beausejour and Denny Hambly	Concerned with traffic congestion and increased cost of living.
Dale Lawrence Jensen – JENTEC	Concerned with the restoration of the Los Angeles river and its riparian environment and separation of automobile and truck traffic into separate rights-of-way. Requested the bicycle path along the river from Union Station to Long Beach be maintained and a new right-of-way be built for trucks only to relieve the congestion.

Table A NOP/NOI Comment Summary

Agency Name	
Dave Hall	Concerned with the following: how the project will impact the completion of the Riverlink project; impacts to the Willow Street wetlands; impacts to the California least tern in San Pedro Bay; impacts to the peregrine falcon nests; and impacts to human health.
Jaime Herrera	Concerned with the cost of the project and meeting the proposed goals and objectives. Requested the project look into alternative technology (electric cars) and public transportation on all freeways.
Kendall Rainwater	Requested clarification on how conveyor belts enhance the movement of containers and if rail will be available to transport the containers from the Ports to these locations, and requested a copy of the 2008 I-710 Major Corridor Study Hybrid Design Concept. Concerned with where the transition of southbound I-405 and northbound I-710 will be. Expressed opposition for double-decking the I-710 freeway.
Long Beach Unified School District	Requested the following: the Draft EIR/EIS should identify the location of schools in the vicinity of the project so that impacts to schools can be evaluated; evaluation of the impacts of truck versus rail goods movement; inclusion of a comprehensive analysis of potential air quality, public health, transportation, and noise impacts to schools; clear identification of any limitations in the HRA and which health effects are being assessed; identification of impacts with regard to traffic, access, circulation, and safety conditions; and identification of impacts from pile driving and other activities associated with construction. Concerned with direct, indirect, and cumulative impacts to schools. Requested notification of construction schedules.
Natural Resource Defense Council	Requested cumulative impacts and direct and indirect effects be considered in the analysis. Requested all data and information contemplated be disclosed that is used for the analysis and conclusions. Requested the project include the fundamentals of CEQA, including the following: evaluation of all reasonable alternatives; detailed project purpose and objectives; and discussions on cumulative impacts, alternatives, and feasible mitigation measures. Requested the project provide a rationale for segmenting out truck and rail into two separate approaches to move goods. Requested the project purpose represent the I-710 corridor as a goods movement corridor and stated

Table A NOP/NOI Comment Summary

Agency Name	
	that the main consideration is how best to facilitate the movement of goods. Included several questions about baseline conditions. Requested the EIR/EIS include the following: a detailed analysis of the effects of diesel particulates on those living and working near the project; evaluation and examination of all potential health effects caused by the project; discussion of traffic-inducing and congestion-producing impacts; discussion of irreversible impacts to habitat, navigable waterways, recreation resources, and water quality; and growth of goods movements infrastructure at the ports and in the Inland Empire.
Paramount Unified School District	Requested all environmental impacts to school in the District be considered and the District be added to the mailing list.
Porona1060@aol.com	Requested the following items be addressed: traffic estimates from the Port of Long Beach to the beginning southern portal of the proposed I-710 Tunnel; any transportation relationships between the project and the I-710 Tunnel/Valley Boulevard and Alhambra Avenue Connector Road Project and how the project impacts implementation of this other project; and other urban transportation plans.
Rose E. Rojas	Requested information about what trees will be considered to make the freeway more attractive and voiced support for designated truck lanes and limited access. Requested information about what will happen to the trucks traveling from Long Beach to SR-60.
Robert L Stiles – Citicar	Provided information about a fuel-saver transit system in response to a need for public mass transit, pollution from diesel trucks, and traffic congestion.
Southern California Edison (SCE)	Concerned with the potential impact the project may have on SCE facilities within the project area, including those impacts associated with the possible relocation of electric facilities and potential need for land acquisition and/or possible condemnation of private property that Metro and/or Caltrans may need to pursue in the project. Disclosed that relocation of any SCE electric facilities operating at or above 50 kilovolts (kV) may require additional CEQA review, which could delay the project.

3.0 NOTICE OF SCOPING / INITIATION OF STUDY LETTERS

Caltrans distributed Notice of Scoping/Initiation of Studies letters to elected officials within the I-710 Corridor Project study area and to a number of agencies, groups, organizations, and other interested parties. The purpose of these letters was to officially inform agencies, groups, organizations, and other interested parties of the initiation of studies for improvements to I-710 and that Caltrans will prepare a Draft EIR/EIS to evaluate the anticipated environmental effects and recommend measures to mitigate those effects pursuant to CEQA and NEPA.

The Notice of Scoping/Initiation of Studies letter were sent to the agencies, elected and City officials, and other interested parties along with the NOP for the I-710 Corridor Project in August 2008. A copy of the agency, elected official and interested parties Notice of Scoping/Initiation of Studies letters are provided in Attachment E. The list of recipients of the Notice of Scoping/Initiation of Studies letter is provided in the master distribution list in Attachment B.

4.0 COOPERATING AND PARTICIPATING AGENCY LETTERS

NEPA requires that the federal Lead Agency invite other federal agencies that have jurisdiction by law or special expertise with respect to any environmental impact involved in a proposed project to be Cooperating Agencies during the environmental process for a proposed project. In addition, Section 6002 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) requires that federal and nonfederal agencies that may have an interest in the project be invited to become a Participating Agency in the project's environmental review process. A Participating Agency has certain opportunities and obligations to comment/provide input at specific times. One of the provisions in Section 6002 stipulates that once issues are raised and resolved, they cannot be raised again later in the review process.

A federal agency can elect to be both a Cooperating and a Participating Agency. Generally, with limited exceptions, only federal agencies can be Cooperating Agencies.

Effective July 1, 2007, FHWA assigned, and Caltrans assumed, all USDOT Secretary's responsibilities under NEPA pursuant to Section 6005 of SAFETEA-LU, codified at 23 United States Code (U.S.C.) 327(a)(2)(A). Caltrans assumed all of FHWA's responsibilities under NEPA for projects on California's State Highway System (SHS) and for federal-aid local streets and roads projects under FHWA's Surface Transportation Project Delivery Pilot Program pursuant to 23 CFR 773, including the I-710 Corridor Project. Caltrans also assumed all of FHWA's responsibilities for environmental coordination and consultation under other federal environmental laws pertaining to the review or approval of projects under the Pilot Program. For purposes of carrying out the responsibilities assumed under the Pilot Program, Caltrans is deemed to be acting as the FHWA with respect to the environmental review, consultation, and other actions required under those responsibilities.

Therefore, Caltrans sent Cooperating Agency letters to seven federal agencies, inviting them to be Cooperating and/or Participating Agencies for the EIR/EIS for the proposed project. If an agency elects to become a Cooperating Agency, they are also considered Participating Agencies. Letters were sent differentiating whether the agency had legislative or regulatory jurisdiction over portions of the study area or whether the agency may have interest over the legislative or regulatory jurisdiction of the study area. Copies of the Cooperating Agency letters are provided in Attachment F.

The list of federal agencies invited to be Cooperating Agencies is provided in Table B. The USEPA and USACE responded to accept the invitation to become a Cooperating Agency and Participating Agency. The USFWS responded to decline the invitation to become a Cooperating Agency but will provide technical assistance as a Participating Agency in the planning process. An agency's nonresponse is considered an acceptance of the invitation.

Caltrans, on behalf of FHWA, also sent Participating Agency letters to agencies that may have an interest in the project. Letters were sent differentiating whether the agency had legislative or regulatory jurisdiction over portions of the study area or whether the agency may have interest over the legislative or regulatory jurisdiction of the study area. The list of agencies invited to be Participating Agencies is also provided in Table B. Copies of the Participating Agency letters are provided in Attachment F.

Table B Agencies Invited to become Cooperating/Participating Agencies

Agency Name	
Federal Agencies	
Office of Env. Policy and Compliance, U.S. Dept. of the Interior Oakland Reg. Patricia Port, Reg'l Env. Officer Jackson Center One, 1111 Jackson Street, Suite 520 Oakland, CA 94607	Federal Emergency Management Agency Environment and Historic Preservation, Region IX Sandro Amaglio, 1111 Broadway, Suite 1200 Oakland, CA 94607-7027
National Park Service, U.S. Dept. of the Interior Pacific West Region John Jarvis, Regional Dir. 1111 Jackson Street, Suite 700 Oakland, CA 94607	National Oceanic and Atmospheric Administration Fisheries Christopher M. Moore, Division Chief 1401 Constitution Avenue, NW, Room 6217 Washington, D.C. 20230
U.S. Fish and Wildlife Service, Ventura Office Steve Kirkland, Biologist 2493 Portola Road, Suite B Ventura, CA 93003	U.S. Army Corps of Engineers Regulatory Division, Los Angeles District Mark Cohen, 911 Wilshire Boulevard, P.O. Box 2711 Los Angeles, CA 90053-2325
U.S. Env. Protection Agency Env. Review Office, Region 9 Susan Sturges, 75 Hawthorne Street San Francisco, CA 94105	Intentionally Left Blank
State Agencies	
California Dept. of Fish and Game Ed Pert, Regional Mgr. 4949 Viewridge Avenue San Diego, CA 92123	Native American Heritage Commission 915 Capitol Mall, Rm. 364 Sacramento, CA 95814
California Highway Patrol S.V. Bernard, Captain 411 N. Central Avenue, Suite 410 Glendale, CA 91203	California Air Resources Board 1001 "I" Street, P.O. Box 2815 Sacramento, CA 95812

Table B Agencies Invited to become Cooperating/Participating Agencies

Agency Name	
California Department of Conservation 801 "K" Street, MS 24-01 Sacramento, CA 95814	Office of Historic Preservation 1416 9th Street, Rm. 1442-7 Sacramento, CA 95814
California Integrated Waste Management Board Office of Education and the Environment 1001 "I" Street, P.O. Box 4025 Sacramento, CA 95814	State Water Resources Control Board 1001 "I" Street Sacramento, CA 95814
California Coastal Commission South Coast District Office John (Jack) Ainsworth, Deputy Dir. 200 Oceangate, 10th Floor Long Beach, CA 90802-4416	California Resources Agency 1416 Ninth Street, Suite 1311 Sacramento, CA 95814
California Department of Toxic Substances Control Los Angeles Environmental Chemistry Lab 1449 W. Temple Street, Room 101 Los Angeles, CA 90026-5698	California Farm Bureau Federation Los Angeles County Farm Bureau 41228 12th Street West, Suite A Palmdale, CA 93551
Governor's Office of Emergency Services 3650 Schriever Avenue Mather, CA 95655	California Public Utilities Commission San Francisco/Environmental Office 505 Van Ness Ave San Fransisco, CA 94102
California Department of Water Resources Division of Environmental Services 1416 9th Street Sacramento, CA 95814	Intentionally Left Blank
Regional/County Agencies	
Los Angeles RWQCB – Region 4 320 W. 4th Street, Suite 200 Los Angeles, CA 90013	Metropolitan Water District Planning Division 700 North Alameda Street, P.O. Box 54153 Los Angeles, CA 90012
South Coast Air Quality Management District 21865 East Copley Drive Diamond Bar, CA 91765	Southern California Association of Governments Philip Law, Corridors Program Mgr. 818 W. Seventh Street, 12th Floor Los Angeles, CA 90017
Metropolitan Transportation Authority CMP/Environmental Review One Gateway Plaza Los Angeles, CA 90012	Alameda Corridor Transportation Authority Arthur B. Goodwin, Dir. of Planning One Civic Plaza, Suite 350 Carson, CA 90745

Table B Agencies Invited to become Cooperating/Participating Agencies

Agency Name	
Southern California Regional Rail Authority (Metrolink) Planning Department 700 S. Flower Street, Suite 2600 Los Angeles, CA 90017	I-5 Joint Powers Authority 919 Appalachian Claremont, CA 91711
Long Beach Transit Larry Jackson, President P.O. Box 731 Long Beach, CA 90801	LAFCO for Los Angeles County 700 North Central Boulevard, Suite 445 Glendale, CA 91203
Los Angeles County Sheriff's Department 4700 Ramona Blvd. Monterey Park, CA 91754	Los Angeles County Department of Public Works Environmental Programs 900 South Freemont, Third Floor Annex Alhambra. CA 91803
Los Angeles County Sanitation District P.O. Box 4998 1955 Workman Mill Road Whittier, CA 90607-4998	Los Angeles Department of Water and Power Planning Division 111 North Hope Street Los Angeles, CA 90012
Los Angeles County Department of Public Works, Environmental Programs 900 South Freemont Avenue Alhambra, CA 91803	Los Angeles County Department of Regional Planning Hall of Records 320 West Temple Street, 13th Floor Los Angeles, CA 90012
County of Los Angeles Parks/Recreation 433 South Vermont Avenue Los Angeles, CA 90020	Los Angeles County Department of Public Health Environmental Health Division 5050 Commerce Drive Baldwin Park, CA 91716
Los Angeles County Fire Department Fire Prevention Division Headquarters 5823 Rickenbacher Road Commerce, CA 90040	Los Angeles County Health Services Office of Planning 313 N. Figueroa Street, Room 704 Los Angeles, CA 90012
Long Beach Transit Larry Jackson, President P.O. Box 731 Long Beach, CA 90801	City of Long Beach Water Dept. Ryan J. Alsop, Dir., Government and Public Affairs 1800 E. Wardlow Road Long Beach, CA 90807
City of Vernon Eric T. Fresch, Acting City Administrator 4305 Santa Fe Avenue Vernon, CA 90058	Gateway Cities Council of Governments (GCCOG) Richard Powers, Exec. Dir. 16401 Paramount Boulevard Paramount, CA 90723

Table B Agencies Invited to become Cooperating/Participating Agencies

Agency Name	
City of Signal Hill Kenneth C. Farfsing, City Mgr. 2175 Cherry Avenue Signal Hill, CA 90755	City of South Gate Ronald Bates, City Mgr. 8650 California Avenue South Gate, CA 90280
City of Maywood Edward Ahrens, City Mgr. 4319 E. Slauson Avenue Maywood, CA 90270	City of Paramount Linda Benedetti-Leal, City Mgr. 16400 Colorado Avenue Paramount, CA 90723
City of Los Angeles James A. Gibson, Exec. Officer, Board of Public Works 200 North Spring Street Los Angeles, CA 90012	City of Lynwood Roger Haley, City Mgr. 11330 Bullis Road Lynwood, CA 90262
City of Lakewood Howard L. Chambers, City Mgr. 5050 Clark Avenue Lakewood, CA 90712	City of Long Beach Patrick H. West, City Mgr. 333 W. Ocean Blvd Long Beach, CA 90802
City of Downey Brian A. Ragland, Public Works Dir. 11111 Brookshire Avenue Downey, CA 90241	City of Huntington Park Gregory Korduner, City Mgr. 6550 Miles Avenue Huntington Park, CA 90255
City of Cudahy George Perez, City Mgr. or Public Works Dir. 5220 Santa Ana Street Cudahy, CA 90201	City of Compton Charles Evans, City Mgr. 205 S. Willowbrook Avenue Compton, CA 90220
City of Commerce Jorge Rifa, City Administrator 2535 Commerce Way Commerce, CA 90040	City of Commerce Daniel Gomez 2535 Commerce Way Commerce, CA 90040
City of Bell Robert Rizzo, City Mgr. 6330 Pine Avenue Bell, CA 90201	City of Bell Gardens John A. Ornelas, City Mgr. 7100 S. Garfield Avenue Bell Gardens, CA 90201
County of Los Angeles Dean D. Efstathiou, Public Works Dir. 900 S. Fremont Avenue Alhambra, CA 91803	Port of Los Angeles Kerry Cartwright, Dir. of Goods Movements 425 South Palos Verdes Street San Pedro, CA 90731
Port of Long Beach Eric Shen, Dir. of Transportation Planning 925 Harbor Plaza Long Beach, CA 90802	City of Carson Jerome G. Groomes, City Mgr. 701 E. Carson Street Carson, CA 90745

Table B Agencies Invited to become Cooperating/Participating Agencies

Agency Name	
Unincorporated Los Angeles County (East Los Angeles) Bruce McClendon, Planning Director 1390 Hall or Records, 320 W. Temple St Los Angeles, CA 90012	Intentionally Left Blank

Table C summarizes the agencies that replied to the invitation to become a Cooperating and/or Participating Agency. The response letters are provided in Attachment G. As indicated previously, an agency's nonresponse is considered an acceptance of the invitation; therefore, all agencies listed in Table B that did not decline the invitation will be considered Participating Agencies for the project.

Table C Summary of Participating/Cooperating Agencies

Agency Name	Comment
EPA Region IX	Accepts the invitation to become a Participating and Cooperating Agency.
USFWS	Declines the invitation to become a Cooperating Agency but will provide technical assistance as a Participating Agency in the planning process.
USACE	Accepts the invitation to become a Participating and Cooperating Agency.
United States Department of Homeland Security – FEMA	Declines the invitation to become a Participating Agency as the agency does not have the jurisdiction to or authority with respect to proposed improvements.
County of Los Angeles Department of Public Works	Accepts the invitation to become a Participating Agency.
Los Angeles County Department of Regional Planning	Accepts the invitation to become a Participating Agency.
County of Sanitation Districts of Los Angeles County	Accepts the invitation to become a Participating Agency.
City of Lynwood	Accepts the invitation to become a Participating Agency and requests the Lynwood Redevelopment Agency be included.
City of Vernon	Accepts the invitation to become a Participating Agency.
Alameda Corridor Transportation Authority	Accepts the invitation to become a Participating Agency.

5.0 PRE-SCOPING AND SCOPING MEETINGS

5.1 PRE-SCOPING MEETINGS

Prior to the review period of the Notice of Preparation, 30 public participation meetings were held with LACs from March 2008 to August 2008, separate from the I-710 scoping meetings, to review the project with the affected communities. The LACs are part of an extensive Community Participation Framework being managed by Metro and the GCCOG for the I-710 Corridor Project. The LACs for the I-710 Corridor Project were appointed by the local city council/county supervisor and provide an ongoing forum for citizen involvement in the project at the community level. The chairs of the LACs also serve on the CAC for the I-710 Corridor Project, which reports to the Project Committee, which also includes an elected official from each local agency. See Attachment H for a copy of the Community Participation Framework for the I-710 Corridor Project and Attachment I for examples of the Pre-Scoping meeting handouts and presentations.

5.2 SCOPING MEETINGS

During the review period of the NOP and NOI, scoping meetings were held in three different locations in the study area to provide an overview of the project and a summary of the environmental process and issues identified to date, and to receive input regarding the project purpose and need, project alternatives, environmental issues, and the suggested scope and content of the EIR.

5.2.1 Public Notification

Several methods of notification were used in addition to the publication of the NOP and NOI to notify the public of the scoping period and meetings: a newsletter, e-mail, public notices, and the project Web site at http://www.metro.net/projects_studies/I710/default.htm.

A newsletter for the project was sent to all current and former I-710 committee members (Tier 1 and Tier 2 Committee members from the previous MCS, and LAC and CAC from the current committee structure). The newsletter was also made available at all City Halls within the project limits and at Supervisor Gloria Molina's office. Additionally, several hundred newsletters and scoping invitations were given to each LAC to distribute within their respective communities. A copy of the newsletter is included in Attachment J.

An e-mail was sent to LAC members with a scoping mailer attached, to provide a brief project update and notification of the scoping meetings. A copy of the e-mail and attachment are included in Attachment K.

Public notices for the public scoping meetings were published in several newspapers with circulation in the study area, including the *Los Angeles Times, Long Beach Press-Telegram*, *Mundo LA, Los Angeles Eastside Sun,* and *Los Angeles Watts Times*. Copies of these newspaper notices are included in Attachment L. Dates of the publication of the notices were as follows:

- August 18, 2008: *Los Angeles Times*
- August 18, 2008: *Long Beach Press Telegram*
- August 21, 2008: *Mundo LA* (published by Latin Publications)*, Los Angeles Eastside Sun* (published by EGP)*, Los Angeles Watts Times*

In addition, information about the I-710 Corridor Project was made available on an ongoing basis via the Internet at www.metro.net/710eir. The Web site provides comprehensive information about the I-710 planning process, including a project overview, project objectives, a description of community participation, and the schedule. The I-710 Web site also provides an opportunity for the public to e-mail comments and questions directly to Metro, which provides this feedback to Caltrans. The NOP, NOI, and meeting handouts are also made available on the Web site. A link to this Web site was provided from the Metro Web site at www.metro.net.

5.2.2 Scoping Meetings

5.2.2.1 Public Agency Scoping Meetings

A public agency scoping meeting was held September 10, 2008, from 2:00 p.m. to 4:00 p.m., and five agency personnel attended the meeting. No formal presentation was given; however, copies of the agendas and handouts provided at the meeting are included in Attachment M.

5.2.2.2 Public Scoping Meetings

Public scoping meetings were held September 9, 10, and 11, 2008, from 6:30 to 8:30 p.m. at Rowan Elementary School in East Los Angeles, Progress Park in the City of Paramount, and Cabrillo High School in Long Beach, respectively. Approximately 50 people each attended the September 9 and 10, 2008, public scoping meetings and approximately 60 people attended the September 11, 2008, public scoping meeting. Spanish translators were at all three public scoping meetings, in addition to a Khmer translator at the scoping meeting in Long Beach.

The public scoping meetings included exhibit stations and presentations explaining the purpose of scoping, the project background, the project study area, the need and purpose of the I-710 project, project alternatives, and key environmental issues to be addressed in the Draft EIR/EIS. Copies of the agendas, handouts, presentation, and sign-in sheets for each of the scoping meetings are included in Attachment M.

5.2.2.3 Comments Received at the Scoping Meetings

The scoping meetings also included a formal public comment portion for the public to verbally provide insights and raise comments/concerns for the project. Comment cards were also passed out and collected at each of these meetings. Table D provides a summary of comments from those who provided verbal and written comments at each of the September 2008 public scoping meetings. Copies of the speaker and comment cards are provided in Attachment N.

Table D Scoping Meeting Comment Summary

Public Scoping Meeting Comment Cards September 9, 2008 – Rowan Elementary School in East Los Angeles	
Cespedes, Tomas	Concerned with the possible connection of I-5 and I-710 and would like to be notified regarding whether their home will be affected.
Salis, Clara	Concerned with air quality and noise impacts and property acquisitions. Requested light rail be considered if a dedicated truck lane is constructed. Requested a tree planting project be incorporated into the project to reduce pollution and noise. Requested cul-de-sacs created by the project be used as opportunities for the community gardens, tree planting, and daycare centers.
Public Scoping Meeting Verbal Comments September 9, 2008 – Rowan Elementary School in East Los Angeles	
Eula, Bob	Stated in 2004 City passed resolution in favor of truck lanes routed directly into the railyards. Concerned with more pollution and I-710/I-5 connection.
Frevele, Dave	Requested timeline for data and property acquisitions. Requested information on how property owners will be compensated if property is acquired and what will happen if owners owe more than amount it is valued at.
Gallo, Herlinda	Stated support for the project.
Hernandez, Martha	Concerned with air pollution and health impacts.
Jimenez, Trini	Concerned with reduced railyard capacity and proposed SCIG project. BNSF could create hundreds of new jobs for qualified residents.
Logan, Angelo	Requested previous documents and studies from the MCS be considered. Concerned with air quality, cost benefit analysis, global warming, and noise.

Table D Scoping Meeting Comment Summary

Marquez, Ramon	Requested light rail and other alternatives be considered (for example, Alameda Corridor). Requested that a parking structure be considered as part of the project and magnetic levitation on the train and super tunnels to reduce noise. Requested a multilevel freeway.
Orona, Peter	Concerned with cars being dumped in the local neighborhood and requested information on the1,500-foot valley connector roads.
Ortega, Miguel	Concerned with pollution, noise and impacts to parks.
Ramirez, Isella	Concerned with air quality and improvements between two railyards and Washington Boulevard. Requested clarification on deadline to submit comments.
Salazar, Carl	Requested use of train over trucks. Concerned with crime, jobs, and traffic.
Salis, Clara	Requested that comments submitted on previous and initial studies are considered. Concerned with air quality, noise, safety, landscaping, and property acquisitions. Requested the I-5 scoping process be reopened.
Sandoval, Arceli	Concerned with safety and would like to see a decrease in traffic flow of trucks.
Public Scoping Meeting Comment Cards September 10, 2008 – Progress Park in the City of Paramount	
Dunbar, Clifford	Concerned with air quality impacts and reduction of diesel particulates. Requested project be four lanes for freight movement using hybrid vehicles.
Jimenez, Trini	Represented BNSF and states support for objectives. Stated public policy should encourage the use of rail when feasible to eliminate truck trips on local highways, reduce emissions, relieve congestion, and improve safety. BNSF has proposed to build a near-dock intermodal facility (SCIG) to eliminate truck trips.
Public Scoping Meeting Verbal Comments September 10, 2008 – Progress Park in the City of Paramount	
Barrios, Jose	Concerned with cost, property acquisitions, and finding funding for the project.
Marchan, Martin and Maria	Requested future notifications on the project. Concerned with pollution and that the project will benefit the environment.

Table D Scoping Meeting Comment Summary

Murphy, Clifton	Requested information about the Alameda Corridor Study and requested the project analyze use of rail instead of cars.
Newman, Bobbie	Suggested use of rubberized asphalt on the I-170 and the project is needed for the environment and the community.
Rizo, Ana Rosa	Concerned with noise and decrease in housing and quality of life. Requested the EIR analyze a zero-emissions alternative.
Rodriguez, Rogeleo	Suggested use of electric cars instead of the freeway. Concerned with more pollution and would like to use a light rail instead of I-710.
Stiles, Bob	Concerned with the traffic on the freeway; he has developed a system concept that can take cars and transport nonstop along the freeway at 120 miles per hour.
Public Scoping Meeting Comment Cards September 11, 2008 – Cabrillo High School in Long Beach	
Carter, Kathi	Requested aerial photos of the I-710 Corridor Project.
Fishel, Alan	Requested information about the following: purpose and need of the project; percentage of the container trucks on I-710 that use railroad reload terminals and why these trucks do not use rail from the start; why the Alameda and Alameda East Corridors are not electricfied to the inland ports or terminals; why there are no plans to widen I-710 to 14 lanes with separate truck and auto lanes; and location of transfer points.
Flores, Maria	Requested information about what streets would be affected and why there is a need for widening on I-710. Suggested improvements to be included in the project (i.e., exit/merging improvements).
Gonzales, Christopher and Molly	Requested a sound wall along the northbound side of I-710 in the City of Bell Gardens, from South Gate to Bell Gardens Elementary School. Concerns with air pollution, safety, and future health.
Smith, Jack C.	Requested there be no double decking between Pacific Coast Highway and Willow Street proposed with the project because of noise and aesthetic impacts. Requested a train in the middle right-of-way become policy for all freeway improvements, similar to I-105. In favor of

Table D Scoping Meeting Comment Summary

	containers moving without trucks.
Warren, Elizabeth	Provided information about local dependency on the ports and I-710 and provided information about several initiatives undertaken by the ports in the last few years. Provided support for the use of on-dock and near-dock rail loading, the Middle Harbor project, BNSF's SCIG, and UP ICTF facilities.
Public Scoping Meeting Verbal Comments September 11, 2008 – Cabrillo High School in Long Beach	
Cabrales, Robert	Concerned with public notification in Huntington Park, traffic congestion from trucks, health impacts, and zero emissions.
Cross, John	Requested I-710 be resurfaced and the interchanges and ramps for I-710 north to I-405 south be straightened. Concerned with traffic congestion and in support of trains that are loaded on dock.
Fishel, Alan	Requested information about the following: purpose and need of the project; percentage of the container trucks on I-710 that use railroad reload terminals and why these trucks do not use rail from the start; why the Alameda and Alameda East Corridors are not electricfied to the inland ports or terminals; why there are no plans to widen I-710 to 14 lanes with separate truck and auto lanes; and location of transfer points.
Gonzales, Christopher	Concerned with sound walls and barriers between homes and the freeway and health impacts. Solution is not to widen the freeway but to implement alternative methods (public transportation).
Green, Elina	Concerned with health impacts and community participation framework. Requested a no build alternative be analyzed, impacts to schools considered, and an HRA be prepared.
Hricko, Andrea	Concerned with health impacts in proximity to freeway, a threefold increase in trucks, and the availability and legal documentation of the NOP posting for the proposed project.
Montez, Victor	Concerned with noise and pollution associated with double decking in Long Beach, use of rail instead of trucks, and alternatives.
Ramirez, Alberto	Concerned with green growth and truck traffic.

Table D Scoping Meeting Comment Summary

Smith, Jack C.	Concerned with double decking and associated noise, health impacts, and visual impacts.
Valdez, Lupe	Representing UP and requested a consultation on any improvements that may impact the railroad operations or right-of-way. Stated there is not enough dock capacity to meet future growth.
Warren, Elizabeth	Provided information about local dependency on the ports and I-710 and provided information about several initiatives undertaken by the ports in the last few years. Provided support for the use of on-dock and near-dock rail loading, the Middle Harbor project, BNSF's SCIG, and UP ICTF facilities.
Zavala, Angeles	Representing Youth for Environmental Justice with Communities for a Better Environment. Concerned with public notification to the affected communities, how many meetings the public will be involved in, how many community members will be involved and are aware of the project, and air pollution.

6.0 COORDINATION WITH INTERSTATE 5 PROJECT

The LAC representing the East Los Angeles community requested the I-710 Corridor Project to coordinate with the I-5 improvement project between I-605 and I-710 since the I-710 and I-5 project study areas overlap and both projects will be following similar environmental planning timelines. The I-5 project began work in August 2007; the NOP was published in February 2008 and scoping meetings were held in February 2008. The I-710 Corridor Project began work in early 2008; the NOP was published in August 2008 and scoping meetings were held in September 2008. Coordination between the two projects is critical for the following reasons: (1) both Draft EIR/EIS public circulation review periods are planned for approximately the same time in 2010, and therefore the public would expect consistent data between the two documents; (2) design of the two projects needs to be coordinated to ensure compatibility of plans and to minimize any throwaway costs for construction; and (3) Commerce and East Los Angeles are directly affected by both projects and coordination needs to ensure that cumulative impacts of the two projects on the communities are fully considered. Therefore, meetings have been regularly held between the two project teams to coordinate engineering, environmental technical studies (e.g., air quality and traffic), and design alternatives feasible with the other projects planned in the area. Coordination will continue between the two projects as the environmental process continues for both projects. The I-710 LACs for Commerce and East Los Angeles have also agreed to function in a similar role for the I-5 project.

Environmental Justice and Regional Inequality in Southern California: Implications for Future Research

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Environmental justice offers researchers new insights into the juncture of social inequality and public health and provides a framework for policy discussions on the impact of discrimination on the environmental health of diverse communities in the United States. Yet, causally linking the presence of potentially hazardous facilities or environmental pollution with adverse health effects is difficult, particularly in situations in which diverse populations are exposed to complex chemical mixtures. A community–academic research collaborative in southern California sought to address some of these methodological challenges by conducting environmental justice research that makes use of recent advances in air emissions inventories and air exposure modeling data. Results from several of our studies indicate that communities of color bear a disproportionate burden in the location of treatment, storage, and disposal facilities and Toxic Release Inventory facilities. Longitudinal analysis further suggests that facility siting in communities of color, not market-based "minority move-in," accounts for these disparities. The collaborative also investigated the health risk implications of outdoor air toxics exposures from mobile and stationary sources and found that race plays an explanatory role in predicting cancer risk distributions among populations in the region, even after controlling for other socioeconomic and demographic indicators. Although it is unclear whether study results from southern California can be meaningfully generalized to other regions in the United States, they do have implications for approaching future research in the realm of environmental justice. The authors propose a political economy and social inequality framework to guide future research that could better elucidate the origins of environmental inequality and reasons for its persistence. ***Key words***: air toxics; cancer; environmental justice; risk; social inequality; treatment, storage, and disposal facilities. ***Environ Health Perspect*** **110(suppl 2):149–154 (2002).**

http://ehpnet1.niehs.nih.gov/docs/2002/suppl-2/149-154morello-frosch/abstract.html

Environmental justice, with its emphasis on public health, social inequality, and environmental degradation, provides a framework for public policy debates about the impact of discrimination on the environmental health of diverse communities in the United States. Indeed, activists, academics, and some decision makers argue that biases within environmental policy making and the regulatory process, combined with discriminatory market forces, result in disproportionate exposures to hazardous pollution among the poor and communities of color. The environmental justice framework also raises the challenging question of whether disparities in exposures to environmental hazards may play an important, yet poorly understood, role in the complex and persistent patterns of disparate health status among the poor and people of color in the United States (*1–13*).

In seeking to redress disparities in exposures to toxics, communities organizing for environmental justice offer environmental health researchers new insights into the junctures of social inequality and public health on one hand, and the political and economic forces that lead to environmental inequality on the other. Emerging research on the broad question of environmental justice attempts to elucidate how socioeconomic and institutional forces create "riskscapes" in which overlapping pollution plumes, emitted by various sources into our air, soil, food, and water, pose a range of health risks to diverse communities, all of which in turn determine inequalities in community susceptibility to environmental hazards. The environmental justice movement has also sparked contentious debates among researchers, policy makers, activists, and industry as to whether environmental discrimination actually exists and why, or whether it is simply the result of other structural forces (*14–24*). These debates have fueled a surge of academic and scientific inquiry into the question of environmental inequality in the United States over the last two decades.

Research on race and class differences in exposures to toxics varies widely, ranging from anecdotal and descriptive studies to rigorous statistical modeling that quantifies the extent to which race and/or class explain disparities in environmental hazards among diverse communities. Although by no means unequivocal, much of the evidence points to a pattern of disproportionate exposures to toxics and associated health risks among communities of color and the poor, with racial differences sometimes persisting across economic strata (*25,26*).

Nevertheless, causally linking the presence of environmental pollution with potentially adverse health effects is an ongoing challenge in the environmental health field, particularly in situations in which populations are chronically exposed to complex chemical mixtures (*3*). With few exceptions, researchers examining environmental inequalities have limited their inquiries to evaluating differences in the location of pollution sources between population groups, while placing less emphasis on evaluating the distribution of exposures or, more important, potential health risks. Of special concern has been the need to move beyond chemical-by-chemical or facility-by-facility analysis toward a cumulative exposure approach that accounts for the exposure realities of diverse populations and incorporates concepts of race and class into assessments of community susceptibility to environmental pollutants (*27*).

We review the evolution of a 3-year environmental justice research initiative in southern California carried out through an academic and community-based collaborative. Our methodological approach entails a regional focus, starting with the premise of previous environmental research that examines the racial distribution of facility siting. We then expand upon this locational approach to look at issues more closely related to health, such as outdoor concentrations of air toxics and associated cancer risks, and then to answer the complex question of temporal trends.

This article is part of the monograph *Advancing Environmental Justice through Community-Based Participatory Research.*

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Implications of the study results in southern California for policy making and developing a framework for future research are discussed in the conclusion.

Creating a Regional Collaborative for Environmental Health and Justice

In 1998, the authors, along with other community partners in southern California, formed an academic–community partnership to address environmental justice issues facing people of color and low-income communities in the Los Angeles Air Basin. (The lead author joined this community-academic collaborative in 1999.) In addition to training, organizing, and policy advocacy, a significant component of this collaborative supported research that would elucidate potential patterns of disproportionate exposures to environmental hazards among diverse communities in the region. Within the collaborative, potential research topics could be proposed by any partner—community or academic—and priorities and project development were decided in a way that was relevant to community organizing and environmental policy making. Although community partners had the most significant influence in the development of the collaborative research agenda, they prioritized basic environmental health research and risk assessment to address some of the persistent methodological challenges in the field of environmental justice research. We have worked toward this goal by making use of advances in air emissions inventories, such as the Toxic Release Inventory (TRI) and ambient air exposure modeling data (*28–30*). Until recently, there has been a paucity of research in which such environmental health and exposure information have been disaggregated by race and socioeconomic status (*31*).

We chose to focus our research efforts on southern California for several reasons: First, the region has a unique regulatory history in terms of its ongoing struggle to solve some of the worst air pollution problems in the country while still promoting economic growth. Second, southern California already comprises a majority of people of color and is rapidly becoming a bellwether of demographic and socioeconomic change for the state as well as the nation. Third, a regional focus in environmental justice research is crucial because industrial clusters, transportation planning, and economic development decisions are often regionally rooted. Thus, the equity question is how the social and environmental health effects of such industries are distributed within the regions that host them. Fourth, minority and low-income communities in the region have become increasingly concerned about whether they bear a disproportionate burden of exposures to air pollution and their associated environmental health risks. Thus, our collaborative is connected to community-based strategies for achieving environmental justice and rooted in a region where organizing on various environmental health issues is already happening. This also makes the results of our research directly relevant to ongoing policy efforts of the South Coast Air Quality Management District to address environmental inequality and to a new state legislative mandate, a law that directs California's Office of Planning and Research to coordinate the state's environmental justice initiatives with the federal government and across state agencies, including the California Environmental Protection Agency (*32*). Finally, the relevance of our work extends beyond southern California; understanding the patterns in this region may inform studies and policies elsewhere as local, state, and federal policy makers are compelled to consider the equity concerns of diverse communities impacted by environmental health risks from hazardous exposures.

In our research we sought to develop various indicators for assessing environmental inequalities: location of potentially hazardous stationary pollution sources such as TRI facilities and treatment, storage, and disposal facilities (TSDFs), and estimated cancer risks associated with outdoor air toxics exposures. We also sought to use the regulatory tools of risk assessment in a comparative framework to answer scientific and policy questions about what ambient concentrations of certain pollutants might in fact mean for distributions of potential health risks among diverse communities. In short, we wanted to address the ultimate question: Is there environmental inequality in southern California, and if so, who bears the burden? Our application of traditional regulatory risk assessment in a comparative framework provides a useful policy tool, particularly in situations in which epidemiologic data are not available and yet where time-sensitive decisions about disparate impact must be made, such as the judicial and administrative examination of Title VI complaints (42 U.S.C. §§ 2000d to 2000d-7) (*33–34*).

Evolution of Research Methodology and Results

Locational Studies

Following the lead of early watershed studies on environmental inequality (*25,35–37*), our first two studies in southern California examined the location of TSDFs in Los Angeles and TRI facilities in the entire region. The first study examining TSDFs found significant demographic differences between tracts with TSDFs versus tracts without (*38*). Those tracts hosting a TSDF or located within a 1-mile radius of a TSDF had significantly higher percentages of residents of color (particularly Latinos), lower per capita and household incomes, and a lower proportion of registered voters. Logistic regression results (Table 1) indicate that communities most impacted by TSDF location in Los Angeles County are working-class communities of color located in predominantly industrial areas. Following previous research (*38–40*), we found that the relationship between income and TSDF location is curvilinear, following an inverted U-shaped curve in which extremely poor tracts have fewer facilities because of less economic and industrial activity, whereas wealthier residents tend to live in tracts with fewer TSDFs, most likely because of their political power to resist pollution-generating activities. This result remained consistent even when the percentages of African American and Latino residents were evaluated as separate groupings (not shown).

Table 1. Logistic regression results for associaton between TSDF location and race/ethnicity, economic, and land use variables.

Independent variable	Parameter estimate (*t*-statistic)
Residents of color (%)	0.03 (6.32)***
Population density	0.00 (0.15)
Employment in manufacturing (%)	0.02 (2.22)**
Per capita income	0.03 (2.59)***
(Per capita income)^2	–0.00 (–2.45)***
Industrial land use (%)	0.03 (7.30)**

n = 1,636 tracts. R^2 = 0.17. ***$p < 0.01$. **$p < 0.05$.

Our second locational study broadened its regional scope by including the South Coast Air Quality Management District (which includes Ventura, Los Angeles, Orange, San Bernardino, and Riverside counties) and examining the distribution of facilities required to report air emissions to the TRI of the U.S. Environmental Protection Agency (U.S. EPA) (*40*). The study distinguished between all TRI facilities and those facilities releasing pollutants classified by the U.S. EPA as high priority for reduction and therefore included in the agency's 33/50 program. (The 33/50 program was designed to target 17 priority chemicals, most of them carcinogens, and set as its goal a 33% reduction in releases and transfers of these chemicals by 1992 and a 50% reduction by 1995 [using a 1988 baseline].) Study results indicated that compared with Anglo residents, Latinos have twice the likelihood of living in a tract with a TRI facility with 33/50 releases, followed closely by African Americans. Logistic regression

Table 2. Logistic regression results for associaton between TRI location and race/ethnicity, economic, and land use variables.

Independent variable	Parameter estimate (t-statistic)
Residents of color (%)	0.01 (5.34)***
Population density	–0.00 (0.12)
Employment in manufacturing (%)	0.10 (15.1)***
Per capita income	0.03 (3.50)***
(Per capita income)^2	–0.00 (–3.91)***
Industrial land use (%)	0.05 (10.7)**

n = 2,567 tracts. R^2 = 0.17. ***$p < 0.01$; **$p < 0.05$.

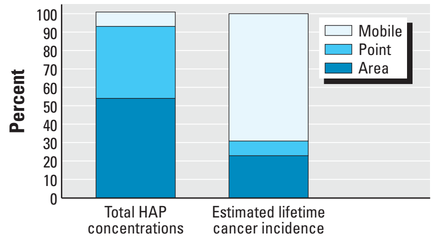

Figure 1. Emission source contributions to air toxics concentrations and estimated lifetime cancer incidence in the South Coast Air Basin. Mobile sources include onroad and offroad vehicles, area sources include small manufacturing and nonmanufacturing facilities, and point sources include large manufacturing facilities such as TRI sources.

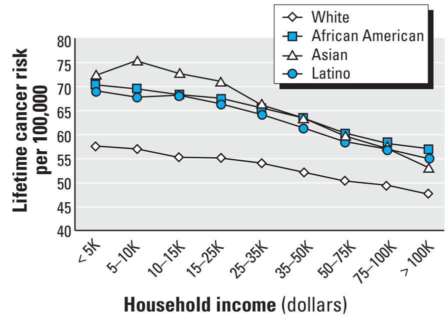

Figure 2. Estimated lifetime cancer risks from ambient air toxics exposures by race, ethnicity and income (South Coast Air Basin).

controlling for income, industrial land use, and population density found that the proportion of minority residents was significantly associated with proximity to a TRI facility (Table 2). A similar curvilinear relationship with income was also observed in this locational study.

Disparities in Outdoor Air Pollution Exposures and Estimated Cancer Risks

Although our preliminary studies focused on the location of potentially hazardous facilities, we sought to quantitatively assess the implications of outdoor air pollution exposures for potential disparities in estimated individual lifetime cancer risks among diverse communities (*27*). Making use of a recent modeling analysis undertaken by the U.S. EPA's Cumulative Exposure Project (*30,41–43*), our study combined estimated long-term annual average outdoor concentrations of 148 air toxics, or hazardous air pollutants (HAPs), listed under the 1990 Clean Air Act Amendments (*44*). We combined these data with demographic and land use information from the 1990 U.S. Census and the southern California Association of Governments. Our study examined a broader scope of air pollutants than previous environmental justice studies, incorporating outdoor HAP concentrations originating from mobile sources (e.g., cars), as well as pollutants from industrial manufacturing facilities, municipal waste combustors, small service industries, and other area emitters. By combining modeled concentration estimates with cancer toxicity information, we derived estimates of lifetime cancer risks and analyzed their distribution among populations in the region.

Estimated lifetime cancer risks associated with outdoor air toxics exposures in the South Coast Air Basin were found to be ubiquitously high, often exceeding the Clean Air Act Goal of one in one million by between one and three orders of magnitude. [In 1990, Congress established a health-based goal for the Clean Air Act: to reduce lifetime cancer risks from major sources of hazardous air pollutants to one in one million. The Act required that over time, U.S. EPA regulations for major sources should "provide an ample margin of safety to protect public health" (*45*).] Figure 1 presents source contributions to total air toxics concentrations and total estimated excess lifetime cancer incidence with the effects of background concentrations removed. Background concentrations are attributable to long-range transport, resuspension of historical emissions, and natural sources derived from measurements taken at clean air locations remote from known emissions sources (*30*).

Interestingly, area and point emissions account for over 90% of total estimated HAP concentrations, but mobile sources are the largest driver of estimated excess cancer incidence, accounting for 70% of the estimated excess cancer incidence associated with outdoor HAP concentrations from these three source categories. This difference is consistent with another exposure study conducted recently in southern California (*46*) and underscores the importance of distinguishing between exposures versus health risks when assessing emission source contributions to pollution problems. Although, on average, point sources do not appear to contribute substantially to modeled concentrations and predicted cancer risks, there are several tracts in the South Coast Basin where point source contributions to both concentration and risk estimates are dominant.

Figure 2 shows how the racial/ethnic disparities in estimated cancer risks persist across household income strata. The *y*-axis shows a population-weighted individual excess cancer risk estimate for each racial and economic category and the *x*-axis displays nine annual household income categories ranging from less than $5,000 to more than $100,000. As indicated in the figure legend, each line in the graph represents one of four racial/ethnic groups that include Anglos, African Americans, Asians, and Latinos. Asians, African Americans, and Latinos have the highest population cancer risk estimates, with risks nearly 50% higher than that for for Anglos. Although risk levels tend to decline for all groups as household income increases, the gap between residents of color and Anglos is fairly consistent across income strata. These preliminary results are likely to be influenced by demographic differences in where population groups reside. Whereas African Americans, Latinos, and Asians are concentrated mainly in the urban core where pollution levels and risks tend to be higher, Anglos are more dispersed, with significant numbers living in less-urban areas where risks are lower. Table 3 presents the multivariate regression models of the association between lifetime cancer risk and race/ethnicity, land use, and economic variables, including the percentage of home ownership, the percentage of industrial, commercial, and transportation land use, median housing value, median household income, and median household income squared. Model 1 uses the percentage of residents of color and model 2 shows a breakdown of the racial/ethnic groups. Multivariate regression results indicate that even after controlling for well-known causes of pollution such as population density, income, land use, and a proxy for assets (home ownership) (*47*), race was consistently shown to be positively associated with higher cancer risks. Note that median household income is entered as a quadratic variable. The curvilinear relationship between income and lifetime cancer risk is consistent with the locational studies, following the inverted U-shaped curve in which extremely poor tracts may have lower cancer risks due to low levels of economic and industrial activities, whereas wealthier residents tend to live in tracts with lower cancer risk levels.

Demographic Transition and the Siting of Environmental Hazards

Although these studies suggest that environmental hazards disparately impact communities of color in southern California, the cross-sectional nature of these results precludes the possibility of assessing the causal sequence of facility siting, that is, whether facilities were sited in communities of color or whether minority residents moved into neighborhoods after facility siting decreased property values and neighborhood desirability. Our subsequent study sought to examine this siting versus minority-move-in hypothesis, which entailed compiling longitudinal data on the siting and location of TSDFs from 1970 to 1990 (*23*). Preliminary results indicate that the proportion of minority residents living within a 1-mile radius of a TSDF increased from 9% in 1970 to over 20% in 1990, whereas the increase for White residents was less, from 5% to nearly 8%. Tracts receiving TSDFs between 1960 and 1990 had a higher proportion of residents of color, were poorer and more blue-collar, had lower initial home values and rents, and had significantly fewer homeowners. Moreover, multivariate analysis showed that there was little evidence of so-called minority move-in into areas where TSDFs had been previously sited.

Finally, we sought to examine whether neighborhoods that had undergone drastic demographic transitions in their ethnic and racial composition were more vulnerable to TSDF siting, possibly due to weak social and political networks that could undermine a community's capacity to influence siting decisions. A tract-level variable of ethnic churning was constructed to measure this phenomenon by taking the absolute sum of racial demographic change between 1970 and 1990. Figure 3 maps this ethnic-churning variable in Los Angeles overlaid onto the siting of TSDFs during the 1970s and 1980s. The apparent visual correlation between high demographic transition and TSDF siting was tested with simultaneous modeling using a two-stage least-squares regression. Results revealed that this type of demographic transition significantly predicted the siting of a TSDF even after controlling for economic and other demographic indicators (not shown). Thus, in historically or uniformly ethnic areas, siting seems less likely to occur than in locations where the proportion of residents of color is high but split and changing between African American and Latino groups.

Table 3. Regression results on associaton between cancer risks associated with air toxics and race/ethnicity, economic, and land use variables.

Independent variable	Model 1[a] parameter estimate (*t*-statistic)	Model 2[b] parameter estimate (*t*-statistic)
Residents of color (%)	0.17 (7.03)***	
Population density	0.18 (22.92)***	0.18 (22.67)***
Home ownership (%)	–0.02 (–0.46)	–0.02 (–0.56)
Median housing value	0.09 (5.08)***	0.08 (4.56)***
Median household income	0.26 (4.67)***	0.22 (4.10)***
(Median household income)^2	–0.0007 (–5.48)***	–0.0007 (–4.85)***
Transportation land use (%)	0.53 (6.19)***	0.53 (6.24)***
Industrial land use%	0.27 (5.57)***	0.28 (5.71)***
Commercial land use (%)	0.30 (6.34)***	0.29 (6.05)***
African American (%)		0.17 (5.40)***
Latino (%)		0.13 (4.79)***
Asian (%)		0.28 (5.75)***

***$p < 0.01$. [a]n = 2,495 tracts; R^2 = 0.41; F statistic = 188.3. [b]n = 2,495 tracts; R^2 = 0.41; F statistic = 155.4.

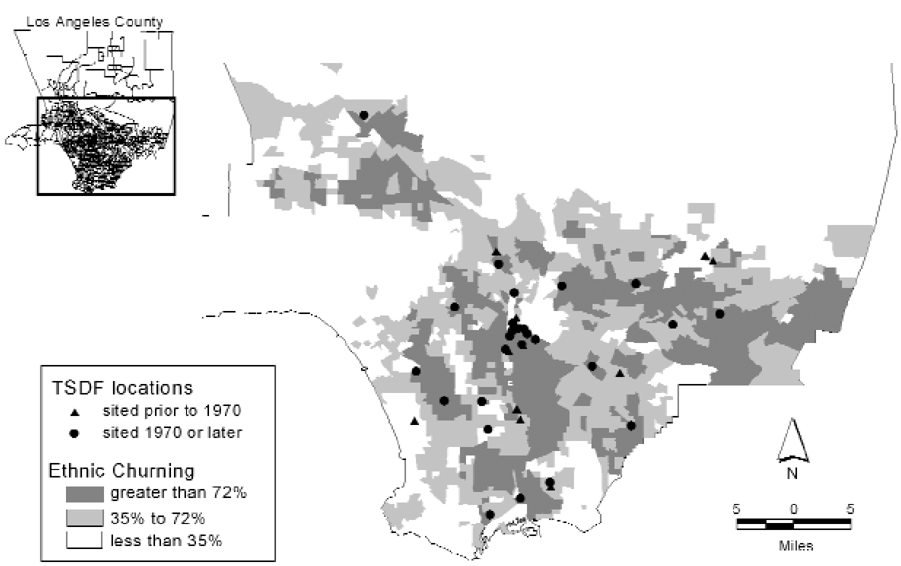

Figure 3. High capacity hazardous waste TSDFs and ethnic churning, 1970–1990, southern Los Angeles County, California. Data from 1970, 1980, and 1990 Census. Each category contains one-third of all Los Angeles County census tracts.

Policy Implications of Research Results

Our studies examining environmental inequality in southern California have consistently revealed a disproportionate burden borne by communities of color, particularly African Americans and Latinos, in the location of TRI and TSD facilities and lifetime cancer risks associated with outdoor air toxics exposures (*27,38,40*). A longitudinal study further suggests that the disproportionate location of TSD facilities in Los Angeles County has been the result of the siting of facilities predominantly in communities of color and not simply a market-induced move-in of poor residents of color to lower-rent areas already affected by environmental hazards (*23*). Moreover, communities undergoing rapid demographic transition seem more vulnerable to the placement of TSDFs. This measurement of ethnic churning merits further inquiry, as it may be a crude indicator of a community's capacity to mobilize social networks and politically resist or influence siting decisions.

Although three of our studies were locational, focusing on the siting of potentially hazardous facilities, we were also able to examine the health risk implications of outdoor air toxics exposures attributable to mobile and nonmobile sources. These latter results suggest that air toxics concentrations and their associated health risks originate mostly from smaller area and mobile sources, raising new challenges for policy makers and environmental justice advocates alike in terms of developing regulatory and pollution prevention strategies for these emission sources. Unlike large industrial and waste facilities that traditionally have been the focus of organizing, research, and regulatory attention, mobile and area sources are smaller, more widely dispersed, and diverse in terms of their emissions and production characteristics, making a uniform regulatory approach and community organizing strategy more difficult. Regulatory oversight of small manufacturing and service operations has been minimal because these facilities tend to be the most difficult to control from a technological perspective compared with large point sources that have been the focus of command and control efforts. Indeed, dispersed, small-scale production often turns industry into a moving target, as smaller firms avoid community scrutiny and regulatory responsibility for the social costs and environmental health impacts of production. Small factories are often undercapitalized, short-term operations that do not have the technology or know-how to safely produce, store, and transport toxic inputs and wastes (*48*). Finally, the proliferation of mobile sources may be eroding the previous gains made from stricter emissions standards. Thus, future emissions reduction efforts must better address mobile and area sources with a particular emphasis on how regional economic development, changing land use patterns, suburbanization, and the development of major transportation corridors impact pollution streams and the distribution of health risks among communities of color and the poor.

Equally important, these study results reinforce the need to take a more holistic approach to environmental equity research. As better data become available, future studies should move away from locational and pollutant-by-pollutant analysis and toward a cumulative exposure approach (across pollutants and emission sources) that better answers the question of what disparities in exposure mean for potential inequities in health risks. Of course, the use of risk assessment, even within an equity analysis framework, remains controversial among the public and policy makers alike (*49,50*). We sought to improve the use of risk assessment by using it comparatively to assess the distribution of cancer risk due to outdoor air toxic exposures among diverse communities.

Conclusion: A Framework for Future Research

Although risk assessment and statistical analysis can show how inequities in environmental health risks are spread among diverse communities, they shed little light on their origins or the reasons for their persistence. These larger questions necessarily lead us in a new direction in our research to address two overarching issues: *a*) using a social inequality framework (based on race, class and income) to facilitate the integration of knowledge from the fields of economics and sociology in a way that enables researchers to better understand the complex dynamics of environmental inequality (*51,52*); and *b*) examining the political and economic forces that lead to environmental inequality, which requires consideration of how institutional discrimination (such as occupational and residential segregation) interacts with larger structural forces, including disparities in patterns of economic and regional development. Figure 4 proposes such a social inequality framework that could be used to develop future research questions. Patterns of social inequality, segregation, and lack of social capital [such as social networks, cohesion, and a community's ability to mobilize politically (*53–55*)] impact a community's capacity to influence or resist environmental policy-making and regulatory enforcement activities (*56*). Similarly, social inequality diminishes a community's ability to shape regional and economic development activities in systematic ways that would benefit (or at minimum not harm) its residents (*57*). The interaction of these institutional and structural processes ultimately places additional environmental stress on communities of color through the placement of potentially hazardous facilities, transportation corridors, and pollutant exposures through various media. Ultimately, the adverse effects of these intersecting processes can be assessed through specific public health outcomes.

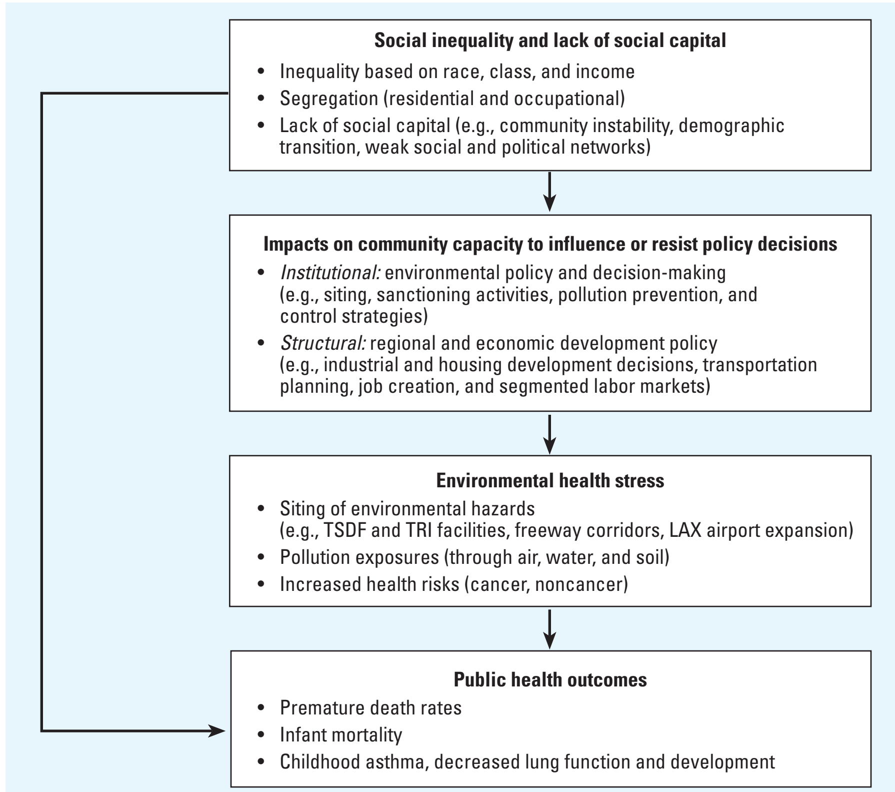

Figure 4. Political economy of environmental inequality.

Research examining the socioeconomic factors that create environmental inequalities can move policy discussions on environmental justice beyond simply tinkering with the regulatory process and toward addressing how social inequalities and discrimination directly and indirectly impact the environmental health of communities of color and the poor. Preliminary research in this area suggests that disparities in political power and residential segregation affect not only the net costs and benefits of environmentally degrading activities but also the overall magnitude of environmental degradation (e.g., air pollution) and health risks (e.g., individual estimated lifetime cancer risk) (*52,58*). Community participation is key to developing long-term regulatory, enforcement, and regional development initiatives that are politically and economically sustainable and that protect public health. The challenge for policy makers and researchers alike is to reorient future inquiry to examine how indicators of inequality and political empowerment can promote environmental protection and environmental justice for everyone.

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Is There Environmental Racism? The Demographics of Hazardous Waste in Los Angeles County*

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Objective. The "environmental justice" movement has suggested that demographic inequities characterize the location of hazardous waste treatment, storage, and disposal facilities (TSDFs). While some researchers have found evidence that TSDFs are disproportionately located in minority areas, others attribute TSDF location to nonracial factors such as income and industrial employment. *Methods.* We used both univariate and multivariate techniques to analyze the location of TSDFs in Los Angeles County, California; the focus on one county allowed us to overcome the problem of "false" addresses for TSDF sites and to introduce specific land use/zoning variables that are not used in the other studies. *Results.* In our univariate results and the multivariate model, we find that (1) industrial land use and manufacturing employment do matter, as suggested by critics of environmental justice; (2) income has first a positive, then a negative effect on TSDF location, a pattern that likely reflects the fact that the poorest communities have little economic activity while wealthier communities have the economic and political power to resist negative environmental externalities; and (3) race and ethnicity are still significantly associated with TSDF location, even when percentage African American and percentage Latino are evaluated as separate groupings. Taken together, the results suggest that communities most affected by TSDFs in the Los Angeles area are working-class communities of color located near industrial areas.

* Direct all correspondence to James L. Sadd, Environmental Science and Studies Program, Occidental College, 1600 Campus Road, Los Angeles, CA 90041 (e-mail: jsadd@oxy.edu). Most of the data used in this study are in the public domain, and all data sources are listed in Table 1. Two proprietary data sets (GIS coverages of 1990 land use and point locations of TSDFs) were made available to the authors for the purpose of this research by the Southern California Association of Governments and Environmental Data Resources, Inc., and we gratefully acknowledge their support. We also thank the *SSQ* manuscript reviewers for their helpful comments. Editor's note: Reviewers were Douglas L. Anderton, Dennis Ehrhardt, Roger G. Noll, and Phillip H. Pollock III.

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Introduction

For more than a decade, community based environmental and social justice organizations nationwide have expressed concerns about disproportionate environmental risk and equity under the banner of "environmental justice" (Capek, 1993; Bullard, 1996). The environmental justice concept and the emergent political movement supporting it suggest that the potential health risks associated with exposure to hazardous materials, polluted air, and contaminated water are greater for racial and ethnic minorities and/or the poor because they represent a disproportionate fraction of residents living in communities located near potential hazards; indeed, the environmental justice concept asserts that demography can be used to predict the location of environmental hazards, with nonminority, affluent residents living in areas far from these potential threats. In urban Los Angeles, groups such as the Mothers of East L.A., Concerned Citizens of South Los Angeles, the Labor/Community Strategy Center, and Communities for a Better Environment have been the local face of this developing national movement and have, for example, challenged the location of municipal incinerators in minority neighborhoods as well as the allocation of public transportation dollars away from modes (such as buses) more heavily used by minorities.

But is there, in fact, environmental "injustice" of the type these groups claim? We address this question by evaluating disproportionate exposure to hazardous waste treatment, storage, and disposal facilities (TSDFs) in Los Angeles County. We focus on TSDFs for several reasons. First, this type of facility does pose some additional risk to nearby residents, particularly in case of fire, earthquake, accidental explosion or release, or illegal discharge and, therefore, represents a potentially significant health hazard. Second, unlike many other categories of environmental hazard, TSDFs also require an extensive government permitting process for siting and operation, which yields a relatively good record of site location.[1] Third, TSDFs and related hazardous waste sites have been the focus of similar studies, which offer some methodological examples of how to evaluate the validity of environmental justice (see GAO, 1983; UCC, 1987; Lavelle and Coyle, 1992; Mohai and Bryant, 1992; Anderton et al., 1994a, 1994b; Coursey et al., 1994; Been, 1995; Pollock and Vittes, 1995; Mohai, 1996; Yandle and Burton, 1996).

In looking for evidence of "environmental injustice," this study addresses three primary questions: (1) What is the geographic distribution of TSDFs in Los Angeles County? (2) Does the geographic distribution of TSDFs correlate with such demographic characteristics as race, economic status, and land use? (3) Of these demographic characteristics, which are statistically significant when considered in the context of a multivariate model?

[1] Been (1995) discusses the problems with verifying location accuracy, a subject we discuss later.

Our study reveals that a simple comparison of tracts with and without TSDFs reveals statistically significant differences by race and economic status along the lines suggested by the environmental justice proponents, as well as significant differences by industrial land use and manufacturing employment along the lines suggested by critics of the environmental justice concept (Anderton et al., 1994a, 1994b). In our multivariate model, race, along with industrial land use and employment in manufacturing, remains a factor; rising income, on the other hand, has a positive then a negative effect on the probability of TSDF location.

While this last finding may seem anomalous to those who have thought income, not race, was the driving force behind the location of environmental hazards, the relationship squares with the results in Been (1995) and makes sense on reflection: some areas are too poor to have any economic activity, even a TSDF, while others are wealthy enough to resist TSDFs' being sited nearby. In short, the most "at-risk" and impacted communities are working class, heavily minority neighborhoods located near industrial activity—exactly the sorts of communities being organized by the aforementioned Los Angeles–based groups.

This study is limited in intent and scope, in part because of the analytical design and, in part, because of limitations inherent in the available data. First, we focus only on Los Angeles County and thus can draw no sweeping conclusions with regard to environmental justice issues elsewhere; this is, in short, a case study.[2] Second, we consider only properly permitted TSDFs; an analysis that includes illegal sites would be complicated by poor data quality but could yield equally interesting results in terms of demographic patterns. Third, we did not study the history of the siting process for the various TSDFs used in this study and, consequently, do not have information on particular incidents of explicit income or ethnic discrimination in site decision making; we merely demonstrate a pattern that could be consistent with discrimination or with other factors. Finally, we did not conduct a time-series analysis and so do not know whether the affected communities changed demographically (e.g., became more "minority" in their residential population) *after* a TSDF was sited, a trend that might suggest market dynamics in residential movement rather than discrimination in siting.[3]

[2] The focus on Los Angeles County was driven by our desire to look at the patterns in our place of residence as well as by the research design; in particular, our geographic focus also allowed us to overcome the problem of "false" tract locations (such as headquarters addresses instead of actual processing sites) by visiting certain questionable sites and taking positioning data. Other geographically focused studies include Coursey et al. (1994), Mohai and Bryant (1992), and Pollock and Vittes (1995).

[3] Lambert and Boerner (1994) have suggested that the siting of a TSDF may cause a decrease in property value and a resulting shift toward a higher proportion of low-income and minority residents. Been (1994a) explores this issue and finds mixed evidence. It is difficult to accurately perform such "before and after" comparisons on a broad scale, in part because the U.S. census tract boundaries are relocated and the format of the census questionnaire, especially with

Despite the aforementioned limitations—many of which are characteristic of other studies in this field—this research makes a useful contribution by providing new evidence that race matters in the location of certain environmental risks in at least one important urban area.

Data and Methodology

All eighty-two Los Angeles County TSDFs currently listed by the California State Department of Toxic Substances Control (DTSC; Tanner, 1993 data set) were used in this analysis. According to this data set, forty-three of these facilities processed less than 50 tons in 1993, thirteen processed between 50 and 1,000 tons, and twenty-six processed more than 1,000 tons during that year; the largest facility processed 141,230 tons in 1993. Geographic coordinates and other data pertaining to these facilities were provided by Environmental Data Resources, Inc., and differentially corrected global positioning systems data were used to confirm correct location; such positioning was especially useful in overcoming the address error problem (Been, 1995: 11). We employed the census tract as the unit of geographic analysis, a more compact and homogeneous analytical unit than the zip code polygons used in the path-breaking study done by the United Church of Christ's Commission for Racial Justice (UCC, 1987). The tracts were matched with demographic data drawn primarily from the 1990 U.S. Census Summary Tape Files (STF-1 and STF-3) and augmented by land use and other data from other public and commercial data sources (see Table 1). Of the 1,652 census tracts in Los Angeles County, 12 had either no land area (they were generally yacht or navy harbors) or no residents and were therefore eliminated from analysis, yielding a usable county total of 1,640 census tracts.[4]

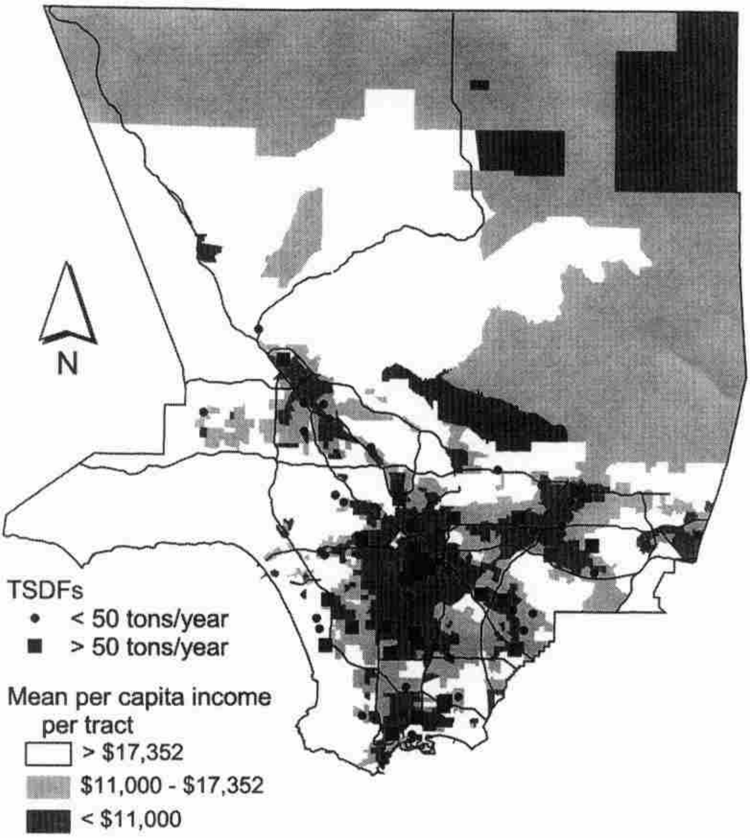
Qualitative Geographic and Univariate Comparisons. An initial qualitative analysis was accomplished by employing a Geographic Information System (GIS—Arc/Info) to visually compare the spatial distribution of TSDFs within Los Angeles County with the geographic distribution of various demographic characteristics using overlay maps (Figures 1 and 2). Figure 1 shows the locations of hazardous waste TSDFs, categorized by tonnage of waste processed per year. Large facilities—those that processed over fifty tons in 1993—are primarily concentrated in the area located just

regard to identifying ethnicity, has changed from decade to decade (see also Anderton, 1996; Mohai, 1996; Yandle and Burton, 1996b).

[4] None of these 12 excluded tracts contain a TSDF (although some do fall within a one-mile radius of a TSDF). For certain variables, however, the range of available tracts was even less than 1,640. For example, tracts where no one was employed generated a missing value for a measure of percentage of employment in manufacturing; as we will see in the regression analysis, this forced out 4 additional tracts, one of which contains a large-capacity TSDF.

FIGURE 1

TSDFs and Mean Per Capita Income, Los Angeles County, 1990

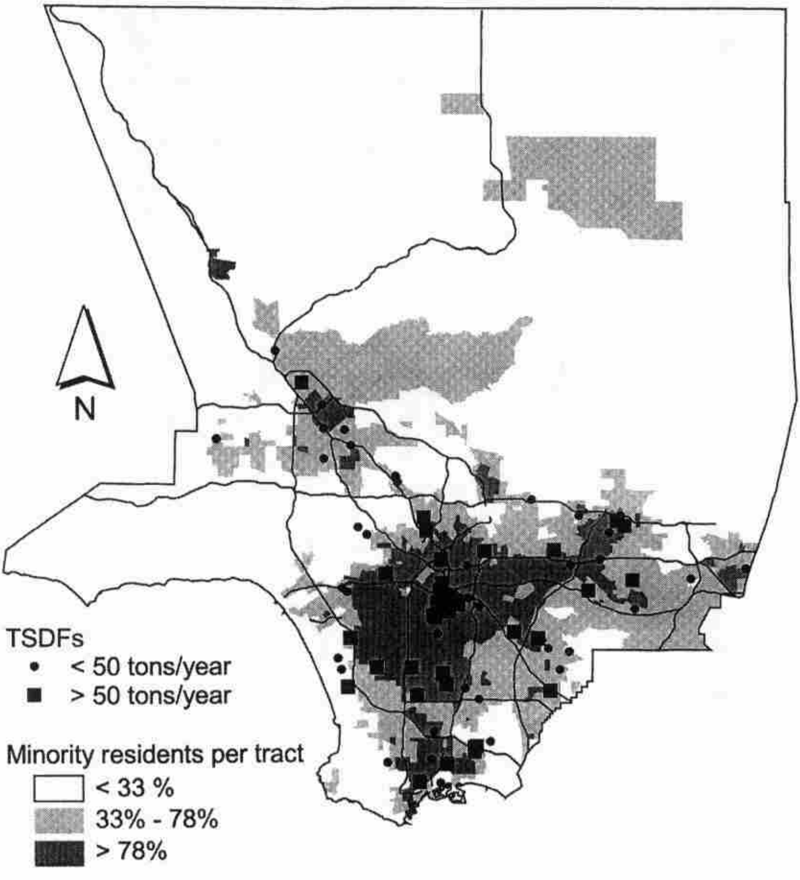


south of downtown Los Angeles; the remaining sites are located throughout southern and West-Central Los Angeles County, usually along freeway routes. These locations are overlaid on a breakdown of very low income tracts (>$11,000 per capita), low-income tracts ($11,000–$17,352 per capita), and tracts where per capita income exceeds the county tract average (for all tracts in our sample) of $17,352 a year. Figure 1 suggests that most of the TSDF tracts are located in the very low income and low-income areas of South-Central and East Los Angeles, the Long Beach/Los Angeles Harbor area, and portions of the central San Gabriel and San Fernando valleys.

Overlaying TSDF location on the percentage of minority residents (Figure 2) is similarly illustrative. There appears to be a geographic correlation between race and TSDFs.

FIGURE 2

TSDFs and % Minority Residents, Los Angeles County, 1990



To investigate the relationships in a more systematic way, we used GIS analytical routines to construct three dummy variables to distinguish various subsamples of Los Angeles tracts. The first, *TSD*, is equal to one for all census tracts that contain at least one TSDF, regardless of capacity; since some tracts have more than one TSDF, this gave us a total of sixty-six tracts with a TSDF. *TSD>50* is equal to one for all tracts containing a large-capacity TSDF, one that processed over fifty tons during 1993 and that may, therefore, pose a higher level of risk; the thirty-nine facilities that meet this criterion are located in thirty-one tracts.

A third dummy variable, *TSD>50/1.0*, expands the potentially exposed community by including all tracts with a boundary within a one-mile radius of a large-capacity TSDF, yielding a tract total of 262.[5] Defining the neighborhood potentially affected by TSDF location by a radius of this general magnitude has been employed in several other studies (Mohai and Bryant, 1992; Anderton et al. 1994b; Pollock and Vittes, 1995) and reflects the assumption that the increased risk and potential damage caused by a TSDF is not constrained to U.S. Census boundaries, but, instead, affects residents of the area surrounding the facility. We considered a one-mile radius surrounding sites to be appropriate for this analysis. Pollock and Vittes (1995) report patterns of significant demographic inequity present within a much larger geographic range.

We then collected twelve different demographic variables for each tract, including (1) percentage minority residents (all but non-Latino whites; see Been, 1995: 5); (2) percentage African American; (3) percentage Latino; (4) per capita income; (5) median household income; (6) percentage employed in manufacturing; (7) percentage of land zoned for residential use; (8) percentage of land zoned for industrial use; (9) median house value; (10) median rent; (11) percentage registered to vote; and (12) population density (see Table 1). We calculated tract means and medians for the different variables, then compared the tracts with and without TSDFs (*TSD*, *TSD>50*), and the tracts located within versus those outside of our one-mile radius (*TSD>50/1.0*) to the overall means for Los Angeles County. Comparisons took two forms: a simple *t*-test of the sample means and a Wilcoxon procedure that is nonparametric and yields a *Z*-statistic for the difference in ranked sums.[6] The results are reported in simplified fashion in Table 2. To conserve space, we report only the county means and then the tract means for each subsample, where *TSD*, *TSD>50*, or *TSD>50/1.0* equals one; we do not report the means for the "companion" tracts with no TSDF exposure. Of course, if the means for TSDF tracts is above the county average, the mean for the companion tracts is below the average. The *t*-value and *Z*-statistics are, however, based on the appropriate comparison between tracts with and without TSD exposure.

The pattern that emerges generally squares with the priors of environmental justice advocates, but there are some interesting and important subpatterns. In all subsamples, the percentage minority (i.e., all those who are not "Anglo") is significantly greater in the tracts with TSDFs or within a one-mile radius of large-capacity TSDFs; however, the percentage African American is actually lower for tracts with any sort of TSD (albeit insignificantly) and becomes significantly higher only when we raise the exposure

[5] Analysis using a fourth dummy variable—all tracts within one-half mile of a large-capacity TSDF—yielded results similar to those for *TSD>50/1.0*. To conserve space, we do not report the results.

[6] The *t*-test can be performed under the assumption of either an equal or an unequal variance in the split samples; when the probability of an equal variance (as given by the *F*-statistic from a Levene test) was below .05, we opted for the unequal variance assumption. The Wilcoxon ranked-sum test is also used in Anderton et al. (1994b).

TABLE 1

Variable Names and Data Sources used in Analysis

TSDF	Hazardous waste treatment, storage, and disposal facilities registered with the California State Department of Toxics (Tanner, 1993 data set)
% minority	% of nonwhite residents in a census tract. Calculated by subtracting non-Hispanic whites from total persons and dividing by total persons (from 1990 Census, STF1)
% African American	% of tract residents identified as non-Hispanic black in 1990 STF1
% Latino	% of tract residents identified as Hispanic-1990 STF1
Per capita income	Per capita income by tract, as reported in 1990 STF3
Household income	Median household income by tract, as reported in 1990 STF3
% manufacturing employment	Ratio of residents employed in nondurable manufacturing to all tract residents employed, as reported in 1990 STF3
% residential land	% land in a tract devoted to residential housing and schools. Computed at the tract level using GIS from 1990 land use GIS coverage (2.5 acre resolution) (provided by Southern California Assn. of Governments)
% industrial land	% of land in a tract devoted to industry, transportation, communications, and utilities. Computed at the tract level using GIS from 1990 SCAG land use GIS coverage
Median house value	Median home value; self-reported, as taken from 1990 STF3
Median rent	Median rent; self-reported, as reported in 1990 STF3
% registered voters	Ratio of registered voters (for November 1994 election) to total number of persons in a tract over age 18. Voting data from Los Angeles County Registrar/Recorder Office; population from the 1990 Census, STF1
Population density	Total population divided by area of census tract. Population data from 1990 STF1; tract area calculated from 1992 Census TIGER data files

radius to one mile (*TSD>50/1.0*). The percentage Latino, on the other hand, is greater in those tracts containing or proximate to TSDFs across all subsamples, a pattern that squares with the findings in Anderton et al. (1994a, 1994b).[7] Per capita and household income are significantly and (nearly) uniformly lower across the subsamples, as is the percentage of registered voters; manufacturing employment is significantly and uniformly lower across the subsamples.

[7] The finding of significance for Latinos in Anderton et al. (1994b) seems to be driven by the pattern in the Southwest, in which Los Angeles County is located.

TABLE 2

Univariate Statistics on Differences between Tracts with and without TSDFs

Variable	L.A. County	*TSD*	*t*-value	*Z*-stat	*TSD*>50	*t*-value	*Z*-stat	*TSD*>50/1.0	*t*-value	*Z*-stat
% minority	56.3	69.2	3.96***	−3.10***	77.1	4.94***	−3.47***	78.2	15.40***	−12.25***
% African American	11.0	9.8	−0.54	−0.42	14.0	0.85	−0.44	16.8	4.67***	− 3.52***
% Latino	34.7	50.3	4.84***	−4.76***	53.5	3.93***	−3.89***	50.1	10.38***	−10.39***
Per capita income	$17,352	$12,730	−4.88***	−3.60***	$11,045	−7.38***	−3.39***	$11,202	−15.15***	−10.79***
Household income	$38,369	$32,170	−4.63***	−2.50**	$29,253	−2.76***	−2.99***	$30,298	−10.75***	−8.31***
% manufacturing employment	20.4	25.7	4.69***	−5.14***	26.6	3.74***	−3.98***	25.9	10.75***	−10.38***
% residential land	64.9	39.5	−9.00***	−7.76***	34.0	−7.36***	−6.16***	57.5	−5.15***	−5.48***
% industrial land	10.8	42.1	9.87***	−9.74***	49.5	8.18***	−7.61***	22.7	9.30***	−10.16***
Median house value	$243,026	$195,434	−4.68***	−3.54***	$186,070	−4.37***	−2.83***	$183,894	−12.46***	−9.64***
Median rent	$683	$623	−3.60***	−2.58***	$583	−3.29***	−3.33***	$598	−9.88***	−9.15***
% registered voters	34.1	28.6	−2.86***	−3.09***	28.2	−1.98**	−2.41**	26.2	−9.03***	−8.74***
Population density	11,044	7,032	−5.15***	−4.54***	6,909	−2.56***	−3.30***	11,838	1.54#	−2.73***

NOTES: ***Significant at the 0.01 level.

**Significant at the 0.05 level.

*Significant at the 0.10 level.

#Significant at the 0.20 level.

The land use mix changes across the subsamples. Whereas for *TSD>50/1.0*, TSDF-exposed tracts do have a pattern of lower residential and higher industrial use, this is less pronounced than for tracts where *TSD* and *TSD>50* equal one, a result that squares with the general supposition that TSDFs are located in the most industrial areas. Median housing values and rents are lower in all exposed tracts, but the tracts means fall most dramatically when we consider large-capacity sites (i.e., *TSD>50* and *TSD>50/1.0*).[8]

Finally, population density is lower in tracts with TSDFs (*TSD* and *TSD>50*), a result that is consistent with the aforementioned pattern of land use. On the other hand, population density is actually higher for those tracts falling in a one-mile radius of a large-capacity TSDF (*TSD>50/1.0*), although the difference is significant only in the Wilcoxon test. Note, however, the lower percentage of land devoted to residential areas in the *TSD>50/1.0* sample, a fact that implies that these "affected" individuals are especially crowded on the available land.[9]

The results do suggest a racial differential in TSDF exposure. For example, while the total number of people living in a census tract containing a TSDF represents 4.2 percent of the entire county population, this subpopulation represents 5.2 percent of all minorities and only 2.9 percent of the Anglo residents; meanwhile, more than one in five minorities live in a census tract located within one mile of a large-capacity hazardous waste TSDF in Los Angeles County, compared with fewer than one in ten Anglos living in similar circumstances. Whether this differential is a function of other variables (such as income or employment type) rather than ethnicity per se remains an open question, however. If, for example, the effects of race/ethnicity disappear once we control for, say, income, land use, and manufacturing employment, then the minority presence in TSDF tracts may be simply an unfortunate result of the strong correlation between percentage minority and these other variables.[10] To separate out the impacts, we follow the procedure of other authors and, in the next section, construct and test a multivariate logit regression of TSDF location.

Multivariate Logit Analysis. The base equation to be tested in our multivariate analysis was as follows:

[8]This result could suggest either siting of TSDFs in areas with lower property values or indicate a postlocation decline in values. See the discussion in Been (1994a).

[9]Following Anderton et al. (1994b), we also divided the tracts within our radius sample (i.e., all tracts where *TSD>50/1.0* = 1) into those with and without an actual large-capacity TSDF. The resulting *t*- and *Z*-statistics were nearly all highly insignificant, in contrast to Anderton's conclusions (which, we should note, were based on a much larger sample and a wider radius). The only significant differences—higher industrial land use and lower residential land use and population density—were unsurprising in light of our findings.

[10]This is generally what Anderton et al. (1994b) find. Been (1995) criticizes these results on methodological grounds and reruns various statistical tests with outcomes more conducive to the perspective that alleges some degree of environmental inequity.

TSDF = f [*MINORITY*(+), *PERCAPIN*(+), *PERCAPIN2*(−), *INDLAND*(+), *EMPMAN*(+), *POPDEN*(−)],

where the signs in parentheses indicate the manner in which each variable was expected to influence prediction of TSDF location. *MINORITY* refers to percentage minority in a particular tract, *INDLAND* refers to the percentage of tract land zoned for industrial use, *EMPMAN* is the ratio of manufacturing employees to all employed individuals in a tract, and *POPDEN* is the tract's population density (normalized to 100 when density is equivalent to the tract mean reported in Table 2). As will be seen, we also enter *AFAMPCT* and *LATINPCT*, the percentage of tract residents who are African American or Latino; runs using other variables are discussed below.

The last key variable in the base equation is *PERCAPIN*, defined as the ratio of per capita tract income to the tract mean reported in Table 2 (normalized, as with *POPDEN*, to 100). Note, however, that *PERCAPIN* is positively signed and that we have introduced a new variable, *PERCAPIN2* (the square of per capita income), for which we predict a negative sign; this functional specification gives us an inverted U-shaped curve in which the probability of a TSDF first increases, then decreases with increasing income. This curvilinear shape reflects the notion that extremely poor census tracts might not contain enough industry to warrant locating a TSDF in that area, even if the low level of income translates into a low level of potential political resistance to such a facility; on the other hand, wealthier residents might have a greater capacity to avoid living near potentially hazardous facilities and/or resist the location of such facilities nearby, implying that the best odds for location of a TSDF would be in tracts within an income range that would not be the lowest in the county. Such a supposition also squares with the pattern reported by Been (1995: 18–19). She breaks up neighborhoods by income and finds that both the poorest and the richest areas bear a disproportionately low burden of TSDFs, with a disproportionately high concentration of such facilities in areas with median family incomes ranging from $10,000 to $40,000.

The actual regressions were performed using as the dependent variable the various TSDF tract designations reviewed in Tables 2 and 3. Reported here are the results for two dummy variables associated with large-capacity TSDFs (*TSD>50* and *TSD>50/1.0*), in part, because large-capacity plants may pose a greater potential hazard and, in part, simply to conserve space; the pattern was similar for the *TSD* variable (which equals one for a tract with any sort of TSDF), but the statistical significance of those runs was generally lower, a result in keeping with the smaller difference between TSDF and non-TSDF tracts evident in Table 2. With each dependent variable, we tried three basic specifications: the first set uses the base regression outlined earlier; the second drops *POPDEN;* and the third drops *MINORITY* and enters separate variables for the two major minority groups.

The results, reported in Table 3, tend to be consistent with both the environmental justice framework and Anderton et al.'s (1994a, 1994b) stress on the importance of industrial employment.[11] Note first that our specification of the income relationship generally works well and that both *MINORITY* and *INDLAND* are quite significant and robust across the specifications. Manufacturing employment is incorrectly signed but insignificant for *TSD>50*; on the other hand, it is positive and significant for the one-mile radius, a pattern that squares with Anderson's assertion that TSDFs may be located near the appropriate workers (or vice versa). Finally, both *AFAMPCT* and *LATINPCT* are positive and significant in the same regression, seeming to challenge the conclusion in Anderton et al. (1994b) that environmental hazards might be more correlated with Latinos than with African Americans.

As can be seen, *POPDEN* is highly insignificant and was therefore dropped. While this is contrary to the findings in Been (1995), in which population density is negatively signed and significant in a logistic regression, the insignificance actually results from our use of a superior measure, *INDLAND*, which has not been available for researchers casting a broader geographic net than we did. If we, for example, drop *INDLAND*, *POPDEN* becomes significantly negative and the other variables follow the same general pattern of signs and significance with one telling exception: *EMPMAN* becomes positive and significant in the *TSD>50* sample. In our view, this suggests that population density has been a stand-in for industrial land use in previous studies. If we calculate a density measure that divides population by only the residential land, it is actually positive but not significant in a regression that includes *INDLAND*.

What about other possible specifications? Using median household rather than per capita income yields essentially the same results. Median house value and median rent fare poorly, an expected result, since both are problematic variables and it is unclear how each should be weighted in determining land values.[12] Percentage of registered voters is insignificant, perhaps because we are already controlling for variables (race, income, and

[11] Indeed, Anderton et al. (1994b) find percentage minority to be generally insignificant in their logistic regressions and argue that this is because they have controlled for the locational decisions of minority residents by including an industrial-employment variable. As noted in the text, our results are different for this case study.

[12] Because of coding limits, for example, a full 10 percent of median rents and 7.3 percent of median household values share the same maximum value. Meanwhile, there is likely to be significant error in the self-reported house value, and upward bias may have been quite possible in the overheated California real estate market extant at the time of the U.S. Census. Weighting house values and rents is also quite difficult; although we know how many units fall in each category, there are computational difficulties in transforming house values in rent-type flows, and the possibility of high-end houses coexisting in the same tract with low-income rental units makes normalization of each sort of value or flow particularly challenging.

TABLE 3

Logit results for TSDF Presence as a Function of Various Demographic Variables

Independent Variable	Dependent Variable					
	TSD>50 (a)	*TSD*>50/1.0 (b)	*TSD*>50 (c)	*TSD*>50/1.0 (d)	*TSD*>50 (e)	*TSD*>50/1.0 (f)
MINORITY	0.030	0.033	0.030	0.033		
	(1.965)**	(6.318)***	(1.967)**	(6.332)***		
PERCAPIN	0.056	0.027	0.056	0.026	0.062	0.009
	(1.692)*	(2.589)***	(1.752)*	(2.726)***	(1.771)*	(.829)
PERCAPIN2	0.000	−0.000	−0.000	−0.000	−0.000	−0.000
	(−1.39)	(−2.451)**	(−1.404)#	(−2.515)***	(−1.588)*	(−1.647)*
INDLAND	0.064	0.033	0.063	0.032	0.063	0.033
	(5.981)***	(7.304)***	(8.02)***	(8.106)***	(7.971)***	(8.261)***
EMPMAN	−0.012	0.020	−0.012	0.022	−0.018	0.025
	(−.542)	(2.216)**	(−.542)	(2.213)**	(−.736)	(2.283)**
POPDEN	0.000	0.000				
	(.020)	(.153)				
AFAMPCT					0.019	0.018
					(1.476)#	(4.010)***
LATINPCT					0.026	0.010
					(1.489)#	(1.677)*
Usable observations	1,636	1,636	1,636	1,636	1,636	1,636
Log likelihood	−102.6	−583.5	−102.6	−583.5	−103.3	−596.1
% cases correct	98.2	85.3	98.2	85.3	98.2	85.1
Pseudo R^2	0.146	0.167	0.146	0.167	0.150	0.154

NOTES: ***Significant at the 0.01 level.

**Significant at the 0.05 level.

*Significant at the 0.10 level.

#Significant at the 0.20 level.

working-class status) often associated with low political participation. Finally, a linear specification of an income variable, as suggested by one anonymous referee, yields a negative but insignificant coefficient, with all other variables retaining their sign and significance pattern; we therefore stick with our preferred specification.[13]

While signs and significance are important, it would also be interesting to know the magnitude of the impacts of different variables. Unfortunately, coefficients in logit regressions are difficult to interpret, primarily because they are telling us the impact on the log of the odds. One way to determine the effect on the more commonly used notion of probability is to transform these coefficients at the mean of the dependent variable; however, the mean for the dependent variable therefore affects the coefficient value, and this can be especially problematical when the mean value for dependent value is quite low, as it is for *TSD>50*. An alternative is to conduct sensitivity analysis, "calibrating" the regression at the tract mean for all the relevant independent variables. We follow the latter procedure here.

Taking as our "best" regressions those reported in columns (c) and (d) of Table 3, we first determined the income "peaks" below and above which the likelihood of being located near a TSDF decreases. For *TSD>50*, this was 99 percent of the mean tract; for *TSD>50/1.0*, it was approximately 125 percent of the mean tract.[14] An increase in per capita income of 10 percent from the peak would decrease the probability of a tract's having a boundary within a one-mile radius of a large-capacity TSDF by 0.002. Meanwhile, a 10 percent increase in minority residents would raise this probability by 0.045, a 10 percent increase in industrial land would raise the probability by 0.043, and a 10 percent increase in manufacturing employment would raise probability by 0.029.[15] Of course, one must recall that the random chance of a given tract's being in the *TSD>50/1.0* subsample is the county incidence rate of 0.159; thus, the aforementioned shifts in minority population, land use, and employment would raise a tract's chance of being located in the TSDF radius by 28 percent, 27 percent, and 18 percent, respectively, while change in probability associated with increasing the peak per capita income by ten percentage points would lower the chance by 1.3 percent.

In the real world, these critical race, income, employment, and land use variables move in parallel and simultaneous fashion. We therefore constructed two "tract profiles," which we consider to be typical of several

[13]A linear specification of income is highly significant only when we drop race; of course, given that the debate is about whether the location of TSDFs reflects racial disparities or simply market forces, this is a highly academic exercise.

[14]"Peaks" of income relative to the mean are similar if median household income is used.

[15]These are estimates from the tract means, but the actual effect on probability is nonlinear. For example, moving from 0 to 10 percent minority raises probability of being located in the *TSD>50/1.0* radius by 0.009; moving from 90 to 100 percent minority raises the probability by 0.077.

Los Angeles County cities and neighborhoods. Each tract profile is defined by a range of model variables: Profile A is characterized by 0 to 20 percent minority residents, a per capita income range of twenty-five thousand dollars to thirty-five thousand, 2.5 to 7.5 percent industrial land use, and 5 to 20 percentage employment in manufacturing. Profile B is 80 to 100 percent minority, per capita income from five thousand dollars to fifteen thousand, percentage industrial use from 20 to 30 percent, and percentage employed in manufacturing between 30 and 45. Twenty tracts in Los Angeles County fit profile A and twenty-three fit profile B. For the profile A tracts, the predicted probability from our regression of a *TSD>50/1.0* is 2.0 percent and the actual incidence is 5 percent; for profile B, the predicted probability of a *TSD>50/1.0* is 43.1 percent and the actual incidence is 34.8 percent. In our view, this suggests a reasonable fit between our regression and the data.

Summary

This article has tried to examine the issue of "environmental justice" by examining the pattern of one potential hazard, TSDFs, in one geographic area, Los Angeles County. The results of univariate analysis suggest a substantial difference between tracts with and without (or close to and far from) such hazards by race/ethnicity, income, land use, employment patterns, political participation, and population density. One key subpattern squares with the analysis in Anderton et al. (1994b); breaking the category "minority" into African Americans and Latinos suggests that the latter may be much more likely than the former to be living in the closest proximity to such TSDFs. Multivariate analysis of the type suggested by Anderton et al. (1994b), Been (1995), and others indicates that (1) even controlling for income, industrial land use, and manufacturing employment, race/ethnicity correlates with the location of TSDFs, and this holds for both African Americans and Latinos; (2) income bears a complicated relationship to the likelihood of TSDF location, with the latter first rising, then falling as income increases (see also Been, 1995); and (3) as suggested by Anderton et al. (1994a, 1994b), TSDF location and the proximity of a manufacturing labor force are significantly correlated in a multivariate analysis (and industrial land use, not tested in Anderton et al. [1994a, 1994b], is even more significant).

While the latter results on the significance of manufacturing employment do support the claims of those arguing that the strength of the minority–TSDF correlation is partially driven by other forces, the persistence of race across our tests suggests that environmental justice proponents may have real cause for their concerns, at least in the Los Angeles area. Most important, the overall pattern we find suggests that the communities most likely to "host" a TSDF are industrial areas with a large concentration of working-class people of color—exactly the group that has been the focus of Los Angeles–based advocates of environmental justice.

This study, of course, leaves open a set of questions that should be the target of future research. As noted in the introduction, we have not conducted a historical analysis of siting and have no evidence of actual discrimination in permit decisions. Moreover, we have not examined whether areas surrounding Los Angeles County TSDFs changed demographically (e.g., became more minority in their residential population) during the period after the facility was sited.[16] Been's (1994a) exploration of this issue is inconclusive. Yandle and Burton (1996a) attempted such a study for hazardous waste landfills in metropolitan areas of Texas and found no evidence for siting bias against racial and ethnic minorities but did detect a bias toward siting these facilities in low-income communities. Their study, however, has received pointed criticism on both contextual and methodological grounds (Anderton, 1996; Bullard, 1996; Mohai, 1996; see also Barkenbus, Peretz, and Rubin, 1996; Yandle and Burton, 1996b). If there is any racial pattern of movement into an area of environmental risk, that is, if more minorities move into areas with potential hazards than do Anglos of similar income levels, we believe this suggests a lack of choice over a broader residential market, and the explanation for the present pattern of environmental inequity based on race and ethnicity would then differ only in its historical details (Andeola, 1994).

In terms of policy, we suggest that TSDFs be seen as a necessary part of the urban economic landscape; any attempt to ban such sites might actually pose even greater and more inequitable hazards by creating incentives for illegal dumping.[17] Still, better zoning separation between industrial and residential land might be a useful policy direction, and serious thought should be given to compensation schemes designed to offset the costs of potential risk (Kunruether et al., 1987; O'Sullivan, 1993; Been, 1994b). In the meantime, policymakers should pay more attention to the demographics of the communities surrounding any proposed new sites and recognize that the opinions of community groups that have raised the charges of environmental injustice are not unreasonable based on the current existing evidence.

[16] Such a pattern, if it exists, might weaken the environmental justice notion and, in turn, raise interesting questions about minority preferences: since we are controlling for income and employment, why would we find more non-Anglos than Anglos of similar income and occupation "choosing" to move to potential hazard areas?

[17] Local governments cannot place an outright ban on hazardous waste facilities; such action, whether the ban be expressly stated or obtained by use of excessive regulation, has been ruled by the U.S. Supreme Court to violate the commerce clause of the Constitution (Shortlidge and White, 1993).

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REASSESSING RACIAL AND SOCIOECONOMIC DISPARITIES IN ENVIRONMENTAL JUSTICE RESEARCH*

PAUL MOHAI AND ROBIN SAHA

The number of studies examining racial and socioeconomic disparities in the geographic distribution of environmental hazards and locally unwanted land uses has grown considerably over the past decade. Most studies have found statistically significant racial and socioeconomic disparities associated with hazardous sites. However, there is considerable variation in the magnitude of racial and socioeconomic disparities found; indeed, some studies have found none. Uncertainties also exist about the underlying causes of the disparities. Many of these uncertainties can be attributed to the failure of the most widely used method for assessing environmental disparities to adequately account for proximity between the hazard under investigation and nearby residential populations. In this article, we identify the reasons for and consequences of this failure and demonstrate ways of overcoming these shortcomings by using alternate, distance-based methods. Through the application of such methods, we show how assessments about the magnitude and causes of racial and socioeconomic disparities in the distribution of hazardous sites are changed. In addition to research on environmental inequality, we discuss how distance-based methods can be usefully applied to other areas of demographic research that explore the effects of neighborhood context on a range of social outcomes.

Since the mid-1980s, scholarly attention to racial and socioeconomic disparities in the distribution of pollution, environmental hazards, and locally unwanted land uses (LULUs) has been increasing. Many quantitative studies examining environmental inequality have been conducted over the past decade. Although most reviews have found that these inequalities tend to be statistically significant (Lester, Allen, and Hill 2001; Mohai and Bryant 1992; Ringquist 2005), there has been considerable variation in the magnitude of the disparities found. Some studies have found no racial or socioeconomic disparities associated with the distribution of environmentally hazardous sites (Anderton et al. 1994; Bowen et al. 1995; Davidson and Anderton 2000). Uncertainties also exist about the causes of racial and socioeconomic disparities in the distribution of environmental hazards. Indeed, the most fundamental question—which came first, the people or the pollution?—has yet to be satisfactorily answered. That is, are present-day disparities the result of a historical pattern of disproportionately siting polluting facilities in minority and poor communities, or are they the result of demographic changes in communities after siting? The few studies that have been conducted have led to contradictory findings (see, e.g., Been and Gupta 1997; Oakes, Anderton, and Anderson 1996; Pastor, Sadd, and Hipp 2001; Saha and Mohai 2005).

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A principal argument of this article is that much of the source of these uncertainties is related to the failure of the most widely used methodology in environmental inequality research to adequately account for the proximity between environmentally hazardous sites and nearby residential populations. The goal of this article is therefore to identify the reasons for and consequences of the failure of this methodology and to demonstrate ways of overcoming these shortcomings by using alternate, *distance-based* methods. By applying distance-based methods in the reanalysis of a leading national study of the demographic disparities around the nation's hazardous waste treatment, storage, and disposal facilities (TSDFs), we demonstrate how and why findings and conclusions about the magnitude and causes of racial and socioeconomic disparities around such sites are changed. We argue that the application of distance-based methods will help resolve existing uncertainties and improve our understanding of the extent and causes of inequalities in neighborhood environmental conditions. Moreover, such methods, we believe, have applicability to wider areas of demographic research that attempt to understand the effects of neighborhood context on a range of social outcomes (Sampson, Morenoff, and Gannon-Bowley 2002).

THE CLASSIC APPROACH: ANALYZING UNIT-HAZARD COINCIDENCE

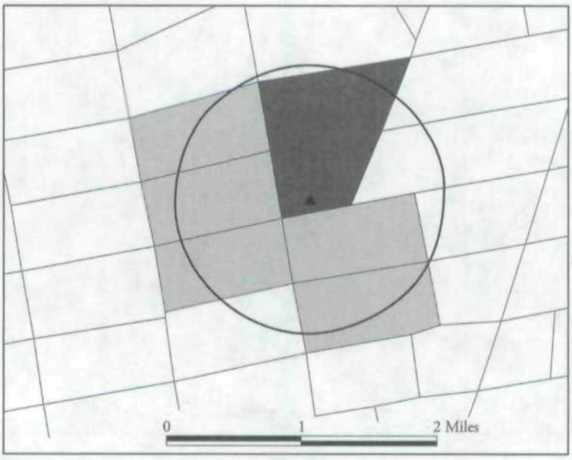
As we suggested earlier, the most widely used approach for assessing demographic disparities in the distribution of environmental hazards and LULUs is also the weakest in its ability to control for the proximity between such hazards and nearby populations. This approach has nevertheless been the typical or "classic" approach to environmental inequality research, including some of the most influential studies (e.g., Anderton et al. 1994; Been 1995; Commission for Racial Justice, CRJ, 1987; Goldman and Fitton 1994). The approach is straightforward. It involves selecting a predefined geographic unit (such as counties, zip code areas, or census tracts), identifying which of the units contain or "host" the hazard, deciding upon an appropriate set of comparison units (essentially, those that do not contain the hazard), and then comparing the demographic characteristics between the two sets. Not taken into account by this method is the exact location of the hazard within the host unit, nor the proximity of the hazard to nearby units. Since this method goes no further than noting whether the general locations of the hazard and host unit coincide, some have referred to this method as "spatial coincidence" (McMaster, Leitner, and Sheppard 1997), although "unit-hazard coincidence" may more precisely describe the approach. Nearly all national-level studies on environmental inequality have used this approach (see Anderton et al. 1994; Anderton, Oakes, and Egan 1997; Been 1995; CRJ 1987; Daniels and Friedman 1999; Davidson and Anderton 2000; Goldman and Fitton 1994; Greenberg 1993; Hamilton 1993, 1995; Hird 1993; Hird and Reese 1998; Lester et al. 2001; Oakes et al. 1996; Perlin et al. 1995; Ringquist 1997; Zimmerman 1993).

An implicit assumption in this approach is that people living in the host units are closer to the hazard under investigation than people living in the nonhost units. That this is not always the case, indeed frequently is not the case, becomes apparent when the exact locations of a set of environmental hazards or LULUs are mapped (rarely done in most environmental inequality research) and their proximity to host and surrounding unit boundaries is examined. Figure 1 provides such an illustration. Here, the precise locations of two of the nation's hazardous waste TSDFs are displayed. Although many other TSDFs similarly illustrate the problems of the unit-hazard coincidence method, those presented in Figure 1 provide especially clear examples. A more comprehensive analysis demonstrating the limitations of this method is provided later in the "Results" section.

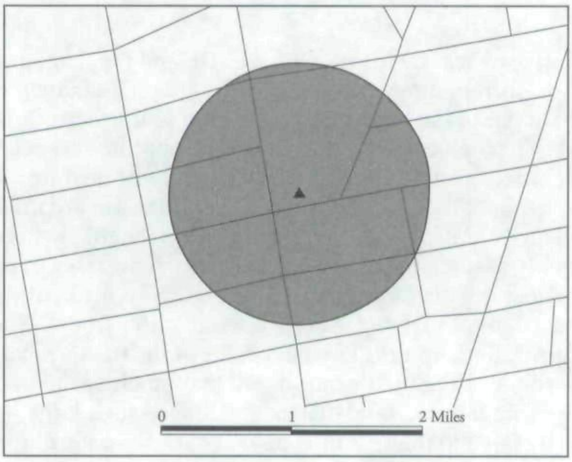
One observation that is apparent from the figure is that, rather than necessarily being located near the host tract's center, the TSDF may be located near a boundary. Indeed, using a national database of 608 TSDFs operating in the early 1990s (see the description below) and 1990 census tracts, we found that 298, or 49%, of them are within 0.25 miles of the boundary of their host tracts, while 433, or 71%, are within 0.5 miles. When the TSDF is

Figure 1. Comparing Neighborhoods Around TSDFs Identified by Unit-Hazard Coincidence and Distance-Based Methods

a. 50% areal containment using a one-mile radius



b. Areal apportionment using a one-mile radius

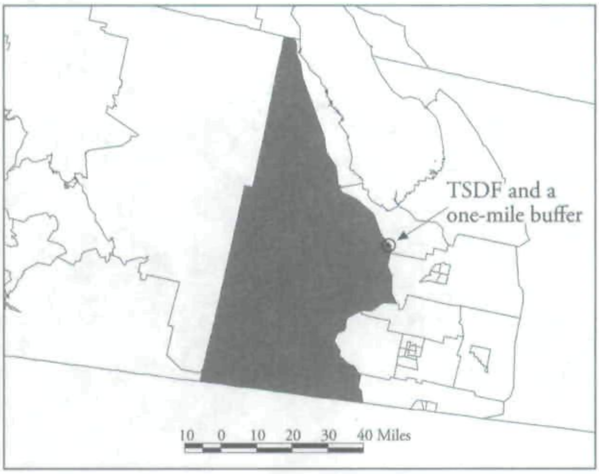


(continued)

near a boundary, much of the adjacent or nearby tracts may be as close to the TSDF as the host tract proper. For example, in Figure 1a, most of the areas of the tracts immediately south and west of the TSDF (shaded light gray) appear to be as near to the TSDF as most of the area of the host tract (shaded dark gray). A one-mile radius captures about as much of the areas of the adjacent and nearby tracts as it does of the host tract. (Consequences of selecting alternate radii are discussed in the "Methods" section.) In spite of their proximity to the TSDF, the unit-hazard coincidence method treats such nearby tracts no differently than nonhost tracts much farther away and places them in the comparison group. However, if

(Figure 1, continued)

c. Large host tract



there is a relationship between the location of a TSDF and the demographic characteristics of the neighborhoods surrounding it, then the demographic characteristics of the nearby tracts may be more similar to the host tract proper than to tracts much farther away. Placing such nearby tracts in the comparison group may thus obscure this relationship.

A second observation from Figure 1 is that the sizes of host tracts may vary dramatically. For example, the host tract in Figure 1a is only 0.85 square miles, while the host in Figure 1c is 916.5 square miles. When the host tract is small, such as the tract in Figure 1a, it can be reasonably assumed that almost everyone in the tract lives close to the TSDF. However, when the host tract is large, such as in Figure 1c, little of the tract's population may be close by. Indeed, the TSDF in Figure 1c is 14.9 miles from the centroid of its host. A circle with a one-mile radius captures less than 0.2% of the tract's area. Given that so much of the tract lies far from the TSDF, it is not likely that much of the tract's population lives near it, at least not within the one-mile distance. Because such large host tracts (i.e., those whose areas lie mostly beyond the specified distance) fail to control for proximity between the TSDF and nearby populations, it is uncertain whether such tracts are able to detect a relationship between the presence of the TSDF and the demographic characteristics of the nearby populations. Indeed, the demographic characteristics of such large host tracts may not be much different from the characteristics of nonhost tracts whose areas similarly lie beyond such a distance (a possibility we examine later). If that is the case, then averaging or aggregating population characteristics of such large host units with small host units (where the proximity between TSDF and nearby populations is better assured) may obscure any relationship that might exist between the TSDF and nearby population characteristics.

DISTANCE-BASED METHODS

Standing in contrast to the unit-hazard coincidence studies are a limited number of studies that have employed distance-based methods. These methods overcome a number of limitations of the classic approach. With these methods, the precise locations of environmental hazards or LULUs are mapped, and their distances to nearby residential populations are specified. The demographics of all units within the specified distances, not just in the host unit proper, are contrasted with the demographics of units farther away. There have been three types of distance-based methods using census data: (1) 50% areal containment, (2) boundary intersection, and (3) areal apportionment. Next we describe each method and its relative advantages over the unit-hazard coincidence approach.

50% Areal Containment and Centroid Containment

The 50% areal containment method involves mapping the location of environmental hazards or LULUs and then averaging or aggregating the demographic characteristics of predefined geographic units (such as block groups, census tracts, and zip code areas) captured by circles of a specified distance from the hazards. However, because the units may take up considerable space, often the circle intersects only a portion of the unit, rather than completely encompassing or completely missing it. One rule that researchers have used to decide whether to count a unit as within the specified distance, and hence within the host neighborhood, is to include all units for which at least 50% of the unit's area is captured and exclude all units, including the host, if the captured area is less than 50%. Alternatively, units have been considered within the host neighborhood if the circle captures the geographic center of the unit (the *centroid-containment method*). The resulting area formed around the hazard approximates a circle with "rough edges" (Figure 1a). The demographic characteristics of the units captured by the 50% areal containment (or centroid containment) method are then averaged or aggregated (i.e., the demographics of the units are weighted by the units' population sizes) and compared against the demographics of the averaged or aggregated units not captured. Averaged demographic characteristics (C_{averaged}) of the captured units are computed by

$$C_{averaged} = \frac{\sum_{i=1}^{n} c_i}{n},$$

where c_i is the demographic characteristic of unit i, and n is the number of captured units. Aggregated (population-weighted) characteristics ($C_{aggregated}$) of the captured units are computed by

$$C_{aggregated} = \frac{\sum_{i=1}^{n} (p_i)(c_i)}{\sum_{i=1}^{n} p_i},$$

where p_i is the population in unit i.

Examples of the centroid containment method are provided by Chakraborty and Armstrong (1997). Variations of the centroid containment and 50% areal containment methods are performed by Anderton et al. (1994) and Davidson and Anderton (2000). These studies represent variations of these methods because they do not take into account the actual locations of the hazards under investigation. Instead of centering circles at hazard locations, these studies center their circles at the host tract centroids. Radii of 0.5, 1.0, 2.5, and 3.0 miles have been used in these studies.

Boundary Intersection Method

The boundary intersection method is similar to the 50% areal containment method but without the restriction on including units with captured areas of less than 50%. All units whose boundaries are wholly contained by, partially intersected by, or tangent to a circle of a specified distance centered at the environmental hazard are considered in the host neighborhood. Examples of the application of this method are provided by Boer et al. (1997), Chakraborty and Armstrong (1997), and Pollock and Vittas (1995). Although the boundary intersection method provides some measure of control for proximity by only including units that have some portion within a certain distance, it captures units that may also have substantial areas that lie well beyond the distance. Because it shares a problem similar to that of the unit-hazard coincidence approach, it is the least effective of the distance-based approaches at controlling for proximity.

Areal Apportionment Method

The areal apportionment method is similar to the version of the boundary intersection method in which the characteristics of all units that are wholly contained by or intersected by a circle of a given radius are aggregated (i.e., weighted by population). However, unlike the boundary intersection method, it does not necessarily give each unit's population full weight in the calculations. Instead, each unit's population is weighted by the proportion of the area of the unit that is captured by the circle. The weighted populations of these units are then used to determine the aggregate demographic characteristics of perfectly circular neighborhoods within a specified distance of the hazard (Figure 1b). The formula for computing the demographic characteristics (*C*) within the neighborhoods of a given radius is as follows:

$$C = \frac{\sum_{i=1}^{n} (a_i / A_i)(p_i)(c_i)}{\sum_{i=1}^{n} (a_i / A_i) p_i},$$

where a_i is the area of unit *i* captured by a given radius, and A_i is the total area of unit *i*, and *n* is the number of units that are wholly or partially contained by a circle of a given radius.

An important assumption of this method is that the proportion of the unit's *area* that is captured by the circle approximates the proportion of the unit's *population* that is captured. This assumes that the population and its characteristics are distributed uniformly within the unit. Of course, this may not necessarily be the case. However, the assumption of uniformity within census units is not unique to this method. It is also implicit in the unit-hazard coincidence method and other distance-based methods and implicit in census data research generally. Furthermore, an important advantage of the areal apportionment method over the other distance-based methods is its avoidance of assigning extremes (i.e., 0% vs. 100%) in weighting partially contained units. Partially intersected units are assigned weights proportional to their intersected areas, reducing the risk that any unit over- or underinfluences the estimated demographic characteristics within a given distance of an environmental hazard. Studies that have employed the areal apportionment method include those by Chakraborty and Armstrong (1997), Glickman (1994), Glickman, Golding, and Hersh (1995), Hamilton and Viscusi (1999), and Sheppard et al. (1999). Radii of one-half, one, two, and three miles have been used with this method.

DISTANCE-BASED VERSUS UNIT-HAZARD COINCIDENCE METHODS

In sum, we have illustrated by examples why the unit-hazard coincidence approach, although it is the principal approach used in the influential national-level environmental inequality studies, is the least likely to adequately control for the proximity between potential environmental hazards and nearby populations. This method fails to control for proximity in two ways. First, it does not take into account a possible association between the potential hazard and the demographic characteristics of nearby nonhost units. It assumes that nonhost units near the hazard are no different demographically from nonhost units much farther away. Second, it assumes that populations in large host units are as near to the potential hazard as populations in small host units, when in reality, populations in the former may be dispersed quite far away. Distance-based methods overcome these limitations by specifying the locations of environmental hazards and sorting units based on their actual proximity to these sites.

Using a national-level database of the country's hazardous waste TSDFs, we demonstrate, through more comprehensive and systematic means, how the unit-hazard coincidence method fails to control for the proximity between TSDFs and nearby populations and why distance-based methods have a greater ability to do so. In so doing, we provide results of the first national-level analysis of the demographics around hazardous waste TSDFs obtained from such methods. We use these results to demonstrate how using distance-based methods alters assessments of racial and socioeconomic disparities around environmental hazards and LULUs.

DATA AND METHODS

There is no single, definitive source of information about the nation's hazardous waste TSDFs. As a result, previous studies employing the unit-hazard method have relied on different sources and hence have identified different universes of TSDFs (see, e.g., Been 1995 and Been and Gupta 1997, compared with Anderton et al. 1994 and Oakes et al. 1996). To isolate the effects of employing different methodologies, we sought to utilize the same universe of facilities as previous studies. Due to the confidentiality that was promised to companies surveyed by researchers at the Social and Demographic Research Institute of the University of Massachusetts, we were unable to obtain adequate identifying information for facilities used in Anderton et al. (1994) and Oakes et al. (1996). However, we obtained U.S. EPA identifiers and address information for the 608 facilities used for the other leading studies of hazardous waste TSDFs (Been 1995; Been and Gupta 1997). This information, provided by Professor Vicki Been at the New York University School of Law, allowed us to identify precise geographic locations of TSDFs within the host tracts.

We identified these locations by geocoding addresses and verifying location information primarily through phone interviews of company employees. For 538 TSDFs, our address and location information was either verified or corrected by the facility personnel. In some cases, we consulted site maps obtained from the companies. For 61 TSDFs that we were not able to contact, state environmental agencies or the U.S. EPA were contacted for this information. For the remaining 9 TSDFs for which insufficient information was available from the above sources, other sources, such as former employees and online commercial mapping services, were consulted.

After TSDF locations were established, we generated one-, two-, and three-mile circular buffers around the TSDFs by using ArcView GIS™ (Version 3.2) and a Lambert's Conformal Conic Projection (for the conterminous United States). We selected these radii because they are within the range used in prior studies and because, as other studies have done, we wanted to examine how demographic characteristics around environmentally hazardous sites vary with varying distances to the site. The radius of influence of larger, more toxic sites is likely to be greater than that of others. Thus, rather than suggesting that there is an ideal radius for all environmental inequality studies, we believe future research will need to explore further how demographic characteristics change with varying distances to hazardous sites of a wide variety, an aim that is currently not possible with the unit-hazard coincidence approach. For hazardous waste TSDFs, however, we found (as we discuss later) that minority and poverty percentages generally decreased with increasing distance from the sites.

To analyze the demographic characteristics within the buffers applying the 50% areal containment and areal apportionment methods, we used 1990 digitized census tracts (GeoLytics, Inc. 1999) and 1990 Summary Tape File (STF) 1A and 3A census data (Wessex, Inc. 1994)[1]. We examined variables that were used in many prior studies to assess demographic

1. We used 1990, rather than 2000, census data in order to more directly contrast our results that use distance-based methods with the results of prior studies that used the unit-hazard coincidence method.

disparities in the distribution of environmental hazards and LULUs. These included percentage African American, percentage Hispanic, percentage nonwhite, mean household income, mean housing values, percentage living below poverty, percentage without a high school diploma, percentage with a college degree, percentage employed in executive management or professional occupations, and percentage employed in precision production or labor occupations (see the Appendix for details about the construction of these variables).

RESULTS

The first step in our analysis was to determine how well, in comparison with the unit-hazard coincidence method, distance-based methods control for proximity between the TSDFs and nearby residential populations. To accomplish this, we determined the exact areas of the 554 tracts hosting one or more TSDFs. We also determined the precise distances of each of the 608 TSDFs to their respective host tract centroids. The host tract area and the distance of the tract centroid to a TSDF serve as indicators of the degree to which the population in a tract is likely to be close to the TSDF or to be geographically dispersed from it.

Because some host tracts contain more than one TSDF, and hence there is not a one-to-one correspondence between TSDFs and host tracts, we computed the mean, median, and standard deviation of the host tract areas and centroid distances to the TSDFs in two ways. In the first way, values were based on those associated with *each of the 608 TSDFs* (i.e., $N = 608$ in all the calculations). Thus, the distance between each of the 608 TSDFs and its respective host tract centroid was included in calculating the mean, median, and standard deviation of the distances. In the calculation of the corresponding values for host tract areas, each tract was represented as many times in the calculations as it contained TSDFs. In the second way, values were based on those associated with *each of the 554 host tracts,* with any double counting removed (i.e., $N = 554$ in all calculations). Thus, in calculating the mean, median, and standard deviation of host tract areas, we counted each tract area only once, regardless of the number of TSDFs within the tract. In calculating the corresponding values for distances between host tract centroids and TSDFs, we used the distances between the host tract centroid and the nearest TSDF within the tract. Because the results were similar but slightly more conservative in the second set of calculations in which values were based on host tracts, we discuss only the second set of values (both sets of values are provided in Table 1, however; see columns 9 and 10).

Regarding the host tracts proper and confirming what we suggested earlier, we found considerable variation in the size of host tracts and in the location of the TSDFs with respect to the host tract centroids and boundaries. For example, although the smallest tract hosting a TSDF is only 0.07 square miles, the largest is 7,521 square miles (see Table 1). Similarly, while in one case a TSDF is only 0.03 miles from the centroid of its host, in another it is nearly 34 miles from the centroid. The mean and median areas of the host tracts are 58.41 and 4.71 square miles, while the mean and median distances of the TSDFs to their host tract centroids are 1.86 and 0.90 miles.

In contrast, the size of host neighborhoods defined by one-, two-, and three-mile buffers around the TSDFs are generally much smaller than they are for host tracts proper. (Because the results from using a two-mile radius lay in between, only results for one- and three-mile buffers are reported in Table 1 and discussed.) For example, if we apply 50% areal containment, the host neighborhoods formed by aggregating the captured tracts have mean areas of 2.39 and 21.77 square miles, using one- and three-mile radii, respectively (the median areas are similar to the means; see Table 1, columns 6 and 8). Furthermore, neighborhood centroids are closer to the TSDFs within them, with mean distances of only 0.40 miles and 0.71 miles (again, the median distances are similar), respectively, compared with 1.86 miles for host tracts. There is also greater consistency in the size of the host neighborhoods and the location of the TSDFs within them, as evidenced by the standard deviations of the relevant values. At the one- and three-mile radii, the standard deviations of

Table 1. Spatial Comparisons of Neighborhoods Surrounding 608 TSDFs Defined by Areal Apportionment and 50% Areal Containment Methods Versus Raw Host Tracts

	Neighborhoods Defined by a 1-Mile Radius Using Areal Apportionment $N = 608$		Neighborhoods Defined by a 3-Mile Radius Using Areal Apportionment $N = 608$		Neighborhoods Defined by a 1-Mile Radius Using 50% Areal Containment $N = 608$		Neighborhoods Defined by a 3-Mile Radius Using 50% Areal Containment $N = 608$		Raw Host Tracts $N = 608$ ($N = 554$)	
Measure	Distance From TSDF to Centroid of Neighborhood (1)	Area of Neighborhood (2)	Distance From TSDF to Centroid of Neighborhood (3)	Area of Neighborhood (4)	Distance From TSDF to Centroid of Neighborhood (5)	Area of Neighborhood (6)	Distance From TSDF to Centroid of Neighborhood (7)	Area of Neighborhood (8)	Distance From TSDF to Centroid of Host Tract (9)	Area of Host Tract (10)
Maximum	0.0	3.14	0.0	28.27	1.00	5.60	2.74	45.25	33.95[a] (33.95)[b]	7,521.43 (7,521.43)
Minimum	0.0	3.14	0.0	28.27	0.03	0.0001	0.00	0.08	0.03 (0.03)	0.07 (0.07)
Mean	0.0	3.14	0.0	28.27	0.40	2.39	0.71	21.77	1.89 (1.86)	73.66 (58.41)
Median	0.0	3.14	0.0	28.27	0.38	2.32	0.54	22.98	0.94 (0.90)	4.90 (4.71)
SD	0.0	0.0	0.0	0.0	0.22	1.06	0.59	7.69	3.47 (3.40)	511.07 (416.14)

[a]The first set of values is based on those associated with each of the 608 TSDFs. Thus, if a host tract contains more than one TSDF, it is included as many times as the number of TSDFs within its boundaries in determining the maximum, minimum, mean, median, and standard deviation of the host tract areas. Similarly, the distance between each TSDF and its host tract centroid is included in determining the maximum, minimum, mean, median, and standard deviation of the distances.

[b]The second set of values (in parentheses) is for the 554 host tracts, where each host tract is counted only once, regardless of the number of TSDFs within the tract, in determining the maximum, minimum, means, medians, and standard deviations of areas and distances. When a tract contains more than one TSDF, the distance used in the calculations is from the host tract centroid to the nearest TSDF.

the areas of the resulting neighborhoods are 1.06 and 7.69 square miles, respectively, while the standard deviations of the distances of TSDFs to neighborhood centroids are 0.22 and 0.59 miles. In contrast, the standard deviations of the areas of the host tracts proper and the distance of TSDFs to host tract centroids are 416.14 square miles and 3.40 miles.

With areal apportionment, the neighborhoods that are formed are also smaller than what they are for host tracts proper, forming perfect circles of one- and three-mile radii centered at the TSDFs with areas of 3.14 and 28.27 square miles. Because they are all perfect circles, there is no variation in the size of the neighborhoods or any deviation of the TSDFs from the neighborhood centroids (both with standard deviations of 0.0 square miles).

That the neighborhoods defined by the 50% areal containment and areal apportionment methods are generally smaller than the host tracts proper, and that their centroids are closer to the TSDFs within them, indicates that the populations residing in these neighborhoods are generally closer to the TSDFs than are populations in the host tracts proper. However, does closer proximity to the TSDFs lead to different outcomes, namely, larger proportions of poor people and minorities?

To answer this question, we compared the demographic characteristics of the host tracts proper against those of the neighborhoods surrounding the nation's 608 TSDFs defined by one- and three-mile radii, using the two distance-based methods (see Table 2). We determined demographic characteristics for aggregate populations, rather than computing averages across areas, because averaging skews results toward the less populated areas.[2] We made the comparisons in two ways. First, we compared the demographic characteristics of the populations residing in the neighborhoods defined by the one- and three-mile radii against the demographic characteristics of the populations within the host tracts proper, taking *all* host tracts into account. Second, we compared the neighborhoods defined by the one- and three-mile radii against only those host tracts *too large to be captured* by these radii. In the first comparison, we wanted to determine whether the proportions of minorities and low-income residents are greater in the neighborhoods defined by the two distance-based methods than those in the host tracts *overall*. In the second comparison, we wanted to see whether these disparities became even greater when the neighborhoods were contrasted against the host tracts that were too large to be captured.

In comparing the neighborhoods defined by a one-mile radius against *all* host tracts proper, we found that the proportion of nonwhites residing in neighborhoods within the circle is over 42.0% (42.8% when applying areal apportionment and 46.2% when applying 50% areal containment), while it is only 25.4% for those living in the host tracts (columns 3, 7, and 1, respectively, in Table 2). Similarly, the proportion of people living in poverty is over 19.0% in the neighborhoods (19.1% when applying areal apportionment; 20.6% when applying 50% areal containment), while it is only 13.6% in the host tracts (see Table 2 for comparisons of other socioeconomic characteristics). Although slightly smaller, the contrasts between neighborhoods defined by the three-mile radius and the host tracts proper remained substantial (compare columns 5, 9, and 1 in Table 2).

As anticipated, in comparing the neighborhoods defined by the one- and three-mile radii against the subset of host tracts too large to be captured by the radii, we found the racial and socioeconomic disparities to be even greater. For example, when the 50% areal containment method is applied, the proportion of nonwhites in host tracts too large to be captured by a

2. We computed the aggregate values by first summing subpopulations in each unit that makes up the host neighborhood, as captured by the distance-based methods, and then using those sums to construct the variables for analysis. For example, in determining the nonwhite percentage by applying the 50% areal containment method, we first determined the total number of nonwhites in the combined neighborhoods captured by the one-mile (or three-mile) radius, the total population (nonwhites plus whites) in the combined neighborhoods, and then divided the two values. This is in contrast to first finding the nonwhite percentage for each neighborhood and then averaging. We similarly determined the demographic characteristics for host tracts, that is, by aggregating their populations rather averaging them.

Table 2. Demographic Comparisons of Aggregate Populations in Neighborhoods Captured by Areal Apportionment and 50% Areal Containment Methods Versus Raw Host Tracts/Host Tract Fragments Not Captured

Variable	All Host Tracts (1)	All Nonhost Tracts (2)	Neighborhoods Within 1 Mile Using Areal Apportionment (3)	Host Tract Fragments Beyond a 1-Mile Radius (4)	Neighborhoods Within 3 Miles Using Areal Apportionment (5)	Host Tract Fragments Beyond a 3-Mile Radius (6)	Neighborhoods Captured by 1 Mile Using 50% Areal Containment (7)	Host Tracts Not Captured by a 1-Mile Radius (8)	Neighborhoods Captured by 3 Miles Using 50% Areal Containment (9)	Host Tracts Not Captured by a 3-Mile Radius (10)
Number of tracts/tract fragments composing neighborhoods	554	60,704	2,910	514	10,957	248	861	324	7,518	111
% African American	12.7	12.0	18.8	9.7	20.0	8.8	20.2	9.0	20.5	9.0
% Hispanic	10.1	8.8	20.1	7.6	16.8	6.6	21.8	7.4	17.0	6.2
% Nonwhite	25.4	24.2	42.8	19.6	41.1	18.0	46.2	18.7	41.8	17.9
% Below the poverty line	13.6	13.1	19.1	11.9	17.2	12.8	20.6	11.4	17.4	13.2
Mean household income	34,526	38,491	31,977	35,481	35,855	34,395	30,598	35,805	35,586	33,583
Mean property value	88,892	111,883	92,442	86,984	102,213	78,418	89,747	89,162	103,970	73,432
% Without a high school diploma	28.5	24.7	34.4	26.9	29.8	29.1	36.5	26.4	30.1	29.9
% With a college degree	14.4	20.4	14.1	14.7	18.6	12.6	13.1	14.9	18.4	11.9
% Employed in executive, managerial, and professional occupations	21.4	26.4	20.7	21.8	24.7	20.1	19.7	22.1	24.5	19.4
% Employed in precision production or labor occupations	31.4	26.1	31.3	31.5	27.1	34.3	32.2	31.4	27.2	35.2
% Unemployed	6.7	6.3	8.9	5.9	8.1	5.9	9.6	5.7	8.2	5.9

one-mile radius is only 18.7% (column 8). This is not only substantially less than the 46.2% found in the 50% areal containment neighborhoods but also less than the 25.4% found when all host tracts are taken together. Likewise, the percentage of people living in poverty in the host tracts too large to be captured is smaller than that of either the 50% areal containment neighborhoods or the host tracts taken as a whole (11.4% versus 20.6% or 13.6%, respectively). See Table 2 for comparison of other socioeconomic characteristics. Similar patterns are obtained when we examine tracts captured and not captured by the three-mile radius.

When the areal apportionment method is applied, virtually identical outcomes are produced. However, in keeping with this method, the demographic characteristics of only those portions, or "fragments," of the host tracts lying beyond the one- or three-mile distance were compared against the characteristics of the neighborhoods captured by these radii. In obtaining the demographic characteristics of these fragments, we weighted the contribution of each host tract by the percentage of its area *extending beyond* the radii. As before, when 50% areal containment was applied, the results in Table 2 reveal that the proportions of nonwhites and people of lower socioeconomic status are substantially smaller in the host tract fragments lying beyond the one- and three-mile radii (columns 4 and 6) than they are in the neighborhoods captured by the circle (columns 3 and 5). These proportions are also substantially smaller than in the host tracts taken as a whole (column 1).

The contrasts found when neighborhoods defined by one- and three-mile radii are compared against host tracts or host tract fragments too large to be captured are particularly revealing: this comparison most clearly demonstrates the effects of sorting tracts based on their proximity to TSDFs. Selecting the units based on proximity reveals substantially larger proportions of minorities and poor people near TSDFs than when units are not sorted. Clearly, proximity matters.

To determine whether the application of distance-based methods also leads to different assessments about the relative importance of racial and socioeconomic factors in the distribution of the nation's TSDFs, we performed logistic regression analyses using both unit-hazard coincidence and 50% areal containment methods and compared the results. We used individual tracts as the units of analysis.[3] In applying the unit-hazard coincidence method, we assigned the dependent variable in the logistic regression a value of 1 if a census tract hosted a TSDF and a value of 0 if it did not. For the 50% areal containment method, the dependent variable took a value of 1 if the tract lay within one (or three) mile(s) of a TSDF and a value of 0 if the tract lay beyond that range. The independent variables included the race and socioeconomic variables described in the "Methods" section, excluding some of the variables (e.g., percentage nonwhite and percentage without a high school diploma) to avoid multicollinearity problems (see Table 3).[4]

3. Tracts, rather than neighborhoods, were used as the units of analysis in the logistic regression because of the difficulty of otherwise defining meaningful units to represent the nonhost neighborhoods in the case of the 50% areal containment method. Because of this difficulty, we follow the precedent of prior environmental inequality studies employing the 50% areal containment method (e.g., Anderton et al. 1994; Davidson and Anderton 2000; Pastor, Sadd, and Morello-Frosch 2004).

4. Because of possible spatial autocorrelation among the census tracts, there is some risk that the statistical significance levels of the independent variables may be inflated due to an underestimation of the standard errors. As Pastor et al. (2004) pointed out, prior environmental inequality research has tended not to employ spatial regression models. One of the difficulties is that spatial regression methods are currently performed using linear regression models that assume a continuous dependent variable. However, logistic regression models are the correct specification for environmental inequality analyses because the unit-hazard and 50% areal containment methods involve dichotomous dependent variables. To conduct a spatial regression, one must assume that the dichotomous dependent variable employed in the logistic regression is continuous and that the model is linear. Despite this limitation, Pastor et al. proceeded to assume a continuous dependent variable and to conduct a spatial regression in a version of their analyses. They found that the outcomes were not appreciably different from those obtained from logistic regression. We similarly replicated our logistic regression analyses using spatial regression methods and found the pattern of results to be similar. Because the results are not appreciably different and because logistic regression is

Table 3. Logistic Regression Results Comparing Unit-Hazard Coincidence and 50% Areal Containment Methods

	Unit-Hazard Coincidence		50% Areal Containment (1-Mile Radius)		50% Areal Containment (3-Mile Radius)	
Variable	Coefficient (1)	Significance (2)	Coefficient (3)	Significance (4)	Coefficient (5)	Significance (6)
% African American	–.003	.986	.698	.000	1.522	.000
% Hispanic	.431	.066	1.482	.000	1.960	.000
Mean household income ($1,000s)	.012	.000	–.025	.000	–.015	.000
Mean property value ($1,000s)	–.002	.058	.005	.000	.004	.000
% With a college degree	.338	.673	–1.704	.012	–.409	.046
% Employed in executive, managerial, and professional occupations	–3.215	.002	–.872	.282	.010	.970
% Employed in precision production or labor occupations	2.323	.000	1.787	.000	.073	.684
Constant	–5.052	.000	–4.197	.000	–2.220	.000
–2 Log-Likelihood	6,010.2		8,077.3		40,995.556	
Model chi-square	153.743	.000	548.233	.000	2786.536	.000
Sample size	59,050		59,050		59,050	

An examination of the results in Table 3 reveals important differences obtained from applying the two methods. For example, when we apply the unit-hazard coincidence method, the race and ethnicity variables are not at all significant predictors (at the .05 level) of the location of TSDFs (see column 2), while the occupation variables are (other socioeconomic variables are either not significant or predict TSDF location in the unexpected direction). Specifically, percentage employed in executive management or professional occupations is negatively associated with TSDF location, while percentage employed in precision production/labor is positively associated. Such results might suggest that a disproportionate presence of hazardous waste TSDFs near where minorities live may be a function of the tendency of TSDFs to be concentrated near where industrial labor pools exist (see, e.g., Anderton et al. 1994).

In contrast, when 50% areal containment is applied (using a one-mile radius), the African American and Hispanic percentages of the tract become highly statistically significant predictors of TSDF location (column 4), suggesting that racial disparities in the distribution of TSDFs are not solely a function of the labor force or other socioeconomic characteristics of nearby neighborhoods. Other factors associated with race (e.g., racial targeting or housing discrimination) may also be linked to TSDF locations (possibilities currently being examined in our research). Nevertheless, a number of socioeconomic variables (e.g., percentage employed in precision production/labor, mean household income, and percentage with a college degree) remain or increase in significance. Moreover, the

the correct specification for models with a dichotomous dependent variable, we display and discuss the results for the latter in this article. The results for the spatial regression, however, are available upon request.

model chi-square increases from 153.7 to 548.2 (compare columns 1 and 3), indicating that the model's overall ability to predict TSDF location is improved when 50% areal containment is applied. When a three-mile radius is used, similar results are obtained, except that percentage employed in precision production/labor is no longer a statistically significant predictor of TSDF location (column 6).

SUMMARY AND CONCLUSIONS

Many studies of racial and socioeconomic disparities in the distribution of environmental hazards and LULUs have been conducted. Although the majority of these have found that racial and socioeconomic disparities in these distributions exist (Ringquist 2005), there has been considerable variation in the magnitude of disparities found, with some studies finding no disparities. We have argued that a principal reason for the variation in findings is the wide reliance on unit-hazard coincidence methodology. We have demonstrated in this article that this method fails to control adequately for the proximity between environmental hazards and LULUs and nearby populations.

The unit-hazard coincidence method fails to control for proximity in two ways. First, it does not take into account the proximity of the hazard to adjacent or nearby units. Nonhost units that are nevertheless close to such sites are treated in the analyses in the same way as units much farther away. Second, it does not take into account the great variation in the size of the units of analysis typically used in such studies, such as tracts and zip code areas, and implicitly assumes that people living in large host units necessarily live as close to the hazard under investigation as people living in small host units. Although it is reasonable to expect that people living in small host units live close to the hazards within them, the same expectation cannot be made about large host units.

Distance-based methods overcome these limitations by including in the defined neighborhoods nearby units that are within a specified distance of a hazard while excluding units, including host units or unit fragments, whose areas lie mostly or entirely outside those distances. In contrast to "raw" units, such as tracts, the neighborhoods defined by distance-based methods are generally smaller and have greater consistency in their size and shape and greater consistency in the location of the hazards within them. We also note the considerable robustness of the results in estimating the demographic characteristics of the defined neighborhoods. The results are very similar regardless of which of the two distance-based methods is employed. Furthermore, although not shown in this article, the results are also very similar regardless of which predefined geographic units are used as the building blocks: block groups, census tracts, or zip code areas.

We demonstrated that when racial and socioeconomic disparities around the nation's TSDFs are analyzed by applying distance-based methods, such disparities are found to be greater than when the unit-hazard method is applied. Furthermore, distance-based methods lead to different assessments about the relative importance of racial and nonracial factors in the distribution of TSDFs. Such outcomes demonstrate the importance of applying distance-based methods in future efforts to determine the extent and causes of racial and socioeconomic disparities in the distribution of not only hazardous waste TSDFs but of a wide variety of environmental hazards and LULUs. Furthermore, because distance-based methods produce consistently sized and shaped geographic areas around hazardous sites, such methods should prove very useful in dealing with the irregularities of census boundary changes in longitudinal studies that seek to track demographic changes around environmentally hazardous sites over time, such as recently done by Pastor et al. (2001) and Saha and Mohai (2005).[5]

5. Although the distance-based methods that we describe in this article have clear applicability and usefulness to environmental inequality research, we anticipate that other distance-based approaches may also prove useful and warrant investigation. One such method that is not currently used in environmental inequality

In addition to environmental inequality research, distance-based methods are applicable to other areas of demographic research, particularly studies of the effects of neighborhood context on various social outcomes. Such studies have been increasing in number and involve examination of the relationship of neighborhood physical and social characteristics to such outcomes as the incidence of crime, adolescent sexual activity, neighborhood attachment, mobility, chronic stress, disease, and others (see, e.g., Barrett, Oropesa, and Kanan 1994; Ford and Beveridge 2004; and Scribner, Cohen, and Farley 1998; for a comprehensive review of such studies, see Sampson et al. 2002). The physical characteristics of neighborhoods in such studies are typically assessed by noting the presence or absence of such features as housing projects, liquor stores, vacant lots, and malls. Proximity to such features is assumed if they are coincident with some geographic unit, such as census tracts. In using the unit-hazard coincidence method, these studies face the same difficulties in discerning neighborhood effects that we examined in this article. In the one exception we are aware of, McNulty and Holloway (2000), taking actual distance into account, found that distance to public housing projects was a more important predictor of the incidence of crime than the racial and socioeconomic characteristics of neighborhoods. Given current widespread availability of GIS technology, we believe that distance-based methods should prove feasible and useful in these, as well as environmental inequality, studies.

APPENDIX: DEFINITION AND CONSTRUCTION OF KEY VARIABLES

Data are from STF 3A data files unless otherwise indicated:

1. Percentage African American: The total number of African Americans (Table P-8, Category 2) divided by the total number of persons (Table P-1).

2. Percentage Hispanic: The total number of persons of Spanish/Hispanic origin (Table P-10) divided by the total number of persons (Table P-1).

3. Percentage nonwhite: The difference between the total number of persons (Table P-1) and number of non-Hispanic whites (Table P-12, Category 1) divided by total number of persons (Table P-1). Includes the four nonwhite racial categories (black, American Indian/Alaskan Native, Asian/Pacific Islander, other nonwhite) and white Hispanic.

4. Percentage living in poverty: The number of persons below the poverty line in 1989 (Table P-119, Categories 36-70) divided by the number of persons for whom poverty status was determined (Table P-119, Categories 1-70). The poverty line is prescribed by Directive 14 of the Office of Management and Budget.

5. Mean household income: The total aggregate household income in 1989 (Table P-81, Categories 1 and 2) divided by the total number of households (Table P-5).

6. Mean housing values: The total aggregate value of specified owner-occupied housing in 1989 (STF 1A; Table H-24) divided by the total number of specified owner-occupied housing units (Table H-25, Categories 1-5).

7. Percentage without a high school diploma: Derived from Table P-57, Categories 1 and 2; represents persons aged 25 years and older without a high school diploma or its equivalent.

8. Percentage with a college degree: Derived from Table P-57, Categories 6 and 7; represents persons aged 25 years and older with at least a four-year college degree.

research is to measure the distance of census tract centroids to the nearest hazard (we thank one of the anonymous reviewers for pointing this out). Although such an approach would involve solving some logistical difficulties (e.g., is it necessary or practical to measure the distance of every one of over 60,000 tracts in the nation to each of the 608 TSDFs?), it would provide the advantage of producing a continuous dependent variable. Other alternate distance-based approaches may also become apparent in the future. Their common elements will be that they take the precise location of the hazards into account and control for proximity between the hazards and nearby residential populations.

9. Percentage employed in executive management or professional occupations: Derived from Table P-78, Categories 1 and 2; represents employed persons aged 16 years and older belonging to either of the following two occupational categories: (1) executive, administrative, and managerial, or (2) professional specialty.

10. Percentage employed in precision production or labor occupations: Derived from Table P-78, Categories 10–13; represents employed persons aged 16 years and older belonging to any of the following four occupational categories: (1) precision, production, craft, and repair, (2) machine operators, assemblers, or inspectors, (3) transportation and material moving operators, or (4) handlers, equipment cleaners, helpers, and operators.

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Racial Inequality in the Distribution of Hazardous Waste: A National-Level Reassessment

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National-level studies examining racial disparities around hazardous waste treatment, storage, and disposal facilities have been very influential in defining the academic and political debates about the existence and importance of "environmental injustice." However, these studies tend to employ methods that fail to adequately control for proximity between environmentally hazardous sites and nearby residential populations. By using GIS and applying methods increasingly used in environmental inequality research that better control for proximity, we conduct a comprehensive reassessment of racial inequality in the distribution of the nation's hazardous waste facilities. We compare the magnitude of racial disparities found with those of prior studies and test competing racial, economic, and sociopolitical explanations for why such disparities exist. We find that the magnitude of racial disparities around hazardous waste facilities is much greater than what previous national studies have reported. We also find these disparities persist even when controlling for economic and sociopolitical variables, suggesting that factors uniquely associated with race, such as racial targeting, housing discrimination, or other race-related factors are associated with the location of the nation's hazardous waste facilities. We further conclude that the more recent methods for controlling for proximity yield more consistent and definitive results than those used previously, and therefore argue for their wider utilization in environmental inequality research. Keywords: environmental justice, environmental inequality, environmental racism, racial inequality, hazardous waste, GIS.

Racial inequalities in life circumstances and outcomes have long been studied, including inequalities in education, employment, income, housing, life satisfaction, poverty, health status, and mortality (Beggs 1995; Eggebeen and Lichter 1991; Hayward et al. 2000; Hughes and Thomas 1998; James and McCammon 1997; Jargowsky 1996; McCall 2001). Since the mid-1980s, there has been increasing attention to racial inequalities in the distribution of environmental quality. Attention to this form of racial inequality began as an "environmental justice" movement emerged in the 1980s and 1990s to protest the placement of waste sites and polluting industrial facilities in predominately African American and Latino communities (Bryant and Mohai 1992; Bullard 1990; Cable and Benson 1993; Schlosberg 1999; Szasz 1995). The impacts of this movement have been significant, spurring much public and academic discourse. Indeed, interest in examining the extent of social inequalities in the distribution of

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environmental quality, their causes and consequences, and potential remedies has spread rapidly in the past decade, not only in sociology but across a multitude of disciplines (Brown 1997; Freudenburg 1997; Pellow 2001; Taylor 2000).

Public policy activities around this issue have also been significant, as evidenced by the U.S. Environmental Protection Agency's (EPA) attempts to formulate policies to remedy environmental injustices, including its creation of an Office of Environmental Justice, by the issuance in 1994 of Presidential Executive Order 12898 calling upon all federal agencies, not just the EPA, to take into account the environmental justice consequences of their actions, and by the introduction of numerous environmental justice bills in the U.S. Congress and many state legislatures across the country (Rechtschaffen and Gauna 2002; Ringquist 2003). At the same time, the environmental justice movement has continued to grow. Given the extraordinarily rapid rise in prominence of environmental justice as an important social issue in public and academic discourse, as well as its implications in current debates about whether race as a factor affecting life outcomes is declining in significance (see, e.g., Cancio, Evans, and Maume 1996; Hughes and Thomas 1998; Wilson 1987), the attention given by sociologists to this form of racial inequality appears warranted.

Many quantitative studies examining racial and socioeconomic disparities in the distribution of environmentally hazardous sites have been conducted over the past decade. Various approaches have been applied to assess such disparities. These approaches have tended to be of two types: (1) pollution dispersion assessments and (2) site proximity assessments. Pollution dispersion assessment studies involve collecting data about the volumes and toxicities of various air and water emissions, timing of emission releases, stack heights, wind directions and speeds, and other factors (Ash and Fetter 2004; Chakraborty and Armstrong 1997; Glickman, Golding, and Hersh 1995). From these data, estimates are made about the geographic dispersion and deposition of the toxic emissions. Census data are then employed to determine the demographic characteristics of those most likely to live where pollution and toxicity levels are concentrated. Some pollution dispersion studies have gone as far as attempting to conduct risk assessments in which human exposure and expected lifetime cancer risks are estimated (for an example, see Hamilton 1999). Obtaining complete and accurate information for modeling pollution dispersions and toxicity levels has been difficult; however, this has been especially so for risk assessments. As a result, relatively few environmental inequality studies employing pollution dispersion or risk assessment methods have been conducted.

By far, the most frequently employed approach for conducting quantitative environmental inequality analyses has been to assess the proximity of hazardous sites to nearby populations. While nearly all national-level environmental inequality studies have involved proximity assessments, all national-level studies of the distribution of hazardous waste treatment, storage, and disposal facilities (TSDFs) have done so. These studies have been very influential in spurring policy development and further research in the area of environmental justice. Although most have found these disparities to be statistically significant (Lester, Allen, and Hill 2001; Ringquist 2005; Saha and Mohai 2005), there has been considerable variation in the magnitude of racial and socioeconomic disparities found. Some studies have found no race and income disparities associated with the presence of environmentally hazardous sites and locally unwanted land uses (Anderton et al. 1994; Davidson and Anderton 2000).

In another paper, the authors (Mohai and Saha 2006) hypothesized that a likely source of these uncertainties has been wide reliance in environmental inequality research on what has been termed "unit-hazard coincidence" methodology. This approach involves selecting a pre-defined geographic unit (such as zip code areas or census tracts), determining which subset of the units is coincident with the hazard and which not, and then comparing the demographic characteristics of the two sets. Implicit in this approach are two assumptions: (1) that adverse impacts tend to be concentrated within close proximity of the hazards, and (2) that populations living within the host units are located closer to the hazard under investigation than populations living in the non-host units. However, we demonstrated that this latter assumption is not always the case and that, in fact, the unit-hazard coincidence method fails to control for proximity in several respects. We furthermore demonstrated how alternate methods, termed "distance-based" methods, better control for proximity and how application of these methods leads to differing results.

In this paper we extend our earlier analysis by applying distance-based methods to make a comprehensive national-level reassessment of racial inequality in the distribution of hazardous waste TSDFs. We compare our results with those of prior published national-level studies, including those by the Commission for Racial Justice (CRJ 1987), Douglas L. Anderton and associates (1994), Benjamin A. Goldman and Laura Fitton (1994), Vicki Been (1995), and John Michael Oakes, Douglas L. Anderton, and Andy B. Anderson (1996). These studies have been very influential in defining the academic and political debates about the existence and importance of racial disparities around environmentally hazardous sites. By comparing our results with these prior national-level studies, we provide further evidence of the extent that use of distance-based methods alters previous estimations about the magnitude of these disparities.

Theoretical Explanations of Environmental Inequality

A wide variety of explanations have been offered as to why environmental inequalities exist. There has been special interest in understanding whether racial disparities are largely a function of socioeconomic disparities or whether other factors associated with race are also related to the distribution of environmental hazards. This latter question, as mentioned above, is especially relevant to the wider debates about the declining significance of race (Cancio et al. 1996; Hughes and Thomas 1998; Wilson 1987). The factors hypothesized to account for the racial and socioeconomic disparities in the distribution of environmental hazards, which we briefly review, tend to fall into three categories that can be termed economic, sociopolitical, and racial (Mohai and Saha 1994; Saha and Mohai 2005).

Economic factors include industry's desire to minimize production costs by siting new facilities in places where land values and operation costs are low (Boone and Madorres 1999; Daniels and Friedman 1999; Hamilton 1995; Hird and Reese 1998; Rhodes 2003). These places may coincidentally be where low-income people and minorities live (thus resulting in disparate siting). Alternatively, the facilities, once sited, may cause a decline in property values and quality of life, motivating affluent whites to move away and the poor and people of color to move in because of increased affordability of housing (resulting in disparate post-siting demographic change). *Sociopolitical factors* involve imbalances in social capital and political power among communities (Bullard 1990; Hamilton 1995; Hird and Reese 1998; Pellow 2002). Disproportionate siting may occur because poor, minority communities have fewer resources to mobilize and less access to decision makers than do affluent, white communities that would enable them to effectively lobby to keep out unwanted land uses. Even without intent by government and industry to do so, white NIMBYism ("not-in-my-backyard" syndrome) may lead, therefore, by default to disproportionate placement of unwanted land uses in minority neighborhoods (Camacho 1998; Cole and Foster 2001; Saha and Mohai 2005). However, decades of systematic disinvestment in many inner city areas, combined with white flight and suburban reinvestment, have created racial and economic segregation, limited inner city development options, and environmental inequality as well (Allen 2003; Hurley 1995; Montrie 2005). *Racial factors* are involved if siting in minority neighborhoods is intentional. Even though it may be difficult to find a "smoking gun" of prejudicial attitudes behind siting decisions, deliberate targeting of new facilities may occur because minority communities over time have come to be recognized as the "paths of least resistance" by government and industry (Bullard and Wright 1987; Saha and Mohai 2005). Even if minority communities are not intentionally targeted for society's unwanted land uses, race may still play a role in environmental inequality because housing segregation may limit the ability of people of color to move away from such sites, beyond the constraints of limited incomes (Mohai and Bryant 1992; Szasz and Meuser 2000). Likewise, racial inequality in education, employment, health care, land use planning, and other societal domains can limit the social and political capital of people of color communities to prevent the siting of polluting facilities and subsequent undesirable neighborhood change (Hurley 1995; Pellow 2002; Pulido, Sidawi, and Vos 1996). The disparate environmental effects of legacies of historical racial oppression have persisted in the present era (Brook 1998; Clark 2002; Lerner 2005; Pellow 2002; Pulido 1996b). Moreover, because of the institutional and systemic nature of racial discrimination, environmental inequality is inextricably linked to other forms of racial inequality (Pulido 1996a; Saha and Mohai 2005; Stretesky and Hogan 1998).

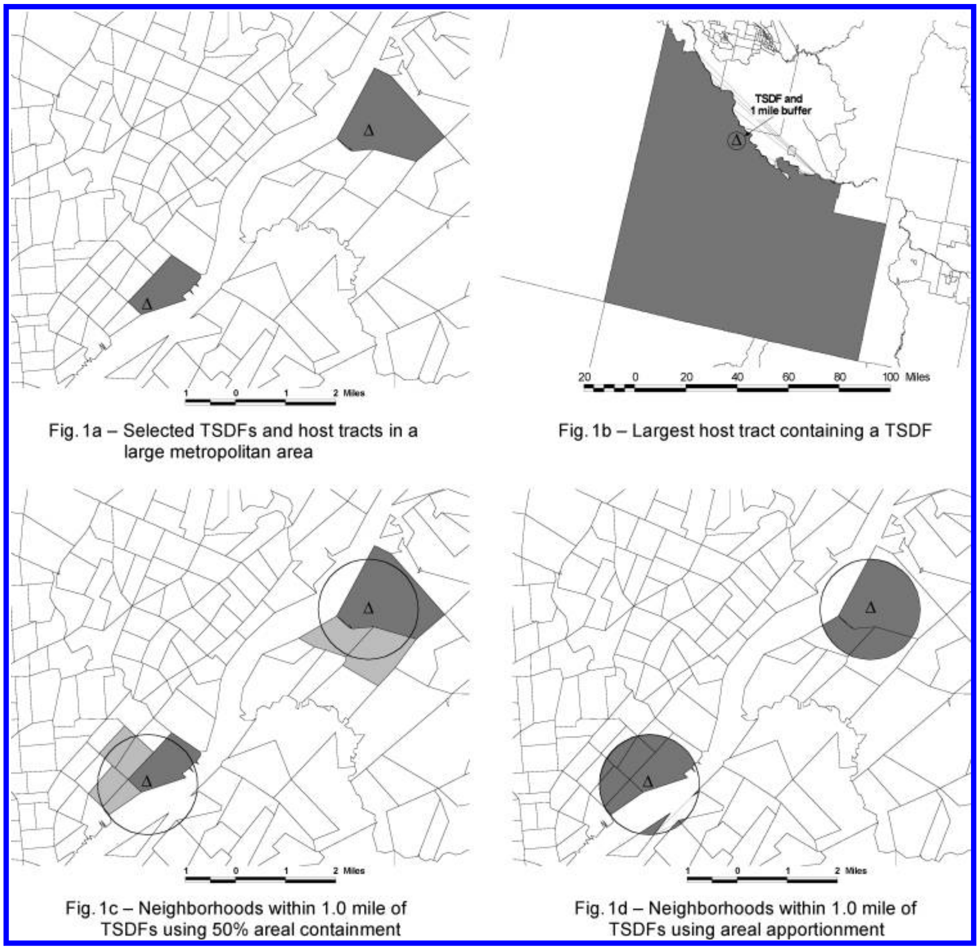
The importance of these and other factors in accounting for inequitable environmental burdens has been examined in both quantitative and qualitative studies. Qualitative case studies examining factors associated with racial inequality have pointed to a complex interplay among class, race, land use politics, and broader societal forces that shape local economic development and decline at specific locations over time (Allen 2003; Boone and Madorres 1999; Hurley 1995; Montrie 2005; Pellow 2002; Pulido et al. 1996; Szasz and Meuser 2000). At the same time, quantitative studies have examined the broad patterns of environmental hazard locations and provided statistical tests of the relative importance of the various economic, sociopolitical, and racial factors hypothesized to account for disparities in hazard locations. Although qualitative studies have provided a detailed and nuanced understanding of causal factors, which is not possible with quantitative studies, the latter have been important in testing hypotheses about causal factors, determining the generalizability of findings, and indeed in helping to first define the problem and its extent (CRJ 1987; U.S. GAO 1983). In this way, both types of studies have informed each other and the direction of environmental justice research.

Outcomes of hypothesis tests from quantitative studies have, nevertheless, tended to be mixed. For example, some quantitative studies have found an independent effect of race on the distribution of environmental burdens (such as Hird and Reese 1998 and Mohai and Bryant 1992) while others have not (such as Anderton et al. 1994 and Hamilton 1995). These mixed results have engendered considerable attention not only among academics, but policy makers and industry seeking to determine or influence the legitimacy of the environmental justice problem (Foreman 1998). We posit that the mixed outcomes from quantitative studies are attributable to the wide use of unit-hazard coincidence methodology, which fails to adequately account for the proximity between environmentally hazardous sites and nearby residential populations, and that more definitive findings can be obtained when proximity is controlled with distance-based methods.

Below is an overview of the unit-hazard coincidence and distance-based methods and how they differ in their ability to control for proximity between environmentally hazardous sites and nearby residential populations.

Unit-Hazard Coincidence versus Distance-Based Methods

As mentioned, the unit-hazard coincidence approach has been the most commonly used in conducting environmental inequality analyses, including by the most influential national studies, such as the Commission for Racial Justice (CRJ 1987), Anderton and associates (1994), Goldman and Fitton (1994), and Been (1995). However, as demonstrated in our earlier paper (Mohai and Saha 2006), this approach fails to adequately control for proximity between environmentally hazardous sites and nearby residential populations in two principal ways. First, it does not take into account the precise geographic location of the hazardous site. It goes no further than determining whether the site is coincident with one of the geographic units of analysis. Not taken into account is the proximity of the site to its host unit's boundary



Source: Data from U.S. Census Bureau (2000)

Figure 1 • ***Comparing Neighborhoods around TSDFs Identified by Unit-Hazard Coincidence and Distance-Based Methods***

or its proximity to adjacent and other nearby units. However, when the precise geographic locations of hazardous sites *are* taken into account, it is often found that they are located near the host units' boundaries and hence very close to adjacent and other nearby units. For example, we found 49 percent, of the nation's hazardous waste TSDFs are within .25 mile of the boundary of their host census tracts, while 71 percent are within .50 mile (Mohai and Saha 2006; see also Figure 1a illustrating the proximity of adjacent tracts southwest of two selected TSDFs). Instead of recognizing the proximity of some of the non-host units to the hazardous sites, the unit-hazard coincidence method places nearby units in the comparison group of units, treating them no differently than non-host units much farther away. However, if there is a relationship between the presence of hazardous sites and the demographic characteristics of nearby populations, then the characteristics of nearby non-host units may be more similar to the host units proper than to non-host units farther away.

Second, the unit-hazard coincidence method does not take into account the considerable variation in the size of the host units. It implicitly assumes that all the host units are of similar size and small enough to assure that the hazardous sites and residential populations within the units are in reasonably close proximity. However, examination of the census tracts hosting the nation's hazardous waste TSDFs reveals that this in fact is not the case. For example, we found that the smallest tract containing a hazardous waste TSDF is less than .1 square mile while the largest is over 7500 square miles, with all sizes in between (Mohai and Saha 2006; see also Figure 1b illustrating the largest host tract). When a host unit is small, such as the former, it can be reasonably assumed that everyone living in it is close to the site. However, when the unit is large, such as the latter, it is uncertain how many people in the unit live close by. Given that there is a greater opportunity and likelihood of people in large host units to live far from such sites, there may be less reason to expect disproportionate numbers of minorities and poor people in such units. Indeed, we found that the non-white and poverty percentages of large host tracts (those whose areas lay mostly beyond one mile of a TSDF) to be less than the non-white and poverty percentages of tracts whose areas lay mostly within one mile (Mohai and Saha 2006).

In contrast to the studies employing the unit-hazard coincidence approach, a limited number of studies have used distance-based methods in which the precise locations of the environmental hazards or locally unwanted land uses under investigation are mapped and their distances to nearby populations are controlled. The demographics of all units, not just the host unit, within a specified distance of the hazardous sites are contrasted with the demographics of units further away. Only one national level study (Hamilton and Viscusi 1999) and only two state level studies (Pollock and Vittas 1995 and Saha and Mohai 2005) of which we are aware use distance-based approaches. The remaining are focused on a single city, county, or metropolitan area (Boer et al. 1997; Chakraborty and Armstrong 1997; Glickman 1994; Mohai and Bryant 1992; Pastor, Sadd, and Hipp 2001; Sheppard et al. 1999). There have been several types of distance-based methods employed using both survey and census data.

Those involving survey data can be termed *point-containment methods* as the location of survey respondents and hazardous sites can be represented as points in geographic space and their distances measured. Mohai and Bryant (1992, 1998) provide among the earliest examples of this approach. Specifically, they mapped the location of hazardous sites and respondents to the 1990 Detroit Area Study (DAS), a metropolitan-wide probability sample survey. They then constructed circles of 1- and 1.5-mile radii around each site and compared the demographic characteristics of respondents living within those distances to those living farther away.

Much more common in environmental inequality research than the use of survey data is the use of census data. However, census data are organized in predefined geographic units (e.g., block groups, census tracts, and zip code areas) that represent two-dimensional space rather than points. Thus, a circle with a radius of a specified distance from a hazardous site often will capture only a portion rather than all or none of the unit. One rule to decide whether or not to count a unit as within the specified distance is to include it if at least 50 percent of the unit's area is contained within the associated circle (thus the term *50 percent areal-containment method*; Mohai and Saha 2006). Alternatively, the unit can be considered within the distance if the circle contains the unit's geographic center (the *centroid-containment method*). Together, the captured units form the host neighborhood around the environmental hazard (see Figure 1c). The demographic characteristics of this neighborhood are derived from those of the captured units, which are either averaged or aggregated (i.e., weighted by the units' population size), and compared against the demographics of the units not captured.

An alternative to 50 percent areal containment or centroid containment methods is the *areal apportionment method*. Rather than including or excluding units in their entirety, depending how much area is captured, the areal apportionment method gives each unit intersected by the circle a certain weight in determining the population characteristics within the circle. Specifically, each unit's population is weighted by the proportion of the area of the unit that is captured by the circle. The weighted populations of these units are then aggregated to determine the demographic characteristics of perfectly circular neighborhoods around the hazard (see Figure 1d).

Because the areal apportionment method weights the populations of partially intersected units by the proportion of the unit's area that is captured by a circle, it reduces the risk that any unit over (or under) influences the estimated demographic characteristics within the circle. This is an advantage over the 50 percent areal containment method where either all or none of a partially-intersected unit's population is counted depending on how much of the unit's area is captured. Nevertheless, the areal apportionment method has a limiting assumption. For the proportion of the partially captured unit's population to equal the proportion of its area that is captured, the population within the unit must be assumed to be uniformly distributed within in it, which may not be the case. However, this assumption is also made in applying other site proximity methods, including the unit-hazard coincidence method.

By applying distance-based methods, we conduct a national level reassessment of racial inequality in the distribution of hazardous waste facilities and compare these results with the results of prior national level studies that have relied on the unit-hazard coincidence approach.

Data and Methods

Studies examining racial and socioeconomic disparities in the distribution of the nation's hazardous waste TSDFs have tended to analyze somewhat different universes of facilities (Anderton et al. 1994; CRJ 1987; Been 1995; Been and Gupta 1997; CRJ 1987; Oakes et al. 1996). This is because there is no single source of information about such facilities. Thus, researchers have had to rely on a combination of various databases and sometimes not the same ones (see Been 1995 for a discussion). The fact that existing facilities close and new facilities may open in the time between studies may also partially account for the different universes of TSDFs employed in prior studies.

Since our objective is to demonstrate that any contrasting findings with prior national level studies are strictly the result of employing different methodologies (i.e., distance-based methods versus the unit-hazard coincidence method) rather than a different universe of facilities, we sought to perform our analyses on the universes of facilities used in the prior studies. Because the analyses of researchers at the Social and Demographic Research Institute (SADRI) at the University of Massachusetts (Anderton et al. 1994; Oakes et al. 1996) and the School of Law at New York University (Been 1995; Been and Gupta 1997) represent the leading (and most recent) national-level academic studies of the racial and socioeconomic inequalities around the nation's TSDFs, we requested information from both Professor Douglas Anderton (of SADRI) and Professor Vicki Been (of NYU School of Law) about the facilities used in their respective studies.

Professor Anderton provided us all the information needed to identify the host and nonhost TSDF tracts employed in the SADRI studies. However, facility names and addresses could not be released from SADRI due to confidentiality promised in surveying the companies. Professor Been was able to provide us with the names, addresses, and EPA identifiers for the 608 facilities employed in her studies. Because this information was necessary for determining the precise geographic locations of the facilities, the subsequent analyses performed in this paper are based on the universe of facilities employed in Been's studies (Been 1995; Been and Gupta 1997). These studies included all the commercial hazardous waste treatment, storage, and disposal facilities in the United States receiving off-site waste operating at the time of her studies (from the early to mid 1990s).

To identify this universe of facilities, Been relied on the U.S. Environmental Protection Agency's (EPA) Resource Conservation and Recovery Information System (RCRIS) database and the 1994 Environmental Services Directory (ESD).[1] The RCRIS database includes all hazardous waste TSDFs in the United States subject to regulation under the Resource Conservation and Recovery Act. The ESD is a commercially produced directory of hazardous waste handlers. Both databases were cross-checked by Been to determine that the facilities included in her studies were operating commercial hazardous waste TSDFs receiving waste from offsite. Where the information was ambiguous (e.g., a facility appeared in the RCRIS database as a TSDF receiving offsite waste, but was not included in ESD), phone calls were made to the companies to verify the facility's status. Phone calls were also made to the companies to verify addresses. Facility locations were matched with the 1990 census tracts in which they coincided.

Since we also needed to know the precise geographic locations of the TSDFs within the host tracts, not just that they were coincident, we performed a series of steps in order to obtain as accurate facility locations as possible. These steps included verifying facility locations and addresses and other information used to map locations (GeoLytics, Inc. 1999). We employed geographic information systems (GIS) software to geocode and map the precise locations of all 608 of Been's TSDFs. For 538 TSDFs, address and location information were obtained directly from or verified by the facility personnel. In some cases, this entailed consulting site maps obtained from the companies. For 61 TSDFs that we were not able to contact (e.g., those that were closed since Been conducted her study), state environmental agencies or the U.S. EPA were contacted for this information. For the remaining nine TSDFs for which insufficient information was available from the above sources, other sources such as former employees and online commercial mapping services were consulted. Again, because the objective of our analysis was to compare the results of different methods and studies, we used Been's entire universe of facilities and 1990 Census data, which most closely matched the time that Been's research was conducted, i.e., when each facility in her universe of TSDFs was in operation.

Once TSDF locations were established, we generated 1-, 2-, and 3-mile circular buffers around their locations. We selected these distances as they are well within the range used in prior proximity assessment studies that use distance-based methods (Anderton et al. 1994; Chakraborty and Armstrong 1997; Hamilton and Viscusi 1999; Hurley 1997; Mohai and Bryant 1992, 1998; Pastor et al. 2001; Saha and Mohai 2005). They are also within the range of distances from hazardous waste sites for which property values and health impacts have been detected (Dolk et al. 1998; Geschwind et al. 1992; Glickman et al. 1995; Kohlhase 1991; Nelson, Genereux, and Genereux 1992). In selecting this range, we furthermore wished to examine how demographic characteristics around hazardous waste TSDFs change with varying distances to these sites. We determined the demographic characteristics within the 1-, 2-, and 3-mile buffers using 1990 census data (Wessex, Inc. [1992] 1994) and applying the 50 percent areal containment and areal apportionment methods. To analyze the demographic characteristics around the nation's TSDFs, we employed 1990 digitized census areas (tracts and block groups) and zip code areas (GeoLytics, Inc. 1998; U.S. Census Bureau 1990).

Census variables examined included those used in many prior studies to assess demographic disparities and to test the relative importance of racial, economic, and sociopolitical explanations of such disparities. Race variables included percent African American, percent Hispanic, and percent persons of color. The latter variable included nonwhite racial minorities and white Hispanics and, for convenience, is hereafter referred to as percent nonwhite. Economic variables included mean household income, mean housing values, percent unemployed, and percent living below the poverty line. Variables directly measuring political activity (such as voting and participating in social movement organizations) within small geographic units (such as census tracts and block groups) are difficult to obtain. However, educational attainment and occupational status have been found to be good predictors of political resources and activity

1. Been's studies relied principally on EPA's RCRIS database to identify hazardous waste TSDFs. Prior national studies, such as those by the Commission for Racial Justice (CRJ 1987) and the Social and Demographic Research Institute at the University of Massachusetts (Anderton et al. 1994), relied principally on the ESD and earlier EPA databases.

(Mohai 1985; Smith and Macaulay 1980) and have been used to assess sociopolitical explanations of environmental disparities in prior studies (Hamilton 1995; Hird and Reese 1998). Education and occupational status variables used in this study included percent without a high school diploma, percent with a college degree, percent employed in executive, management or professional occupations (i.e., professional "white collar" jobs), and percent employed in precision production or labor occupations (i.e., "blue collar" jobs).

Results

We found that on average the neighborhoods defined by 50 percent areal containment and areal apportionment methods, using 1-, 2-, and 3-mile radii, were much smaller than the host tracts proper (see Mohai and Saha 2006).[2] For example, we found the average area of the host tracts to be 58.41 square miles, while the average areas of the host neighborhoods defined by 50 percent areal containment and areal apportionment methods were less than 3.25 square miles at the 1-mile radius and less than 28.5 square miles at the 3-mile radius. Furthermore, the average distances of the TSDFs to their neighborhood centroids were found to be smaller for the neighborhoods defined by the distance-based methods than for the host tracts. For example, we found the average distance of TSDFs to their host tract centroids to be 1.89 miles, while for host neighborhoods defined by either of the two distance-based methods these were less than .5 mile at the 1-mile radius and less than .75 mile at the 3-mile radius. Thus, the neighborhoods defined by the 50 percent areal containment and areal apportionment methods are generally smaller than the host tracts proper, and the populations residing in these neighborhoods are generally closer to the TSDFs in them than are populations residing in the host tracts proper.

We therefore wanted to determine whether by using distance-based methods we would find, nationally, larger proportions of poor people and people of color living near hazardous waste TSDFs than those living farther away and whether the differences found would be greater than what has been found in prior national studies using the unit-hazard coincidence method. In making this assessment, we focus on the outcomes resulting from aggregating populations rather than averaging them across neighborhoods. This is because we were interested in knowing the demographic characteristics of host TSDF neighborhoods nationally and averaging skews the results towards the less populated neighborhoods. However, results from averaging can also be found in Table 1 and the Appendix. In order to assess whether the outcomes are affected by the size and type of geographic unit used as the building block for the host neighborhoods, we replicated the analyses three times under each distance-based method: (1) once using census tracts as the building block units, (2) again using block groups (which are generally smaller units), (3) and again using zip code areas (which are generally larger).

For purposes of providing a baseline comparison, we first examined nationally the results yielded by the unit-hazard coincidence method, i.e., we first contrasted the demographic characteristics of all host and non-host tracts in the country. As mentioned above, we were especially interested in knowing the demographic characteristics for aggregated populations and thus display these values in columns 2 and 3 of Table 1 (averaged values along with their statistical significance levels, nevertheless, are also given; columns 4 through 7). Table 1 shows that for most characteristics the differences between host and non-host tracts are not very great. For example, the difference in the nonwhite percentages between host and non-host tracts is only 1.2 percent (i.e., 25.4 percent for host tracts compared with 24.2 percent for non-host tracts).

2. For the 50 percent areal containment method, the host neighborhood is defined as the collection of tracts captured by the radius of a specified distance (i.e., 1, 2, or 3 miles). For the areal apportionment method, the host neighborhood is defined as the perfectly circular area within the radius of the specified distance. For the unit-hazard coincidence method, the neighborhood is defined as the host tract proper. See pages 12–16 and Figures 1C, 1D, and 1A, respectively.

Table 1 • *Demographic Comparisons of Aggregate and Average Populations in Host Tracts and Non-Host Tracts*

(1) Variable	*(2)* All Host Tracts (Aggregated)	*(3)* All Non-Host Tracts (Aggregated)	*(4)* Host Tracts (Averaged)	*(5)* Non-Host Tracts (Averaged)	*(6)* T-Test	*(7)* Sign.
Total population in 1000s	2,396	246,314	4,325	4,058	2.373	.018
Race variables						
Percent black	12.7	12	14.4	13.4	.960	.337
Percent Hispanic	10.1	8.8	10.2	7.8	3.016	.003
Percent nonwhite	25.4	24.2	27.1	24.4	2.218	.027
Economic variables						
Mean household income	$34,526	$38,491	$33,157	$37,310	−8.036	.000
Mean property value	$88,892	$111,883	$82,693	$106,013	−9.467	.000
Percent below poverty line	13.6	13.1	15.6	14.6	1.872	.061
Percent unemployed	6.7	6.3	8.1	7.1	3.729	.000
Sociopolitical variables						
Percent without a high school diploma	28.5	24.7	31.3	26.5	7.171	.000
Percent with college degree	14.4	20.4	18.7	25.1	−13.405	.000
Percent employed in executive, managerial, or professional occupations	21.4	26.4	19.2	24.6	−13.094	.000
Percent employed in precision production, trans., or labor occupations	31.4	26.1	33.5	27.5	12.918	.000

Source: Data from U.S. Census Bureau (1990)

Note: Sample sizes range from $N = 546$ to 554 tracts for hosts and $N = 58{,}670$ to 60,704 tracts for non-hosts depending on missing values.

Similarly, the difference in the percentages of those living in poverty is only .5 percent (13.6 percent for host tracts compared with 13.1 percent for non-hosts). Nevertheless, nearly all differences except for the African American percentage and percentage living in poverty are statistically significant at the 0.05 level (column 7).

Next we examined the results obtained by employing the 50 percent areal containment method (see Table 2). These results reveal that, nationally, racial and socioeconomic disparities between neighborhoods that are within and those that are beyond the 1.0 and 3.0 mile distances are much more substantial than the disparities revealed by the unit-hazard coincidence method (results for the 2-mile radius lay in between and are thus not shown). For example, using tracts as the building block unit, the difference in the nonwhite percentages between neighborhoods within and beyond 1 mile of a TSDF is 22.2 percent (46.2 percent within 1 mile compared with 24 percent beyond 1 mile; see columns 3 and 6). At the same time, the difference in the percentages living in poverty is 7.6 percent (20.6 percent within 1 mile compared with 13 percent beyond). Using the generally smaller block groups *reduces* the disparities only slightly (a difference in the nonwhite percentages of 20.4 percent; a difference in the poverty percentages of 7 percent). Using larger zip code areas *increases* them slightly (a difference in the nonwhite percentages of 25.5 percent; a difference in the poverty percentages of 8.7 percent). Demographic disparities are also substantial for neighborhoods defined by a 3-mile radius compared to areas beyond 3 miles. Differences between the host and non-host neighborhoods, defined by either 1- or 3- mile buffers, are statistically significant for all demographic characteristics, except when mean property values are estimated from zip code areas (for details of the statistical results, see Table A in Appendix).

Table 2 • *Demographic Characteristics of Aggregate Populations in Neighborhoods Defined by 50 Percent Areal Containment Method Using Block Groups, Census Tracts, and Zip Code Areas as the Building Block Units*

Variables	*Neighborhoods within 1-Mile Radius*			*Beyond 1-Mile Radius*			*Neighborhoods within 3-Mile Radius*			*Beyond 3-Mile Radius*		
(1)	*(2) Block Groups*	*(3) Tracts*	*(4) Zip Code Areas*	*(5) Block Groups*	*(6) Tracts*	*(7) Zip Code Areas*	*(8) Block Groups*	*(9) Tracts*	*(10) Zip Code Areas*	*(11) Block Groups*	*(12) Tracts*	*(13) Zip Code Areas*
No. of units composing neighborhoods	3,432	859	62	222,966	60,399	29,405	28,290	7,517	1,060	198,108	53,741	28,407
Total pop. in 1000s	3,210	2,896	1,035	245,500	245,814	247,675	29,996	29,201	25,370	218,714	219,509	223,340
Race vars.												
Percent black	19.1	20.2	15.3	11.9	11.9	12.0	20	20.5	21.5	10.9	10.9	11
Percent Hispanic	21.4	21.8	29	8.6	8.7	8.7	16.8	17.0	18.7	7.7	7.7	7.7
Percent nonwhite	44.4	46.2	49.6	24.0	24.0	24.1	41.1	41.8	44.6	21.9	21.9	21.9
Economic vars.												
Mean household income	$31,191	$30,598	$31,808	$38,546	$38,543	$38,481	$35,703	$35,586	$35,729	$38,831	$38,835	$38,761
Mean property value	$91,343	$89,747	$128,246	$111,043	$111,856	$110,811	$102,870	$103,970	$105,789	$111,745	$112,488	$111,299
Percent below poverty line	20.0	20.6	21.8	13.0	13.0	13.1	17.2	17.4	17.8	12.6	12.5	12.6
Percent unemployed	9.2	9.6	9.3	6.3	6.3	6.3	8.1	8.2	8.4	6.1	6.1	6.1
Sociopolitical vars.												
Percent without a high school diploma	35.9	36.5	39.5	24.6	24.6	24.7	29.9	30.1	30.9	24.1	24.1	24.1
Percent with college degree	13.4	13.1	15.2	20.4	20.4	20.4	18.4	18.4	18.2	20.6	20.6	20.6
Percent employed in exec., mana., or prof. occup.	20.0	19.7	21.6	26.4	26.4	26.4	24.7	24.5	24.4	26.6	26.6	26.6
Percent empl. in prec. prod., trans., or labor occup.	32.1	32.2	31.9	26.1	26.1	26.2	27.2	27.2	27.4	26.1	26.1	26.1

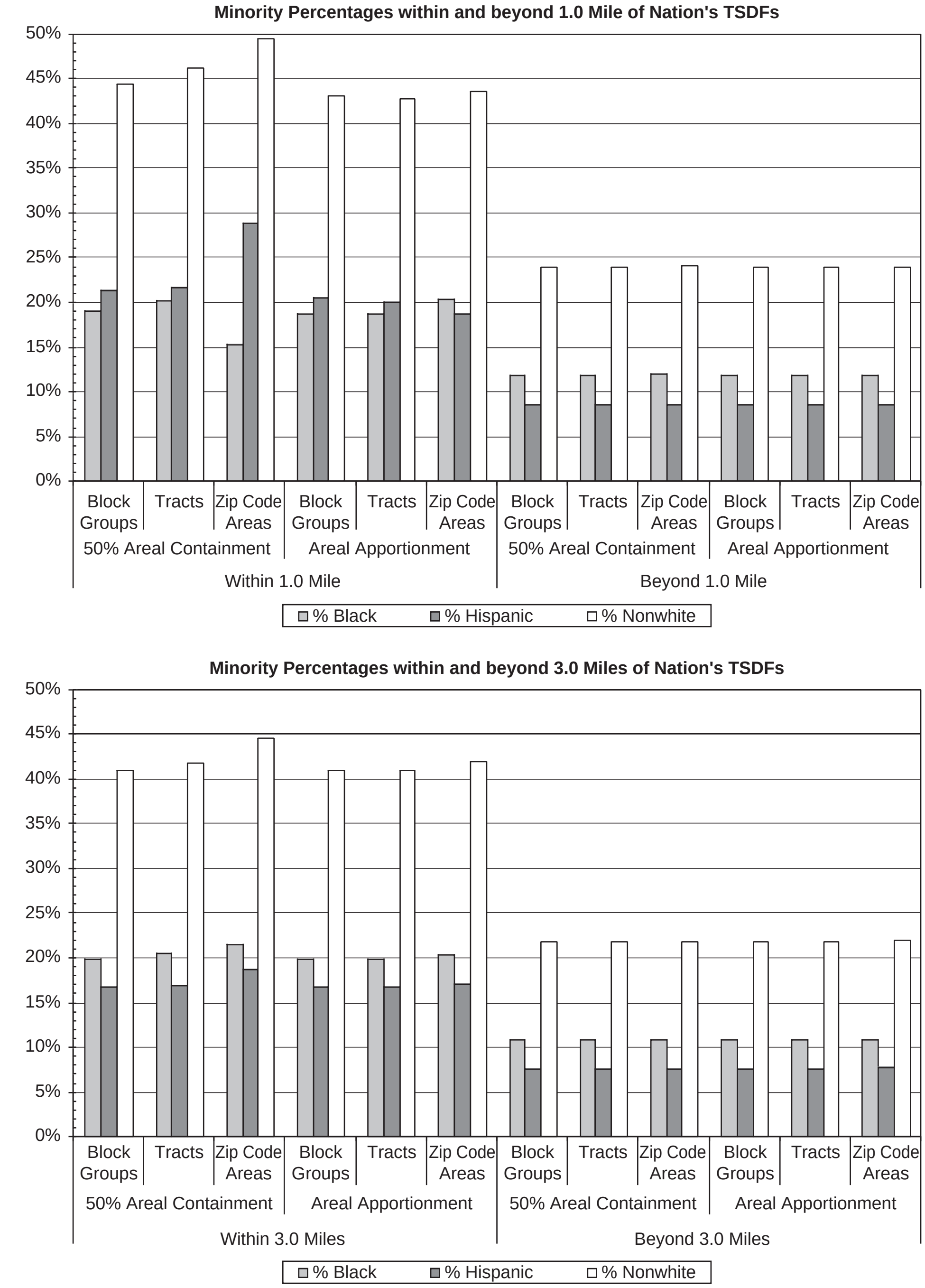
Source: Data from U.S. Census Bureau (1990)

The results in Table 2 not only reveal substantially greater differences, nationally, in the demographic characteristics between host and non-host neighborhoods when the 50 percent areal containment rather than unit-hazard coincidence method is applied, they also demonstrate that the 50 percent areal containment method produces remarkable consistency in the estimates of the various demographic characteristics across the building block units (block group, census tract, and zip code area). This is especially so for results produced at the 3-mile radius. At the smaller, 1-mile radius, the results are likewise very consistent, but there are a couple of exceptions. At the 1-mile radius, zip code areas produce a somewhat smaller African American percentage (15.3 percent) than do block groups (19.1 percent) or tracts (20.2 percent). Also, zip code areas produce a somewhat greater Hispanic percentage (29 percent compared to 21.4 percent for block groups and 21.8 percent for tracts) and greater mean housing values ($128,246 compared to $91,343 for block groups and $89,747 for tracts). Because zip code areas are the largest of the three geographic units used as building blocks, we surmise that at small radii (such as 1 mile) the neighborhoods produced by them are the most likely to deviate from those of a perfect circle. The greater the deviation from a perfect circle, the less reliable the demographic results become. Nevertheless, except for the three variables mentioned, zip code areas at the 1-mile radius produce results that are very similar to those obtained by using block groups and tracts as the building block units (see Figure 2 illustrating the consistency of estimates for the racial percentages using the various building block units at both the 1- and 3-mile radii).

We then examined the results obtained by employing the areal apportionment method (see Table 3). These results are very similar to those obtained using the 50 percent areal containment method (compare values in Tables 2 and 3; see also Figure 2), thus providing further evidence of the substantial racial and socioeconomic disparities between host and non-host neighborhoods. However, an important improvement over the latter method is that there is greater consistency in the results across the three different building block units using areal apportionment. When this method is used, zip code areas produce results that are virtually identical to those produced by block groups and tracts for nearly all variables, even at the smaller, 1-mile radius. For virtually all variables, estimates produced by the three units differ by no more than one or two percentage points when using areal apportionment (Table 3 and Figure 2). Differences between host and non-host areas, defined by either 1-or 3-mile radii, are statistically significant for all demographic characteristics, including when mean property values are estimated from zip code areas (see Table A-2 in Appendix).

Although the results produced from areal apportionment are somewhat more consistent across the various building block units than those produced from 50 percent areal containment, that the results derived from the two methods are nevertheless very similar demonstrates the reliability and robustness of distance-based methods in estimating population characteristics within the small areas defined by the 1- and 3-mile circular buffers. The above results also clearly show that, in contrast to the unit-hazard coincidence method, controlling for proximity by using distance-based methods (50 percent areal containment and areal apportionment) reveals substantial racial and socioeconomic disparities in the location of the nation's TSDFs. To further highlight the contrasting results obtained from using distance-based versus unit-hazard coincidence methods, we compared the above results with those obtained from the leading national studies that have analyzed the distribution of hazardous waste TSDFs by race and socioeconomic characteristics. These studies include Commission for Racial Justice (CRJ 1987), Goldman and Fitton (1994), Anderton and associates (1994), Been (1995), and Oakes, Anderton, and Anderson (1996).

Table 4 compares the values of some of the key racial and socioeconomic variables obtained from those studies. The disparities revealed are much less than those obtained by using distance-based methods. This is especially true regarding racial disparities. Indeed, Anderton and associates (1994) found that the percentage of African Americans is actually



Source: Data from U.S. Census Bureau (1990)

Figure 2 • ***Minority Percentages within and beyond Specified Distances of Nation's TSDFs Using 50 Percent Areal Containment and Areal Apportionment Methods***

Table 3 • ***Demographic Characteristics of Aggregate Populations in Neighborhoods Defined by Areal Apportionment Method Using Block Groups, Census Tracts, and Zip Code Areas as the Building Block Units***

Variables	*Neighborhoods within 1-Mile Radius*			*Beyond 1-Mile Radius*			*Neighborhoods within 3-Mile Radius*			*Beyond 3-Mile Radius*		
(1)	*(2) Block Groups*	*(3) Tracts*	*(4) Zip Code Areas*	*(5) Block Groups*	*(6) Tracts*	*(7) Zip Code Areas*	*(8) Block Groups*	*(9) Tracts*	*(10) Zip Code Areas*	*(11) Block Groups*	*(12) Tracts*	*(13) Zip Code Areas*
Total pop. in 1000s	3,468	3,554	3,572	245,242	245,156	245,137	30,208	29,900	27,480	218,502	218,809	221,230
Race vars.												
Percent black	18.8	18.8	20.4	11.9	11.9	11.9	20.0	20.0	20.4	10.9	10.9	11.0
Percent Hispanic	20.5	20.1	18.8	8.6	8.6	8.7	16.8	16.8	17.2	7.7	7.7	7.8
Percent nonwhite	43.2	42.8	43.6	24.0	24.0	24.0	41.0	41.1	42.0	21.9	21.9	22.0
Economic vars.												
Mean household income	$31,629	31,977	$33,493	$38,547	38,545	$38,524	$35,747	35,855	$36,598	$38,827	38,808	$38,683
Mean property value	$92,427	92,442	$101,419	$111,051	110,320	$110,962	$102,993	102,213	$108,325	$111,740	111,002	$111,107
Percent below poverty line	19.4	19.1	18.5	13.0	13.0	13.0	17.2	17.2	17.1	12.6	12.6	12.6
Percent unemployed	9.0	8.9	8.7	6.3	6.3	6.3	8.0	8.1	8.1	6.1	6.1	6.1
Sociopolitical vars.												
Percent without a high school diploma	35.1	34.4	33.1	24.6	24.6	24.6	29.8	29.8	29.7	24.1	24.1	24.2
Percent with college degree	13.7	14.1	15.4	20.4	20.4	20.4	18.5	18.6	19.0	20.6	20.6	20.5
Percent employed in exec., mana., or prof. occup.	20.4	20.7	22.1	26.4	26.4	26.4	24.7	24.7	25.1	26.6	26.6	26.6
Percent empl. in prec. prod., trans., or labor occup.	31.8	31.3	29.8	26.1	26.1	26.1	27.2	27.1	26.8	26.1	26.1	26.1

Source: Data from U.S. Census Bureau (1990)

Table 4 • *Comparison of Results of Leading National Studies of Racial and Socioeconomic Disparities in the Distribution of Hazardous Waste TSDFs*

Variables	*CRJ (1987)*		*Goldman and Fitton (1994)*		*Anderton and Associates (1994)*		*Been (1995)*		*Oakes, Anderton, Anderson (1996)*	
(1)	*(2) Host Zip Codes*	*(3) Non-Host Zip Codes*	*(4) Host Zip Codes*	*(5) Non-Host Zip Codes*	*(6) Host Tracts*	*(7) Non-Host Tracts*	*(8) Host Tracts*	*(9) Non-Host Tracts*	*(10) Host Tracts*	*(11) Non-Host Tracts*
Percent black					14.5	15.2	14.4	13.5	17.1	16.3
Percent Hispanic					9.4	7.7	10.3	7.8	10.8	9.7
Percent nonwhite	23.7[a]	12.3	30.8 (34.0)[b]	14.4 (24.7)			27.2	24.2		
Percent below poverty line			14.7 (14.6)	12.7 (12.7)	14.5	13.9	15.7	14.6	17.1	14.3
Per capita income			$14,633 ($14,744)	$16,870 ($16,870)						
Median family income							$31,602	$34,586		
Mean household income	$25,711	$23,718								
Median property value							$76,125	$96,808		
Mean property value	$81,436	$71,812			$47,120	$58,352			$82,609	$121,615

Note: All the above studies compare the demographic characteristics of host and non-host units in the nation as a whole, except for the Anderton and associates and Oakes, Anderton, and Anderson studies, which compare host and non-host units in only those metropolitan areas where TSDFs are already located.

[a]The values represent the demographic characteristics of *averaged* host and non-host units, respectively.

[b]The values in parentheses represent the demographic characteristics of the *aggregated* host and non-host units, respectively.

slightly less in host than in non-host tracts.[3] Although the African American percentages were found to be slightly greater in host than in non-host tracts by Been (1995) and Oakes and colleagues (1996), the differences were nevertheless less than 1 percent. The CRJ (1987) and Goldman and Fitton (1994) studies found racial disparities between host and non-host zip code areas to be much greater (mean nonwhite percentages of 23.7 percent and 12.3 percent, respectively, and aggregate nonwhite percentages of 34 percent and 24.7 percent, respectively). However, these differences are still substantially smaller than those obtained by using 50 percent areal containment and areal apportionment methods.

Given that distance-based methods reveal greater racial disparities in the distribution of the nation's TSDFs than prior studies, does application of these methods also lead to different assessments about the possible underlying causes of these disparities? A comprehensive accounting of all the possible factors that may affect racial disparities in the distribution of the nation's TSDFs is beyond the scope of a single quantitative study. However, we can nevertheless assess, as many prior quantitative studies have done, the relative effect of various key economic and sociopolitical variables on the racial disparities.

To determine whether application of distance-based methods leads to different assessments about the relative importance of economic and sociopolitical factors in accounting for racial disparities in the distribution of the nation's TSDFs, logistic regression analyses were performed using unit-hazard coincidence, 50 percent areal containment, and areal apportionment methods and the results compared.[4] In applying the unit-hazard coincidence method, and using census tracts as the units of analysis, the dependent variable in the logistic regression took a value of 1 if the tract hosted a TSDF and a value of 0 if it did not. In applying the 50 percent real containment method, the dependent variable took a value of 1 if the tract lay within 1 mile of a TSDF and a value of 0 if the tract lay beyond 1 mile. In applying the areal apportionment method, we used 1216 one-mile circular neighborhoods as the units of analysis. Half of these neighborhoods were centered at the 608 TSDFs. The other half were centered at 608 randomly located points within the conterminous United States.[5] In the analyses, the dependent variable took a value of 1 if the neighborhood was centered at a TSDF and a value of 0 if it was centered at one of the randomly placed points. The independent variables used in all three analyses included the race, economic, and sociopolitical variables described in the methods section, excluding some of the variables (e.g., percent nonwhite, mean property values, and percent without high school diplomas) to reduce multicollinearity problems (see Table 5). Because the probability of a neighborhood hosting a locally unwanted

3. Anderton and associates (1994) and Oakes and colleagues (1996) confined their comparison of host and non-host tracts to only those metropolitan areas already containing a TSDF. This differs from the approach of the other studies in Table 4, which compared all the host and non-host units in the nation as a whole. Furthermore, the Anderton and associates (1994) and CRJ (1987) studies employed 1980 census data, while all the other studies employed 1990 census data. These differences in approaches and data may partly account for differences in the findings.

4. In addition to the logistic regression analyses, spatial regression analyses were also performed using unit-hazard coincidence, 50 percent areal containment, and areal apportionment methods to take into account the effects of possible spatial autocorrelation. The pattern of results using spatial regression was similar to that using logistic regression, an outcome that is consistent with other studies (see, for example, Pastor, Sadd, and Morello-Frosch 2004; Mohai and Saha 2006). Spatial regression methods assume a linear model with a continuous dependent variable. However, the dependent variable in our analyses, and indeed most environmental inequality analyses, is dichotomous. Because results are not appreciably different whether using spatial or logistic regression and because the latter is the correct specification for models with a dichotomous dependent variable, we display and discuss the results of logistic regression in this article. Spatial regression results can nevertheless be obtained from the authors upon request.

5. We found that 519 TSDFs were located in metropolitan areas and 89 were located in non-metropolitan areas. In order to provide a representative sample of randomly selected points in both types of areas, we stratified the sample and generated 519 random points in the metropolitan areas and 89 in the non-metropolitan areas. We furthermore replicated our random point generation and statistical analyses two more times: (1) one additional time where the random points were distributed between metro and nonmetro areas in similar numbers to actual TSDF locations, and (2) a second time where no constraints were put on the metro/nonmetro distribution of the random points. All three replications yielded similar results.

Table 5 • *Logistic Regression Results Applying Unit-Hazard Coincidence, 50 Percent Areal Containment, and Areal Apportionment Methods (1-Mile Radius)*

Variables	*Unit-Hazard Coincidence (N = 59,050 tracts)*			*50% Areal Containment (N = 59,050 tracts)*			*Areal Apportionment (N = 1216 circular neighborhoods)*		
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*
	Coefficient (B)	*Est. Odds Ratio (Exp(B))*	*Signif. Level.*	*Coefficient (B)*	*Est. Odds Ratio (Exp(B))*	*Signif. Level*	*Coefficient (B)*	*Est. Odds Ratio (Exp(B))*	*Signif. Level*
Race/ethnicity									
Percent black	.093	1.097	.663	.497	1.644	.001	5.407	222.957	.000
Percent Hispanic	.262	1.299	.292	1.781	5.936	.000	3.106	22.324	.000
Economic									
Log of mean household income ($1,000s)	1.524	4.589	.005	−.669	.512	.141	−5.166	.006	.000
Percent below poverty	−1.087	.337	.138	−1.063	.345	.048	−8.499	.000	.000
Percent unemployed	2.279	9.762	.035	4.766	117.479	.000	4.178	65.232	.092
Sociopolitical									
Percent with college degree	−.914	.401	.269	−.832	.435	.187	1.391	4.018	.382
Percent employed. in exec., managerial & professional occup.	−3.279	.038	.001	−.704	.495	.336	5.357	211.995	.006
Percent employed in precision production, trans., or labor occup.	2.155	8.629	.000	1.761	5.819	.000	2.771	15.978	.003
Constant	−6.777	.001	.000	−4.010	.018	.000	5.782	324.325	.000
−2 Log Likelihood	6046.8			8218.4			1511.8		
Mode x^2 (df = 10)	171.592		.000	563.627		.000	171.124		.000

Source: U.S. Census Bureau (1990)

land use is believed to be non-linearly related to income (Been 1995; Pastor, Sadd, and Morello-Frosch 2004), diminishing sharply with rising income, we furthermore adopted Manuel Pastor, Jim Sadd, and Rachel Morello-Frosch's (2004) approach of entering the log of mean household income into the regression analyses.[6]

Examination of the results in Table 5 reveals important differences obtained from applying unit-hazard coincidence and distance-based methods. For example, when applying the unit-hazard coincidence method, the African American and Hispanic percentages of the census tracts are not at all significant predictors of the location of TSDFs (see column 4), while percent employed in management/professional occupations and percent employed in precision production/labor are the strongest predictors (with significance levels of .001 and .000, respectively). Percent unemployed is also statistically significant (alpha = .035; other non-race variables are either not significant or predict TSDF location in the unexpected direction). Such results may be interpreted to mean that any disparities found between minority and white communities in the distribution of the nation's TSDFs may largely be a function of the disparities in political clout between "blue" and "white collar" communities in keeping out such facilities, rather than that African American and Hispanic communities are necessarily targeted for TSDFs or that housing discrimination keeps some African Americans and Hispanics from moving out while steering others toward the TSDFs.

In contrast, when the 50 percent areal containment method is applied, the African American and Hispanic percentages of the tracts become highly statistically significant predictors of TSDF location (at .001 and .000 levels of significance; see column 7, Table 5). The statistical significance of the race variables increases at the same time that two of the economic variables, percent living in poverty and percent unemployed, also increase in statistical significance (alphas = .048 and .000, respectively). Percent employed in precision production/labor occupations also remains highly statistically significant, although percent employed in management/professional occupations is no longer so. Similar results are obtained using the areal apportionment method, except that percent unemployed does not quite reach the .05 level of significance. Thus, in contrast to the earlier interpretations using the unit-hazard coincidence method, the results obtained by using the two distance-based methods may be taken to mean that, although there is evidence to indicate that economic and sociopolitical factors influence TSDF location, these factors by themselves do not entirely account for the racial disparities found in their distribution. Other factors related to race, such as racial targeting or housing discrimination, also appear to be playing a role.

Summary and Conclusions

Although it is the most widely used approach in conducting environmental inequality assessments, the unit-hazard coincidence method inadequately controls for proximity between environmentally hazardous sites and nearby populations. Rather than determining the precise geographic location of the site, this method only considers whether the site and a host unit are coincident and assumes people living in the host unit are closer to the site than people living in non-host units. Not taken into account, however, is the proximity of the site to nearby units. Even though people in nearby units may be as near to the site as those in the host tract proper, nearby units are considered to be no different demographically than non-host units much farther away. Also not taken into account is the large variation in the sizes of host units. Even though people in large host tracts may be dispersed quite far from the hazardous sites in them, large host units are given the same weight as small host units in the analyses. If the proposition is true that hazardous sites are disproportionately located where

6. We also conducted the logistic regression analyses using the non-transformed mean household income and found no appreciable differences in the pattern of results.

minorities and poor people live, then reliance on the unit-hazard coincidence method has likely led to underestimations of the actual magnitude of racial and socioeconomic disparities around a wide variety of environmentally hazardous sites. Furthermore, assessments about the relative importance of various factors thought to account for the disparities have also likely been affected.

Distance-based methods, such as the 50 percent areal containment and areal apportionment methods, represent a significant improvement over the unit-hazard coincidence method in controlling for proximity between environmentally hazardous sites and nearby residential populations. These methods take into account the precise geographic locations of hazardous sites and sort units or parts of units—whether host or non-host—that are within a specified distance of these sites from those that lie beyond the distance. Distance-based methods not only better control for proximity around environmentally hazardous sites than does the unit-hazard coincidence method, they also assure greater consistency in the size and shape of the geographic areas around the hazard, and greater consistency in the location of the hazards within these areas. We also note the considerable robustness in the results obtained by the 50 percent areal containment and areal apportionment methods. The results obtained are very similar regardless of which of these two distance-based methods is employed. Results are also very similar regardless of which predefined geographic unit is used as the building block unit: block groups, census tracts, or zip code areas.

We demonstrated that when racial disparities around the nation's TSDFs are analyzed applying distance-based methods, such disparities are found to be much greater than when the unit-hazard coincidence method is applied. Although minorities made up only a quarter of the nation's population in 1990, over 40 percent of the population living within 1 mile of hazardous waste TSDFs were persons of color. The nearly 20 percent difference (43.2 percent compared to 24 percent; see columns 2 and 5 in Table 3) in the minority percentages between host and non-host neighborhoods within 1.0 mile of a TSDF is clearly much greater than the 1 percent to 3 percent differences that are found when the unit-hazard coincidence method is applied. Even at a distance of 3 miles, the difference in the proportion of nonwhites in host and non-host neighborhoods is found to be greater.

Furthermore, distance-based methods lead to different assessments about the relative importance of economic and sociopolitical factors in accounting for racial disparities in the distribution of the nation's TSDFs. When logistic regression analysis is performed with unit-hazard coincidence, the African American and Hispanic percentages of tracts appear to have no independent effect on the location of TSDFs beyond what can be explained by differences in economic and sociopolitical variables. When 50 percent areal containment and areal apportionment are applied, racial disparities in the distribution of the nation's TSDFs persist despite controlling for the economic and sociopolitical make-up of the tracts, suggesting that factors uniquely associated with race, such as racial targeting at the time of siting, housing segregation after siting, and institutional forms of discrimination may play a role in present-day TSDF locations. Determining precisely what factors play a role in present-day racial disparities in industrial and hazardous waste facility location will of course require further study. Nevertheless, our analysis demonstrates that future quantitative studies employing multivariate analyses to test hypotheses about cause and effect relationships will likely yield different results from many prior studies where proximity between hazardous sites and nearby populations were not adequately controlled.

Finally, even though measuring proximity to environmentally hazardous sites is not the same as measuring actual exposure to health risks, the methods we describe are relevant for examining racial and socioeconomic disparities in the dispersion of pollution risks as well. Pollution dispersion and risk assessment techniques involve measuring the types and quantities of toxic emissions, timing of release, meteorological conditions affecting emission dispersion (such as wind speed and direction), and other factors so that fallout patterns ("pollution footprints") and their level of risk can be determined (Andrews 2003, Ash and Fetter 2004, Chakraborty and Armstrong 1997; Glickman et al. 1995, Hamilton 1999). Fifty percent areal containment and areal apportionment methods can be applied to determine which geographic units or portions of units fall within the footprint boundaries. The demographic characteristics of the aggregated units within the footprint boundaries can then be compared with those outside the boundaries (see, e.g., Glickman et al. 1995; and Chakraborty and Armstrong 1997).

Currently, relatively few environmental justice studies have involved pollution dispersion and risk assessment modeling, largely because of the difficulties in acquiring the necessary data for them, particularly when a great number of polluting facilities are examined as in national studies such as ours. Because of the uncertainties of such modeling associated with the incompleteness of data about the type, quantity, and timing of toxic releases, meteorological conditions, fallout patterns, etc. (Andrews 2003), the advantages of more straightforward proximity measures ought not to be overlooked. They provide "hard numbers" about the location of environmentally hazardous sites and their proximity to nearby residential populations. And although at best they are only an indirect measure of potential health risk, they nevertheless indicate the presence of other probable quality of life impacts of concern to nearby residents, including visual blight, noise, noxious odors, traffic congestion, depressed property values, social stigmatization, and others (Edelstein 2004; Mohai 1995; Mohai and Bryant 1998).

The prominence of debates in both academic and political arenas about the role of race in the distribution of environmental costs and benefits and the importance of studies attempting to gain a better understanding of the role race plays in society in general underscore the need for applying the best methodologies available. Whether pollution dispersion assessments or site proximity assessments are seen as the best ways to evaluate environmental injustices, the goal in either case will be to best match the location of the potentially affected or exposed populations with that of the environmental hazard. We believe that distance-based methods provide distinct improvements in making such matches over previous methods, such as the unit-hazard coincidence method. Furthermore, given the current widespread availability of GIS technology, the application of distance-based methods should be feasible even for national level environmental inequality studies.

Appendix

Tables A.1 and A.2 provide the results of statistical analyses of the differences in demographic values between host and non-host neighborhoods defined by 50 percent areal containment and areal apportionment methods. In conducting statistical tests involving the 50 percent areal containment method, the analyses were performed three times, once each time using block groups, census tracts, and zip code areas, respectively, as the geographic units of analysis. Because neighborhoods beyond the 1- and 3-mile distances from TSDFs make up the vast majority of the geographic areas (over 99 percent of either block groups, tracts, or zip code areas), the demographic values of the combined populations within these units were treated as constants in one-sample *t*-tests (see Table A.1). It was found that all differences between host and non-host neighborhood (defined by either 1 or 3 buffers) were statistically significant at the .05 level, except for mean property values when zip code areas are used as the units of analysis.

In conducting statistical tests involving the areal apportionment method, the units of analysis were either 1 or 3 mile perfectly circular neighborhoods around the nation's TSDFs. These perfectly circular neighborhoods were constructed three times, once using block groups as the building block units, again using tracts as the building blocks, and a third time using zip code areas as the building blocks. As with the 50 percent areal containment method, demographic values for areas beyond the 1- and 3-mile circular neighborhoods were treated as constants in one-sample t-tests (see Table A.2). As before, this was done because the vast majority of the area and population in the United States lies beyond the 1- and 3-mile host areas. Moreover, it would have been difficult to represent non-host areas using 1- or 3-mile circular buffers, other

Table A.1 • ***Results of One Sample T-Tests Comparing Demographic Values of Units within 1 and 3 miles of TSDFs against Values Beyond 1 and 3 Miles Using 50 Percent Areal Containment Method***

Block Groups within 1 and 3 Miles of a TSDF

Variable	*Mean within 1 mi.*	*S.D.*	*Constant beyond 1 mi.*	*T-Test*	*d.f.*	*Sign.*	*Mean within 3 mi.*	*S.D.*	*Constant beyond 3 mi.*	*T-Test*	*d.f.*	*Sign.*
Percent black	20.4	31.3	11.9	15.612	3,309	0.000	22.4	33.6	10.9	57.085	27,747	0.000
Percent Hispanic	17.3	25.9	8.6	19.197	3,309	0.000	13.9	23.2	7.7	44.332	27,747	0.000
Percent nonwhite	41.4	36.3	24.0	27.481	3,309	0.000	39.8	37.0	21.9	80.519	27,747	0.000
Mean household income	$29,897	$13,193	$38,546	−37.621	3,294	0.000	$33,679	$19,082	$38,831	−44.874	27,583	0.000
Mean property value	$87,456	$67,590	$111,043	−19.865	3,027	0.000	$98,915	$86,278	$111,745	−25.051	25,357	0.000
Percent below poverty line	20.8	18.1	13.0	24.759	3,302	0.000	18.8	18.1	12.6	57.854	27,679	0.000
Percent unemployed	10.5	9.6	6.3	24.976	3,291	0.000	9.6	9.5	6.1	60.294	27,628	0.000
Percent without HS diploma	38.2	19.6	24.6	39.844	3,304	0.000	32.4	19.5	24.1	70.590	27,716	0.000
Percent with college degree	11.7	11.9	20.4	−42.106	3,304	0.000	16.3	16.2	20.6	−44.116	27,716	0.000
Percent employed in exec., mana. or prof. occup.	17.9	12.8	26.4	−38.125	3,287	0.000	21.9	15.0	26.6	−51.575	27,587	0.000
Percent empl. in prec. prod., trans., or labor occup.	33.9	15.4	26.1	29.045	3,287	0.000	29.2	14.9	26.1	34.550	27,587	0.000

Census Tracts within 1 and 3 Miles of a TSDF

Variable	*Mean within 1 mi.*	*S.D.*	*Constant beyond 1 mi.*	*T-Test*	*d.f.*	*Sign.*	*Mean within 3 mi.*	*S.D.*	*Constant beyond 3 mi.*	*T-Test*	*d.f.*	*Sign.*
Percent black	21.3	30.3	11.9	9.020	841	0.000	23.8	33.0	10.9	33.782	7,412	0.000
Percent Hispanic	18.6	25.4	8.7	11.357	841	0.000	14.4	22.4	7.7	25.766	7,412	0.000
Percent nonwhite	43.8	34.7	24.0	16.560	841	0.000	42.0	35.9	21.9	48.260	7,412	0.000
Mean household income	$28,998	$10,800	$38,543	−25.539	834	0.000	$33,192	$16,762	$38,835	−28.848	7,343	0.000
Mean property value	$92,930	$67,747	$111,856	−8.009	821	0.000	$108,565	$91,826	$112,488	−3.630	7,218	0.000
Percent below poverty line	22.2	16.4	13.0	16.222	838	0.000	19.8	16.8	12.5	37.093	7,387	0.000
Percent unemployed	11.1	8.1	6.3	17.305	840	0.000	9.9	8.2	6.1	39.341	7,387	0.000

(continued)

Table A.1 • *(continued)*

Census Tracts within 1 and 3 Miles of a TSDF

Variable	*Mean within 1 mi.*	*S.D.*	*Constant beyond 1 mi.*	*T-Test*	*d.f.*	*Sign.*	*Mean within 3 mi.*	*S.D.*	*Constant beyond 3 mi.*	*T-Test*	*d.f.*	*Sign.*
Percent without HS diploma	38.8	17.7	24.6	23.336	840	0.000	32.9	18.0	24.1	41.906	7,403	0.000
Percent with college degree	16.7	11.9	20.4	−9.093	840	0.000	21.7	15.8	20.6	6.053	7,403	0.000
Percent employed in exec., mana. or prof. occup.	18.0	10.7	26.4	−22.811	838	0.000	22.0	13.0	26.6	−30.182	7,367	0.000
Percent empl. in prec. prod., trans., or labor occup.	33.7	12.7	26.1	17.331	838	0.000	28.7	12.6	26.1	18.032	7,367	0.000

Zip Code Areas within 1 and 3 Miles of a TSDF

Variable	*Mean within 1 mi.*	*S.D.*	*Constant beyond 1 mi.*	*T-Test*	*d.f.*	*Sign.*	*Mean within 3 mi.*	*S.D.*	*Constant beyond 3 mi.*	*T-Test*	*d.f.*	*Sign.*
Percent black	19.1	23.7	12.0	2.265	57	0.027	20.0	26.8	11.0	10.948	1,050	0.000
Percent Hispanic	20.8	22.1	8.7	4.155	57	0.000	13.0	19.7	7.7	8.646	1,050	0.000
Percent nonwhite	44.3	28.6	24.1	5.384	57	0.000	36.8	31.6	21.9	15.314	1,050	0.000
Mean household income	$31,799	$11,545	$38,481	−4.408	57	0.000	$34,841	$14,699	$38,761	−8.633	1,047	0.000
Mean property value	$127,117	$78,643	$110,811	1.565	56	0.123	$113,419	$91,659	$111,299	0.741	1,025	0.459
Percent below poverty line	21.7	16.6	13.1	3.964	57	0.000	17.7	14.3	12.6	11.541	1,049	0.000
Percent unemployed	10.3	6.2	6.3	4.884	57	0.000	8.9	6.6	6.1	13.930	1,050	0.000
Percent without HS diploma	37.0	16.5	24.7	5.696	57	0.000	30.2	15.1	24.1	13.083	1,050	0.000
Percent with college degree	15.7	12.6	20.4	−2.867	57	0.006	17.6	13.2	20.6	−7.359	1,050	0.000
Percent employed in exec., mana. or prof. occup.	21.8	11.0	26.4	−3.203	57	0.002	23.5	11.3	26.6	−8.778	1,049	0.000
Percent empl. in prec. prod., trans., or labor occup.	31.6	12.4	26.2	3.326	57	0.002	28.0	11.0	26.1	5.722	1,049	0.000

Source: Data from U.S. Census Bureau (1990)

Table A.2 • ***Results of One Sample T-Tests Comparing Demographic Values of 1- and 3-mile Circular Areas around TSDFs Against Values Beyond 1 and 3 Miles Using Areal Apportionment Method***

Circular Areas within 1 and 3 Miles of TSDFs Constructed from Block Groups

Variable	*Mean within 1 mi.*	*S.D.*	*Constant beyond 1 mi.*	*T-Test*	*d.f.*	*Sign.*	*Mean within 3 mi.*	*S.D.*	*Constant beyond 3 mi.*	*T-Test*	*d.f.*	*Sign.*
Percent black	15.2	22.8	11.9	3.610	606	0.000	16.0	20.5	10.9	6.181	607	0.000
Percent Hispanic	11.0	19.5	8.6	3.050	606	0.002	10.1	17.5	7.7	3.347	607	0.001
Percent nonwhite	28.9	28.8	24.0	4.158	606	0.000	28.8	26.0	21.9	6.575	607	0.000
Mean household income	$32,841	$11,541	$38,547	−12.181	606	0.000	$34,424	$10,876	$38,827	−9.982	607	0.000
Mean property value	$83,398	$55,666	$111,051	−12.199	602	0.000	$89,712	$5,9387	$111,740	−9.138	606	0.000
Percent below poverty line	15.6	12.0	13.0	5.222	606	0.000	15.1	9.3	12.6	6.555	607	0.000
Percent unemployed	7.9	5.3	6.3	7.585	606	0.000	7.5	3.7	6.1	8.984	607	0.000
Percent without HS diploma	31.2	14.6	24.6	11.165	606	0.000	28.6	12.4	24.1	8.960	607	0.000
Percent with college degree	13.5	9.5	20.4	−17.748	606	0.000	16.0	8.8	20.6	−12.853	607	0.000
Percent employed in exec., mana. or prof. occup.	19.8	8.6	26.4	−18.914	606	0.000	22.2	7.3	26.6	−15.004	607	0.000
Percent empl. in prec. prod., trans., or labor occup.	32.6	10.0	26.1	16.120	606	0.000	30.1	8.6	26.1	11.447	607	0.000

Circular Areas within 1 and 3 Miles of TSDFs Constructed from Census Tracts

Variable	*Mean within 1 mi.*	*S.D.*	*Constant beyond 1 mi.*	*T-Test*	*d.f.*	*Sign.*	*Mean within 3 mi.*	*S.D.*	*Constant beyond 3 mi.*	*T-Test*	*d.f.*	*Sign.*
Percent black	15.2	21.7	11.9	3.760	606	0.000	16.1	20.1	10.9	6.343	607	0.000
Percent Hispanic	11.0	19.0	8.6	3.147	606	0.002	10.2	17.4	7.7	3.546	607	0.000
Percent nonwhite	28.9	27.9	24.0	4.370	606	0.000	29.0	25.7	21.9	6.775	607	0.000
Mean household income	$33,204	$11,303	$38,545	−11.642	606	0.000	$34,506	$10,566	$38,808	−10.039	607	0.000
Mean property value	$8,5427	$57,171	$110,320	−10.727	606	0.000	$90,411	$59,253	$111,002	−8.569	607	0.000
Percent below poverty line	15.6	11.1	13.0	5.752	606	0.000	15.2	9.2	12.6	6.971	607	0.000
Percent unemployed	7.8	4.6	6.3	8.023	606	0.000	7.5	3.5	6.1	9.568	607	0.000
Percent without HS diploma	30.6	14.0	24.6%	10.508	606	0.000	28.4	11.9	24.1	9.006	607	0.000

(*continued*)

Table A.2 • *(continued)*

Circular Areas within 1 and 3 Miles of TSDFs Constructed from Census Tracts

Variable	*Mean within 1 mi.*	*S.D.*	*Constant beyond 1 mi.*	*T-Test*	*d.f.*	*Sign.*	*Mean within 3 mi.*	*S.D.*	*Constant beyond 3 mi.*	*T-Test*	*d.f.*	*Sign.*
Percent with college degree	14.2	9.4	20.4	−16.130	606	0.000	16.2	8.6	20.6	−12.658	607	0.000
Percent employed in exec., mana. or prof. occup.	20.3	8.3	26.4	−17.896	606	0.000	22.3	7.0	26.6	−14.886	607	0.000
Percent empl. in prec. prod., trans., or labor occup.	32.0	9.6	26.1	15.272	606	0.000	29.9	8.4	26.1	11.244	607	0.000

Circular Areas within 1 and 3 Miles of TSDFs Constructed from Zip Code Areas

Variable	*Mean within 1 mi.*	*S.D.*	*Constant beyond 1 mi.*	*T-Test*	*d.f.*	*Sign.*	*Mean within 3 mi.*	*S.D.*	*Constant beyond 3 mi.*	*T-Test*	*d.f.*	*Sign.*
Percent black	16.0	21.5	11.9	4.725	607	0.000	16.1	19.6%	11.0	6.452	607	0.000
Percent Hispanic	10.6	18.3	8.7	2.614	607	0.009	10.1	17.0%	7.8	3.382	607	0.001
Percent nonwhite	29.3	27.0	24.0	4.872	607	0.000	29.0	25.0%	22.0%	6.887	607	0.000
Mean household income	$34,070	$10,225	$38,524	−10.740	607	0.000	$34,746	$10,099	$38,683	−9.612	607	0.000
Mean property value	$88,737	$58,093	$110,962	−9.433	607	0.000	$91,834	$59,808	$111,107	−7.946	607	0.000
Percent below poverty line	15.4	9.8	13.0	6.063	607	0.000	15.1	8.7%	12.6	7.080	607	0.000
Percent unemployed	7.6	4.0	6.3	8.324	607	0.000	7.4	3.3%	6.1	9.729	607	0.000
Percent without HS diploma	29.3	12.6	24.6	9.248	607	0.000	28.1	11.4%	24.2	8.356	607	0.000
Percent with college degree	15.4	8.7	20.4	−14.314	607	0.000	16.7	8.4%	20.5	−11.221	607	0.000
Percent employed in exec., mana. or prof. occup.	21.8	7.3	26.4	−15.724	607	0.000	22.8	6.8%	26.6	−13.824	607	0.000
Percent empl. in prec. prod., trans., or labor occup.	30.7	8.5	26.1	13.393	607	0.000	29.4	8.0%	26.1	10.262	607	0.000

Source: Data from U.S. Census Bureau (1990)

than by locating a random sample of points outside the host areas and constructing buffers around them (as we did for the logistic regression in Table 5), However, we wanted to include demographic values for the *entire* United States rather than for only a sample of areas. It was found that all differences in demographic values between host and non-host neighborhood (defined by either 1 or 3 buffers) were statistically significant at the .05 level.

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The riskscape and the color line: examining the role of segregation in environmental health disparities

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Abstract

Environmental health researchers, sociologists, policy-makers, and activists concerned about environmental justice argue that communities of color who are segregated in neighborhoods with high levels of poverty and material deprivation are also disproportionately exposed to physical environments that adversely affect their health and well-being. Examining these issues through the lens of racial residential segregation can offer new insights into the junctures of the political economy of social inequality with discrimination, environmental degradation, and health. More importantly, this line of inquiry may highlight whether observed pollution – health outcome relationships are modified by segregation and whether segregation patterns impact diverse communities differently.

This paper examines theoretical and methodological questions related to racial residential segregation and environmental health disparities. We begin with an overview of race-based segregation in the United States and propose a framework for understanding its implications for environmental health disparities. We then discuss applications of segregation measures for assessing disparities in ambient air pollution burdens across racial groups and go on to discuss the applicability of these methods for other environmental exposures and health outcomes. We conclude with a discussion of the research and policy implications of understanding how racial residential segregation impacts environmental health disparities.

Keywords: environmental justice, segregation, health disparities, race/ethnicity

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1. Introduction

"The color line is not static; it bends and buckles and sometimes breaks."

(Drake and Cayton, 1945)

Race, as a social construct and mechanism of classification, has historically defined and continues to shape the distribution of power, privilege, and economic resources in American society (Crenshaw, 1988; Jones, 2001; Lawrence, 1987; Wellman, 1993). Myriad forms of past and present discrimination in the U.S. are imprinted onto our urban landscape, as evidenced by the persistent spatial separation of diverse communities along racial/ethnic and, to a lesser extent, class lines (Farley, 1995; Jargowsky, 1997; Logan and Molotch, 1987; Massey and Denton, 1993; Massey and Gross, 1994; Walker, 1981). Wide-ranging and complex political, socioeconomic, and discriminatory forces coupled with patterns of industrialization, disinvestment, and development have segregated people of color, particularly African Americans, into neighborhoods with some of the highest indices of urban poverty and deprivation (Peet, 1984; Schultz et al., 2002; Walker, 1985). Indeed, uneven industrial development, the movement of economic opportunities away from inner cities, real estate speculation, discrimination in government and private financing, and exclusionary zoning have led to systemic racial segregation among diverse communities with important implications for community health and individual well-being (Bobo, 2001; Harvey, 1989; Logan and Molotch, 1987; Massey, 2004; Morello-Frosch, 2002; Sinton, 1997; Wilson, 1996). The socioeconomic effects of urban segregation are further amplified by racialized boundaries in schools, the workplace and in some regions through policies such as immigration law and welfare reform (Hersh, 1995; Morello-Frosch, 2002; Pulido et al., 1996).

Although elements for understanding the relationship between residential segregation and community environmental health can be found separately in the sociology literature and the environmental justice literature, only two previous investigations have combined these lines of inquiry to analyze the relationship between outdoor air pollution exposure and segregation (Lopez, 2002; Morello-Frosch and Jesdale, 2006). Some researchers have recently argued that residential segregation is a crucial starting point for understanding the origins and persistence of environmental health disparities (Gee and Payne-Sturges, 2004; Lopez, 2002; Morello-Frosch, 2002b; Morello-Frosch et al., 2001, 2002b). Here we examine theoretical and methodological questions related to racial residential segregation and environmental health. We seek to address the following questions: 1) What are the various ways that segregation is conceptualized and how are these concepts measured? 2) Given that most measures of segregation consider only dyads, to what extent are existing measures of segregation valid for multi-ethnic regions? 3) How have segregation measures been applied to examine environmental health disparities such as air pollution? 4) Can these methods be used for other exposures and health issues? The paper begins with an overview of race-based segregation in the United States and proposes a framework for understanding its implications for environmental health disparities. We then discuss applications of segregation for assessing disparities in ambient air pollution burdens across racial groups and go on to discuss the applicability of these methods for other environmental exposures and health outcomes. Finally, we conclude by outlining some of the policy and regulatory implications of using residential segregation measures to research and track structural drivers of environmental health disparities.

2. Environmental health disparities in the context of neighborhoods and regions

The burgeoning literature on health disparities has compelled researchers to move beyond proximate causes of poor health toward identifying socioeconomic factors that shape distributions of health and disease in populations (House and Williams, 2000; Kaplan and Lynch, 1999; Link and Phelan, 1995; Navarro, 2002). This requires examining how the socioeconomic conditions of residential environments affect health and well-being and how the historical and locationally based antecedents of contemporary health issues continue to impact communities. Indeed, research strongly suggests that place affects health (Macintyre et al., 2002; Yen and Syme, 1999). Yet, despite the proliferation of work on the issue of segregation, there is a lack of scientific consensus about what it is about neighborhoods, and segregated neighborhoods in particular, that affects health (Evans and Kranowitz, 2002). Neighborhood-level factors associated with racial residential segregation may affect individual health by influencing food security (access to affordable markets with fresh fruits and vegetables); proximity to crucial services such as health care, parks, and open space (Center for Third World Organizing, 2002; Diez-Roux, 1997; Morland et al., 2002); the social environment (social capital, cohesion, and crime rates) (Conley, 1999; Kawachi and Berkman, 2003; Keister, 2000; Sampson, 1987); and the physical environment (traffic density, abandoned properties, and housing quality) (Reynolds et al., 2002; Shenassa et al., 2004; Wallace, 1990).

Researchers, policy-makers, and advocates concerned about environmental justice argue that communities of color who are segregated in neighborhoods with high levels of poverty and material deprivation are also disproportionately exposed to physical environments that adversely affect their health and well-being. Examining these issues through the lens of racial residential segregation offers insights into the junctures of the political economy of social inequality with discrimination, environmental degradation, and health. This perspective also highlights how diverse legacies of discrimination shape current spatial distributions of pollution sources among diverse communities. More importantly, this line of inquiry may reveal whether observed pollution – health outcome relationships are modified by segregation and whether segregation disproportionately impacts certain populations. These issues are all important for understanding how place-based measures of social inequality shape environmental health disparities among diverse communities.

Segregation also promotes a regional perspective for understanding the dynamics of environmental health disparities. For example, conventional theories regarding regional development suggest that the formation of large cities in the United States was consonant with a history of industrial agglomeration in the urban core followed by a more recent countervailing trend of selective suburban economic development that drove desirable land uses to the periphery while remaining undesirable land uses continued to cluster in center cities and older ring suburbs. The morphology of the urban landscape is also shaped by shifting patterns of capital and state investment; governments at the local, state, and federal levels often promote industrial expansion by facilitating investment flows to outlying regional areas through highway construction and other infrastructure projects, tax breaks, and mortgage subsidies (Hise, 1997; Logan and Molotch, 1987). Historically, working-class and poor communities of color have been spatially bound in this process, remaining close to aging, large production facilities, because of limits imposed by job search, work hours, income, and exclusionary and discriminatory housing development policies (Guhathakurta and Wichert, 1998; Massey and Denton, 1993). Preliminary research using longitudinal data has sought to disentangle the causal sequence of facility siting in poor communities of color over time. Results have found little evidence of so-called “minority move-in" into areas where potentially hazardous facilities had been previously located suggesting that the facilities are sited in previously established poor minority communities (Been and Gupta, 1997; Pastor et al., 2001; Saha and Mohai, 2005).

Imposed limitations on the spatial mobility of certain populations also undercuts their economic mobility because of the close connection between these two phenomena (Massey and Fong, 1990; Massey et al., 1991). Indeed, the historical and contemporary racial segmentation of the housing market erodes the property values of Black housing and limits the capacity of Black families to accumulate wealth through home equity (Conley, 1999; Oliver and Shapiro, 1995). Segregation can also cause so-called "spatial mismatch" between the location of lucrative jobs and the residential location of the communities that need them (Kain, 1968; Preston and McLafferty, 1999), leading to longer commute times, and possibly higher pollution burdens overall. Conversely, wealthier, mostly White, classes enjoy the mobility and privilege to pursue emerging economic opportunities and to escape the toxic zones of industrial activity (Pulido, 2000). Therefore, segregation can play out so that certain groups become concentrated, centralized, and isolated in abandoned inner city cores where employment opportunities are few and where communities are clustered around industrial sites, undesirable land uses, and/or transportation corridors that pose significant health hazards (Pulido et al., 1996).

Segregation, whose effects are experienced by individuals, is a phenomenon that occurs at a group level. By definition, segregation refers to the distribution of a specific demographic group across a geographic region, such as a metropolitan area. Therefore, the community health effects of segregation must be examined and remedied through policy decisions and interventions at the regional, metropolitan, state, or national levels. In general, the structural forces that create segregation tend to operate regionally, as evidenced by many current political and economic regions that are not producing optimal outcomes for communities of color, the working class, and the poor, in terms of economic growth, and environmental quality (Pastor, 2001; Pastor et al., 2000). Metro areas and cities that are integrated along economic, political, and environmental lines have a more equitable distribution of resources and tend to collectively fare better on a number of important outcomes. Examples of such benefits include a stronger, more stable tax base, healthy communities, and planned land use development (Pastor, 2001; Pastor et al., 2000). The importance of regional equity can be extended to address regional disparities in health and the potential for improving outcomes by linking together the future of suburbs and cities. From a public health perspective, the rationale for taking a regional approach to examining links between segregation, environments, and health disparities is twofold: First, research strongly suggests that it is more fruitful to assess drivers of environmental health disparities at the regional level because economic trends, transportation planning, and industrial clusters tend to be regional in nature, even as zoning, facility siting, and urban planning decisions tend to be local (Morello-Frosch et al., 2002a). Second, research that examines how health inequities play out regionally could have implications for the development of interventions and policy initiatives that ameliorate fundamental drivers of environmental health and disease among diverse communities.

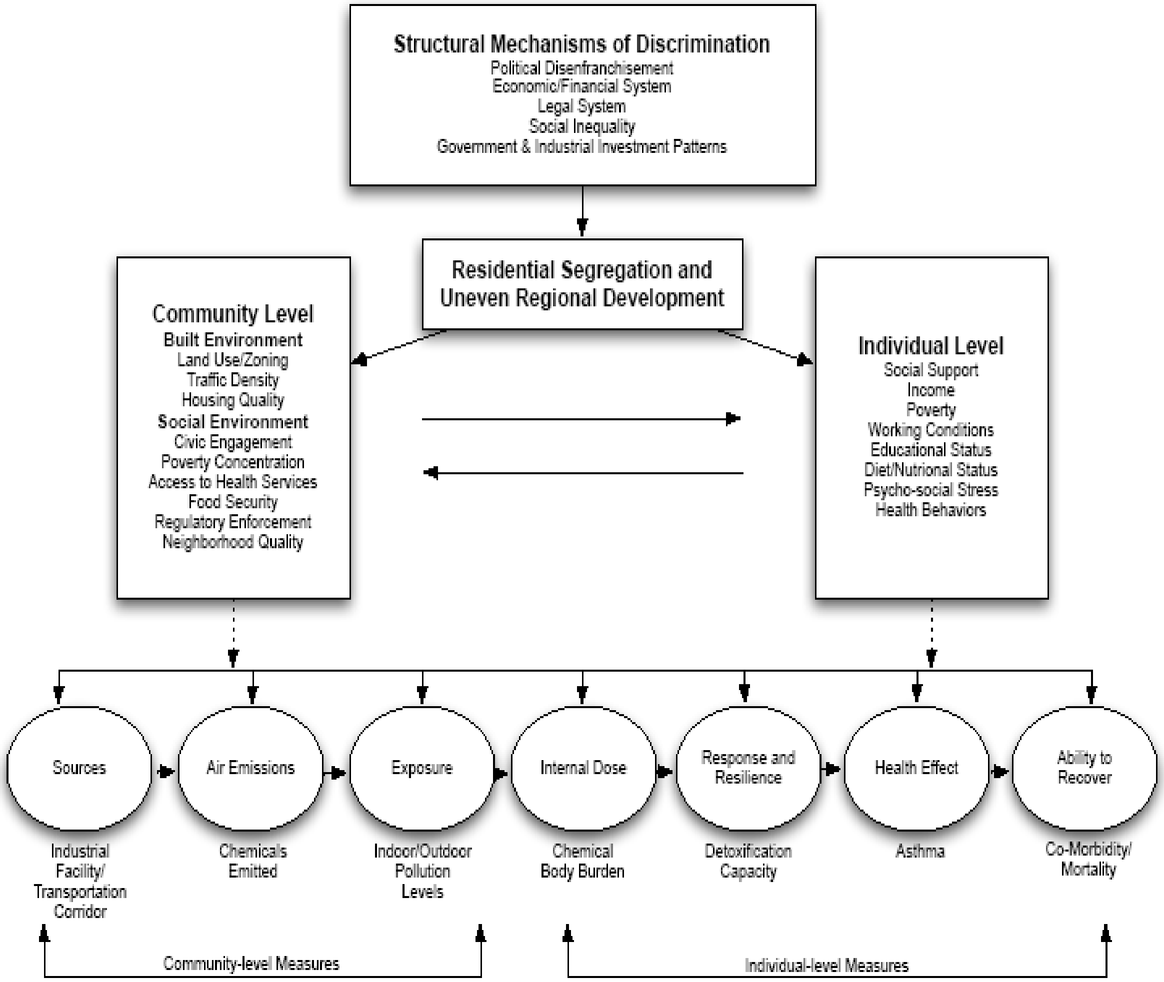

Fig. 1. Framework for understanding segregation and environmental health.

3. A conceptual framework for linking segregation to environmental health disparities

We propose a framework for understanding the relationship between racial residential segregation and various indicators of environmental health inequalities. Building on concepts proposed by other health inequality researchers (Gee and Payne-Sturges, 2004; Schultz et al., 2002), Figure 1 demonstrates an ecosocial or biosocial framework (Krieger, 1994, 1999; Massey, 2004) that connects a spatial form of social inequality (i.e., racial segregation) to community-level conditions that disproportionately expose communities of color to environmental hazards and stressors. These stressors potentially amplify individual-level vulnerability to the toxic effects of pollution. We posit that this dynamic may partially explain persistent racial and class-based health disparities that are environmentally mediated.

The top of the figure shows the structural mechanisms that lead to residential segregation and result in community- and individual-level factors that influence disease burdens among diverse populations. Segregation solidifies racial disparities in socioeconomic status (SES), and it shapes the distribution of resources and wealth at the individual and community levels with important implications for community health. The bottom of the figure shows how these community and individual-level factors influence the exposure-health outcome continuum by increasing exposures to environmental hazards, amplifying the probability of adverse health effects, and affecting the ability to recover from hazardous exposures. This exposure-health outcome continuum connects the emission of a contaminant from a source (e.g., an industrial facility or transportation corridor in a neighborhood) to human exposure via various media (e.g., air), body burden and internal dose of contaminants, individual resilience (e.g., through detoxification mechanisms) and the occurrence of a health effect (e.g., asthma), and the ability to recover. The framework assumes that environmental contaminants lead to human exposures that can overcome the body's defense systems and have adverse health effects. This dose, if not effectively metabolized, neutralized, or excreted by the body's detoxifying and/or immune systems, can lead to biological effects that may alter system functioning and damage target organ systems. Individual and community-level stressors shape the effects of these differential exposures, including increasing or decreasing absorption, ability to detoxify or recover from toxic exposures, and the ultimate short- and long-term health effects from environmental contaminants. Community- and individual-level stressors and buffers can protect against or amplify vulnerability to the toxic effects of contaminants (Brunner, 2000; Gordon, 2003; Perera et al., 2003; Rauh et al., 2004; Rios et al., 1993). Therefore, it is important to examine both community and individual levels of stressors (Diez-Roux, 1997, 1998, 2000) to assess their impact on health outcomes that are environmentally and socially mediated. These factors can include both social and biological elements, including pre-existing health conditions, socioeconomic circumstances, and psycho-social stress (Brunner, 2000; McEwen and Lasley, 2002).

The case of childhood asthma highlights connections between the elements of our conceptual framework, as researchers have begun to examine how stressors at the individual and community levels may influence the development and severity of disease among diverse populations (Busse et al., 1995; Gilliland et al., 1999; House and Williams, 2000; Institute of Medicine, 2000; Wright et al., 1998). Discriminatory forces leading to segregation drive community-level disparities in the quality of the built environment (e.g. traffic density and housing quality) and the social environment (e.g. poverty concentration, access to health services, food security, and regulation). Each of these community-level dimensions can act as stressors or buffers that impact individual-level vulnerability to air pollutant exposures that may be associated with childhood asthma. Gold and Wright hypothesize that community- and individual-level factors can act as potential modifiers of the relationships between pollutant exposures and asthma, through: 1) differential environmental exposures, 2) psychosocial stress and 3) the impact of 1 and 2 on individual health behaviors (Gold and Wright, 2005). Most important, these community-level stressors (e.g. poor housing conditions, food insecurity and poor neighborhood quality) can influence individual living conditions and health behaviors (e.g. household crowding, diet/nutritional status, and smoking). The interplay of these individual and community-level stressors results in a feedback loop: individual factors influence community exposures that compound individual vulnerability, which ultimately influences the biological pathways linking pollutant exposures to asthma exacerbation and possibly the development of disease.

For example, tobacco smoke exposure is an important factor associated with the occurrence of childhood asthma (Li et al., 2005; Strachan and Cook, 1998), and smoking prevalence is often associated the target marketing of tobacco products in poor communities of color (Pollay et al., 1992) and with chronic stress (Kleinschmidt et al., 1997). Similarly, community food security includes access to affordable supermarkets, which can affect an individual's dietary intake of fresh fruits and vegetables. Recent research indicates that diet and nutritional status impacts respiratory health in children (Gilliland et al., 2003). Certain vitamins found in fruits and vegetables may protect the lungs against oxidative stress and promote healthy lung function and development (Gilliland et al., 2003). In addition to environmental factors, chronic life stress experiences may also affect childhood asthma morbidity. Recent studies indicate that higher levels of caregiver stress, due to lack of community social support, access to preventive health care services (Wright et al., 1998, 2002) and exposure to community violence (Wright et al., 2004) are associated with more severe asthma morbidity.

4. The dimensions and measurement of racial residential segregation

The fields of sociology and demography have given substantial attention to theorizing and measuring dimensions of segregation (Duncan and Duncan, 1955a, 1955b). Although a report by the U.S. Census lists over a dozen measures (Iceland et al., 2002), five basic dimensions of racial and ethnic segregation dominate the literature: *evenness*, *isolation*, *concentration, centralization,* and *clustering* (James and Taeuber, 1985; Massey and Denton, 1988; Stearns and Logan, 1986; White, 1986). *Evenness* measures the degree to which the proportion of a particular racial or ethnic group living in residential areas (e.g. census tracts) approximates that group's relative percentage of an entire metropolitan area (Massey et al., 1996). This measure is the most extensively used indicator of segregation, both in the sociological and public health literature (Acevedo-Garcia et al., 2003). *Isolation/Exposure* assesses the extent to which a member of a particular racial/ethnic group is likely to have contact with members of the same group (isolation) or, conversely, the degree to which different groups would be exposed to each other by sharing common residential areas (exposure) (Massey et al., 1996). The point of this measure is to assess the diversity of neighborhoods and to capture some assessment of the daily experience of segregation felt by certain racial groups. *Concentration* measures the population density of a certain racial/ethnic group within a metro area (Massey and Denton, 1988). *Centralization* refers to a group's proximity to the center of a metropolitan area, which in some of the nation's older cities is characterized by extremely high levels of poverty, poor housing quality, and economic abandonment (Massey and Denton, 1988). *Clustering* assesses whether minority census tracts are contiguous and form a sort of "ethnic enclave" or are fairly spread out throughout a metro area (Massey and Denton, 1988). A table summarizing the formulae to derive these segregation measures appears in Appendix A. Census tracts and metropolitan statistical areas tend to be the primary macro and micro units of analysis to calculate these measures, but segregation measures can be derived using other units as well (e.g., zip codes or block groups to characterize the segregation of counties) (Iceland and Steinmetz, 2003).

Nearly all of the segregation measures focus on dyadic racial/ethnic comparisons: Black/White, Asian/White, Hispanic/White, and so on. Usually Non-Hispanic Whites serve as the reference group in these comparisons. Although these measures are informative, generalized measures can illustrate patterns of segregation in a context of diversity where multiple racial/ethnic groups are simultaneously segregated from one another (Iceland, 2004). The generalized dissimilarity index, which is a variation of the dyadic evenness measure described above, measures segregation among many racial/ethnic groups simultaneously and provides a method for examining segregation in a way that accounts for the rise of multiracial metropolitan areas (Grannis, 2002; Reardon and Firebaugh, 2002; Sakoda, 1981).

Racial composition, or the existence of census tracts with a high proportion of specific minority groups, has been interpreted as a measure of the magnitude of segregation in a metro area. For example, the percentage of Blacks in a census tract has been used to study the health effects of segregated neighborhoods (Acevedo-Garcia et al., 2003; Fang et al., 1998; Jackson et al., 2000; Yankauer, 1950). Using racial composition as a way to operationalize segregation, these studies assume that racial composition directly reflects a dimension of racial/ethnic unevenness in a particular metro area. However, racial composition may not always be a true reflection of segregation *per se.* This is because segregation is a contextual measure that depends on the relationship between racial groups in neighborhoods (e.g., census tracts) across a larger geographic area (e.g., a metro area). Thus, while percent minority measures reflect the composition of a particular neighborhood, it does not assess whether a metro area's spatial organization reflects larger dynamics of racial inequality. For example, if a particular neighborhood in City X were composed of over 75% Latinos, this may give the impression that Latinos are highly segregated in that particular city. However, if the entire population of City X is 80% Latino, then the racial composition of that neighborhood merely reflects the larger racial composition of the metro area.

Table 1: Metropolitan Segregation with Whites Dissimilarity Index* for 1980-2000

	1980	1990	2000
African Americans	73.8	68.8	65.0
American Indians	37.3	36.8	33.3
Asian & Pacific Islanders	41.2	42.0	42.1
Hispanic	50.7	50.6	51.5

Source: U.S. Census 2000
**See text for explanation of the dissimilarity index.*

Table 1 shows patterns of racial segregation in the United States between 1980 and 2000. The segregation measure is a dyadic dissimilarity index, which calculates the level of inequality in the distribution (or unevenness) of each racial/ethnic group compared to Whites. Given the history of discrimination in the U.S., it is not surprising that African Americans experience the highest levels of residential segregation, although these levels have declined slightly over the last twenty years. It should be noted that the major portion of this decline has occurred in smaller metropolitan areas with smaller populations of African Americans. For other racial/ethnic groups, there has been surprisingly little change in their levels of segregation over the last twenty years.

In sum, the choice of which segregation measure to use depends on what dimension is being investigated. In general, segregation measures tend to be correlated; metropolitan areas with high levels of segregation along one dimension tend to have high scores on the other dimensions as well. All of the measures have different conceptual implications for environmental health research and assessing disparities in pollution exposures and outcomes that may be environmentally mediated. Evenness is best adapted to study how segregation potentially modifies exposure-health outcome relationships. This measure can be used to compare environmental health indicators between metro areas and it is not affected by the relative proportion of the demographic groups being examined. The isolation or the exposure metrics reflect how members of minority groups actually experience residential segregation within metro areas and within their neighborhoods (Farley, 1984), through for example, access to supermarkets or the location of dismenities such as chemical plants or smelters that are fairly rare across the landscape.

The other three dimensions of residential segregation, (concentration, centralization, and clustering) are used less frequently, but tend to characterize the spatial patterns of segregation within metro areas. These measures may be particularly useful when examining environmental health questions involving a small number of metropolitan statistical areas (MSAs) that are similar in demographic make-up and overall size. These last three measures can help researchers better grasp how different spatial forms of segregation may disproportionately expose certain population groups to specific environmental stressors that ultimately degrade community health.

5. Analytical applications of segregation measures in environmental health

It remains unclear how socioeconomic inequality and segregation degrade the health of populations living in hazardous physical and social environments and ultimately lead to environmental health disparities. Place-based inequality measures, such as segregation, may modify and compound the adverse effects of hazardous environmental exposures, although this issue has not been thoroughly researched (Evans and Kranowitz, 2002). Few environmental health issues have been studied in the context of segregation, but air pollution has received some attention. These studies illustrate potential pathways between segregation and environmental health outcomes. They also provide a framework for discussing other environmental health problems that have yet to be fully studied in the context of segregation. Below are three examples of analytical applications where measures of segregation can be used to understand environmental health inequalities related to outdoor air pollution.

5.1. Criteria pollutants

Since the passage of the 1970 Clean Air Act and the establishment of National Ambient Air Quality Standards (NAAQS), the monitoring of criteria air pollutants (carbon monoxide, sulfur dioxide, oxides of nitrogen, particulates, lead, and ozone) has become ubiquitous in most metropolitan areas. Exceedances of the NAAQS can bring sanctions and public action to insure compliance. Monitoring is usually limited to a small set of strategically placed locations to assess the overall air quality across an entire metropolitan area. These data allow for studying the association between segregation and overall levels of criteria air pollutants, but not necessarily permitting the study of neighborhood level effects.

Table 2 shows the results of a regression analysis using metropolitan area-wide criteria air pollutants levels as dependent variables and segregation and other metro-level factors as independent variables. Criteria air pollutant levels for each available metropolitan area were obtained from the U.S. EPA's Aerometric Information and Retrieval System (AIRS) database, which contains annual metropolitan area-wide averaged levels of selected criteria air pollutants (EPA, 2004). Black-White Dissimilarity Index scores were calculated by the Mumford Institute using 2000 Census data (Mumford Center, 2000). Other potential metropolitan level explanatory variables, such as the percent of the total population living in poverty, total population, per capita income, percent of civilian labor force employed in manufacturing, and the percent of Black residents, were obtained from the U.S. Census. Controlling for these metro-level SES variables, Black-White segregation was associated with increased metropolitan-wide levels of sulfur dioxide and ozone. Segregation was also associated with increased levels of PM_{10}, but this association was not statistically significant. Segregation was associated with decreased levels of carbon monoxide and oxides of nitrogen.

Table 2: Criteria Air Pollution and Black-White Residential Segregation

Pollutant	Number of Metropolitan Areas	Coefficient	95% Confidence Interval
Carbon Monoxide	130	-0.019	(-.0021, -.036)*
Particulate Matter	201	0.006	(-.054, .066)
Oxides of Nitrogen	94	-0.00002101	(-.0000093, .000051)
Sulfur Dioxide	135	0.00004713	(.000014, .000080)**
Ozone	197	0.000233	(.000097, .00037)**

* Significant at the .05 level
** Significant at the .01 level

Multivariate regression comparing metropolitan area average pollutant level with Black-White dissimilarity index
Regression controlled for metropolitan level percent of people living in poverty, total population, per capita income, percent of civilian labor force employed in manufacturing

Table 3: Relationship between segregation and inequality of exposure to air toxics

	Total Unweighted	Cancer Weighted	Non-Cancer Weighted
Asian - White	0.0034	0.0011	0.0015
Segregation	(-.0018, .0086)	(-.0058, .0080)	(-.0032, .0062)
Hispanic - White	0.007	0.0059	0.0054
Segregation	(.0029, .0111)**	(.0017, .0192)**	(.0018, .0091)**
Black - White	0.007	0.0046	0.0052
Segregation	(.0048, .0091)**	(.0021, .0071)**	(.0033, .0092)**

** Significant at the .01 level

Multivariate regression comparing metropolitan area net difference score with dissimilarity index
Regression controlled for metropolitan level percent of people living in poverty, total population, per capita income, percent of civilian labor force employed in manufacturing and percent of subject group residents.

Source: Lopez 2002.

5.2. Air Toxics

Unlike criteria air pollutants, air toxics, also referred to as hazardous air pollutants (HAPs), have no set air quality standards and they are not routinely monitored. However, through its National Air Toxics Assessment (NATA) database, EPA has modeled annual ambient HAP concentrations for 1996 for each census tract in the continental U.S. based on emissions data and estimates of local land uses and population (US EPA, 2005). Lopez examined the relationship between total ambient air toxics levels and metropolitan segregation (Lopez, 2002). Three methodologies were used to assess cumulative exposures in this analysis: summation of all HAPs (total unweighted); summation of the estimated lifetime cancer risks for the metropolitan area average concentration of each HAP (cancer weighted); and the summation of the ratio of estimated metropolitan area average concentration of each HAP to its corresponding non-cancer reference concentration. The association between HAPs and Black-White segregation was assessed in a similar way to that used for the criteria air pollutants. Results showed that levels of Black-White segregation were associated with higher levels of total HAPs, cancer risks, and non-cancer risks after controlling for other potential metro-level explanatory variables (Lopez, 2002).

The study also applied a Net Difference Score methodology that describes the probability that a randomly selected Black person within a metro area lives in a census tract with higher levels of HAPs than a randomly selected White person, minus the probability that the Black person is living in a census tract with lower levels of HAPs than the White person. In almost every metropolitan area (out of 331 total) Blacks were more likely to be living in census tracts with higher concentrations of HAPs regardless of which cumulative summation methodology was used. In addition, the level of inequality was associated with increased segregation, even after controlling for other potential explanatory factors. Results were similar for Hispanics and Asians who were also more likely to be living in census tracts with higher pollutant burdens (Table 3) (Lopez, 2002).

A second analysis of the 1996 NATA data examined whether segregation patterns across over 300 MSAs modified racial disparities in cancer risk burdens associated with ambient air toxics concentrations (Morello-Frosch and Jesdale, 2006). In this study, the generalized index of dissimilarity was used to capture concurrent segregation across multiple racial/ethnic groups (Iceland, 2004; Sakoda, 1981). Other covariates in this analysis included: state grouping based on six regional categories of the continental United States in order to account for geographical variation in racial/ethnic segregation levels and its historical causes; population density; MSA population size; county-level voter turnout as a proxy for community civic engagement; local area deprivation, as measured by the Townsend index (Krieger et al., 2003), and poverty level.

A population risk index (PRI), which estimates a population-weighted average of census-tract-level cancer risks associated with modeled ambient air toxics exposures (Morello-Frosch et al., 2001), was used to assess environmental inequities across segregation, poverty, and racial/ethnic categories. Figure 2 shows the racial distribution of lifetime estimated cancer risk burdens associated with ambient HAP exposures across three levels of multi-racial segregation. The y-axis on the graph shows a population-weighted individual excess cancer risk estimate for each racial and segregation category. As indicated in the figure legend, each line in the graph represents one of the five racial/ethnic groups. The graph shows two patterns: first, it indicates that cancer risks across all metropolitan areas increase with increasing segregation levels for all racial/ethnic groups and that overall, Hispanics and Asians, followed by African Americans, have some of the highest estimated cancer risk burdens associated with ambient air toxics in metro areas with higher segregation, as compared to the average across all groups and compared to Whites and Native Americans. Figure 3 shows the racial breakdown of cancer risk burden across poverty levels. Although there is a persistent racial gap across all levels of poverty, there does not appear to be a gradient with rising area-level poverty, suggesting that the effect of segregation functions independently of poverty in terms of its association with exposure burdens across racial categories.

Poisson models were used to examine the relationship between segregation and estimated cancer risks by stratifying by race/ethnicity and calculating risk ratios for each level of segregation, using low segregation as the referent group. The model controlled for metro area regional grouping, metro area population size, tract-level poverty and material deprivation (Townsend Index), and tract-level population density. Results indicate that increasing segregation amplifies the cancer risks associated with ambient air toxics for all racial groups, although the effect appears to be strongest for Latinos and African Americans (Morello-Frosch and Jesdale, 2006).

Taken together, these three air pollution/segregation studies imply that metropolitan areas with higher segregation levels tend to have worse air quality compared to low segregation areas. In addition, increased segregation may also be associated with increased racial inequality in exposure and estimated health risk burdens. The health implications of criteria pollutants and air toxics have been well documented (Leifkauf, 2002; Neidell, 2004; Peel et al., 2005). Therefore, to the extent that these pollutants are associated with myriad adverse health effects, the overall increase in pollutant levels associated with segregation may be important for understanding factors that contribute to environmental health disparities.

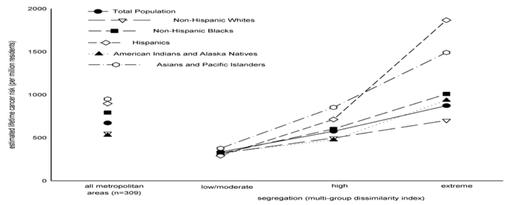

Fig. 2. Estimated cancer risk by race/ethnicity and racial/ethnic residential segregation, among residents of continental US metropolitan areas

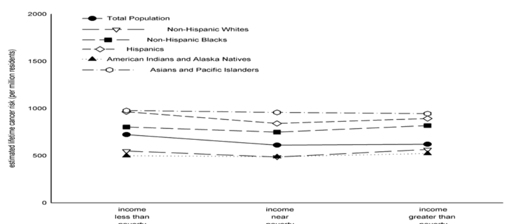

Fig. 3 Estimated cancer risk by race/ethnicity and poverty status, among residents of continental US metropolitan ares.

One way to better understand why segregation increases pollutant burdens and widens disparities in exposures would be to better link land use information with the location and density of major emissions sources. For example, research suggests that on average, mobile sources of ambient pollution account for a significant portion of health risks associated with certain pollutants (particularly air toxics) (Morello-Frosch and Jesdale, 2006; Morello-Frosch et al., 2001; Reynolds et al., 2002), and that exposure to these sources are inequitably distributed across race and class lines (Gunier et al., 2003). Similarly, the relationship between neighborhood racial make-up and the siting of hazardous facilities has been long researched (Institute of Medicine, 1999; Pastor et al., 2001; Sadd et al., 1999; U.S. GAO, 1983; United Church of Christ, 1987). In general, these studies have found that both race and income are important predictors of disparate siting, although some have found that income is more important than race and others found the opposite (Fullilove, 2004; Pastor et al., 2004; Perlin et al., 1995; Sterling et al., 1993; Szasz and Meuser, 1997). Assessing whether segregation is associated with the proliferation of certain emissions sources (such as major traffic corridors) would help broaden understanding of the links between place-based inequality, land use patterns, and pollution distributions among diverse communities living in major metropolitan areas.

6. Applying segregation measures to study other environmental hazards and health outcomes

The techniques used to examine relationships between segregation and inequities in ambient air pollution exposures can be applied to other environmental health issues to elucidate socioeconomic drivers of environmental health disparities. Moreover, although the focus of this paper is on residential segregation, links between segregation and environmental health disparities can also be examined in other contexts, such as the workplace (e.g., to examine occupational health disparities) and in schools (e.g., to examine disparities in children's environmental health).

6.1. Lead & residential pesticide use

Childhood lead exposure is an environmental hazard for which there have been persistent disparities by race and income. While the prohibition of lead in gasoline and paint has resulted in a decreased risk of lead poisoning for most Americans, there is a continued problem of elevated lead levels for children living in older, substandard housing (Haley and Talbot, 2004; Mielke and Anderson, 1983). Increased levels of lead have been associated with an increased risk of a range of cognitive and behavioral outcomes (Needleman, 2004; Needleman et al., 1979). Certainly, there is evidence that low income communities of color, particularly African Americans, are concentrated in areas with older housing. This older housing is disproportionately likely to be contaminated with lead and more likely to be in such a state of disrepair, which increases the risk of lead exposure to residents, particularly children. These trends point to segregation as a distal cause of lead-related cognitive health effects that may disproportionately impact children of color. Nevertheless, no studies have examined this issue in terms of residential segregation. Yet the persistent racial and class-based disparities in childhood lead poisoning suggest that residential segregation may be concentrating communities of color, particularly African Americans, into poor inner-city neighborhoods with housing that has lead paint and lead contaminated soils (Breysse et al., 2004; Roberts et al., 2003). There are large disparities in elevated blood levels between Whites and Blacks, with Blacks being 13.5 times as likely to have blood lead levels above 20 μg/dL as Whites (Bernard and McGreehin, 2003). The role of segregation in causing these disparities, through increased likelihood of exposure to lead contaminated environments, could be investigated further as a way to understand some of the underlying social drivers that make the racial disparities in childhood lead poisoning persist.

Similarly, residential pesticide use is widespread in the United States, with approximately 80-90% of American households using pesticides (Landrigan et al., 1999; Whitmore et al., 1994). Recent studies indicate that residential exposures to pesticides are associated with adverse birth outcomes (Eskenazi et al., 1999; Perera et al., 2003; Whyatt et al., 2002). Although little is known about residential pesticide use among minority populations in the United States, surveys suggest that frequency of use is more intense in public housing and in areas of high population density in housing (Surgan et al., 2002). Applying segregation measures to understand patterns of racial and class-based disparities in exposures to urban pesticides could also elucidate how consumer pesticides used to control pests in substandard housing or public housing projects may disproportionately affect certain minority groups.

7. Segregation in relation to health outcomes that may be environmentally mediated

There are profound racial differences in residential patterns and in environmental exposure burdens. Together, these may imply that segregation and the resulting inequality in the toxicity of residential environments may be contributing to racial differences in morbidity and mortality. The following suggest some of the potential associations and causal pathways between segregation and health outcomes that are environmentally mediated or that may enhance community vulnerability to the toxic impacts of contaminant exposures.

7.1 Adult Mortality

There is a growing body of evidence linking racial segregation to increased mortality risk among both Blacks and Whites, though the risk tends to be greater for Blacks (Collins and Williams, 1999; Cooper et al., 2001a,b; Polednak, 1996, 1997, 1991; Williams and Collins, 2001). Overall metropolitan levels of segregation were associated with increased total mortality and increased avoidable mortality (LaVeist, 2003). Controlling for individual risk factors, neighborhoods with high concentrations of Blacks have also been found to have higher levels of mortality (Schultz et al., 2002). The potential causes of these relationships are not well known, but most likely mean increased exposure to social, economic and environmental risk factors (Bosma et al., 2001; Deaton and Lubotsky, 2001; Howard et al., 2000; McLaughlin and Stokes, 2002). In addition, the quality of health care and other services available to Blacks is lower (Leiyu and Starfield, 2001; Sheifer et al., 2000). In the context of segregation, these risk factors have the potential to act synergistically to raise allostatic levels of stress and simultaneously increase sensitivity to exposures, reduce the ability to access treatment and assistance, and reduce the ability to recover from environmentally mediated illnesses (Massey, 2004; Wallace and Wallace, 1998; Wallace, 1988). As a result, over time, mortality may increase (Fiscella and Franks, 1997; Kennedy et al., 1999). Further research on the health effects of segregation and adult mortality might include a better exploration of the health effects of individual pollutants, the study of how pollutants work synergistically with place-based measures of social inequality to increase adverse health outcomes, and modeling the impacts of exposures to pollutants in individuals with overstressed immune systems or who may be disproportionately vulnerable to the effects of pollution exposure due to place-based and individual-level factors.

7.2 Infant mortality and other birth outcomes

Since the first studies exploring the relationship between residential segregation and birth outcomes in the United States were published in the 1950s, the literature has been rather limited in scope and volume. It has focused almost exclusively on Black-White disparities in infant mortality rates, and has used a single dimension of segregation at a time, usually a measure of unevenness such as the index of dissimilarity. The research that does exist, however, has addressed the link between segregation and infant mortality from a few angles and at different levels of aggregation, from intra-city explorations of infant mortality rates by neighborhood (Yankauer, 1950, 1990; Yankauer and Allaway, 1958) to inter-city examinations of the variation in Black-White infant mortality ratios (Jiobu, 1972; LaVeist, 1993). The literature over the past 50 years has established clear links between residential segregation, infant mortality, and Black-White infant mortality disparities. It is evident that racial inequalities in social environments engendered by racial segregation have put Black populations at a serious disadvantage relative to White populations, and have had a resounding impact on infant mortality rates among Blacks in the United States (Guest et al., 1998; LaVeist, 1989, 1993; Yankauer, 1990). These effects have consistently been shown to be at least partially independent of potential confounders, such as poverty levels (Bird, 1995). There are, however, a few serious gaps in the literature to date. First, the literature focuses solely on infant mortality, and has not assessed links between segregation and other birth outcomes, such as birth weight or preterm birth. Second, the literature only examines differences between Black and White infant mortality rates, and defines residential segregation as a Black-White phenomenon. Finally, no research has specifically examined the extent to which differential air pollution exposure may mediate and partially explain the relationships between broad social inequalities, neighborhood environments, and persistent racial disparities in birth outcomes.

Analyzing links between segregation, differential exposure to pollution, and birth outcomes among various racial and ethnic groups in the United States would be an important contribution to the literature. More specifically, differences in exposure to air pollutants due to residential segregation may be viewed as the physical manifestations of poor neighborhood environments that lead to poor birth outcomes. Preliminary research indicates that disadvantaged populations often experience a disproportionate amount of air pollution exposure (Woodruff et al., 2003). Other studies have linked air pollution exposure to negative birth outcomes (Dejmek et al., 1999; Dolk et al., 2000; Ritz and Yu, 1999; Ritz et al., 2000, 2002)and found racial disparities in exposure burdens and in relationship to birth outcomes (Ritz and Yu, 1999; Ritz et al., 2000; Ritz et al., 2002; Woodruff et al., 2003). With one notable exception (Ponce et al., 2005), none of these studies have specifically examined place-based SES measures or segregation in conjunction with individual-level variables that may be associated with poor birth outcomes. Moreover, these studies have not assessed whether residential segregation amplifies observed associations between adverse birth outcomes and pollution exposures and how these dynamics play out across racial and ethnic groups. Examining this question, particularly in relation to birth outcomes that may be partially mediated by environmental factors might help elucidate how segregation contributes to environmental health disparities.

7.3 Asthma

Several factors related to the etiology of asthma may be associated with or exacerbated by segregation. Asthma rates are higher among Blacks than Whites (CDC, 2004; Grant et al., 2000), and the disease has been identified as the primary preventable cause of hospitalizations (Flores et al., 2003; Masoli et al., 2004; Pendergraft et al., 2004). The disparate risk of asthma is heightened by the dearth of access to health care in many Black majority communities. In addition to being less likely to have health insurance, hospitals in Black majority neighborhoods have been more likely to shut down than in other neighborhoods (Sager, 1983).

Asthma is often triggered by roaches, dust mites, and mold, all of which are linked to housing quality (Platts-Mills et al., 1995). Segregation, by limiting the housing options of communities of color and the poor, may lead to increased exposure to these triggers. Ozone, carbon monoxide, PM_{10}, and other pollutants have been implicated as asthma exacerbaters (Leifkauf, 2002; Loh and Sugarman-Brozan, 2002; Peden, 2002), and one study linked ozone exposure with the development of asthma among young children who play outdoor sports

(McConnell et al., 2002). If segregation is linked to increased levels of these pollutants, this may represent another pathway to ill health. The interplay of diverse factors leading to poor asthma outcomes might be better understood in the context of segregation including: attending schools in segregated districts with disparities in the quality of school facilities, living in poor quality housing, exposure to indoor and outdoor air pollution, and the distribution of preventive care and emergency care facilities.

8. Conclusions and implications for research and policy

Advocates working on environmental justice issues have urged scientists, policymakers, and the regulatory community to consider the junctures of socio-economic inequality, environmental protection, and public health. Certain disparities in exposures to environmental hazards may be related to or mediated by the degree of racial residential segregation, and these exposures may have important clinical and environmental health significance for populations across racial and class lines. Additional research, incorporating new models of exposure, should include segregation as a health risk factor. Moreover, while most research has focused on the health consequences of Black-White segregation in metropolitan areas, other minority groups may be similarly affected. Finally, the health impacts of rural segregation, particularly the experiences of Native Americans which were not addressed in this paper, should also be examined.

Although the literature on segregation and health has expanded significantly in recent years, studies that specifically address environmental health disparities are in their infancy. In general, most of this work has been limited to cross-sectional studies. Future research will require the development of longitudinal studies that look simultaneously at people and places—

that is, the trajectories of individuals in conjunction with the trajectories and evolution of the neighborhoods and metro areas where they live. These studies could also examine residential segregation in conjunction with segregation in other domains such as the educational system and the workplace.

A regional equity perspective is critical to understanding the interplay of individual factors and place-based measures of social inequality in shaping patterns of environmental health disparities (Morello-Frosch, 2002). Racial segregation and other SES disparities manifest themselves in major metropolitan areas along divides between the city core and the suburbs and across diverse neighborhoods (Gee and Payne-Sturges, 2004; Subramanian et al., 2005). Moreover, segmentation of housing markets, spatial mismatch of labor markets, and decentralization of metropolitan governance contributes to unequal access to economic opportunities, services, and the fragmentation of local control over land use and zoning in ways that affect community environmental health (Alshutler et al., 1999; Conley, 1999; Kain, 1992; Keister, 2000; Oliver and Shapiro, 1995; Preston and McLafferty, 1999). As discussed earlier, there is mounting evidence that various aspects of social inequality have contributed to the greater burden of environmental hazard exposure and health risks for communities of color and the poor. Social inequality, such as residential segregation, may affect the options that communities have to address environmental and health problems. For example, poverty may affect the likelihood of having health insurance, and linguistic isolation may hinder effective engagement with public officials. Therefore, it is necessary to incorporate these broad but significant indicators of place-based inequality and SES with individual-level factors into a comprehensive assessment of environmental health disparities. Ultimately, this enables policy makers and regulators to understand not only whether a community may be overburdened, but also whether it has the capacity and resources to recover, reduce exposures, and protect public health.

How the regulatory community should address fundamental socioeconomic drivers of environmental health remains an open question. The capacity of environmental and public health agencies to proactively engage with these issues is constrained by legislative mandates that structure the priorities of their research, regulatory, and enforcement activities. Agencies that conduct research can begin to grapple with how to integrate place-based inequality measures and neighborhood-level SES measures with the individual-level factors that have traditionally commanded regulatory attention. Furthermore, research can begin to track the effects of segregation more systematically to determine the independent effects of segregation on environmental health, and how this form of place-based social inequality contributes to environmental health disparities. Indeed, segregation may disparately affect certain racial/ethnic groups more than others. It is also possible that segregation adversely affects the health of all racial and ethnic groups, even in areas where disparities might persist. For example, one study suggests that segregation affects physical inactivity risk, even for Whites (Lopez, in press). By developing indicators of social inequality and segregation and integrating these with environmental health data, regulatory agencies can generate the information necessary to inform regional authorities and community stakeholders about how to address some of the possible drivers of environmental health disparities and whether these relate to the built environment, transportation policies, fair housing, or land use planning. Although environmental and public health agencies may not be able to participate directly in these debates, they can generate the data and scientific information necessary to inform the discussion.

For example, suppose the body of evidence shows that segregation amplifies observed relationships between poor air quality and certain adverse health outcomes, and that segregation has worse health consequences for members of racial minority groups. Regulatory strategies such as air quality monitoring could be enhanced in segregated neighborhoods where poor air quality is a particular concern. Similarly, this information could help communities and local agencies understand how to target their efforts to reduce emissions from major sources. These targeted monitoring and emission source reduction strategies would have to be done in partnership with communities who would play a critical role in helping to identify smaller emissions sources that typically fall below the regulatory radar screen but that may be located near sensitive receptors (e.g., residential communities or schools). Communities can also help agencies balance the need for more effective regulation with the promotion of economic opportunities within a region. Previous agency-community collaborations of this sort include monitoring and source reduction efforts conducted by the California Air Resources Board and the communities of Barrio Logan in San Diego, and Wilmington in the Los Angeles area (Cal-EPA, 2003, 2004).

Rising interest within the regulatory community and the public about environmental health inequalities necessitates developing new analytical approaches that leverage existing data to sort through complex equity issues. Examining these issues through the lens of segregation can reveal connections between individual and place-based factors that shape health disparities, elucidate innovative methodologies to evaluate environmental justice concerns, and assess the viability of regional approaches to address racial equity in pollution control and prevention.
NOTE: No human subjects or experimental animals were used in this study.

Appendix A: Summary Table of Measures for Five Segregation Dimensions

Measure	Dimension	Formula	Composition Invariant[1]	Multi-group Extension[2]	Spatial[3]
Index of dissimilarity	Evenness	$D = \Sigma[t_i \lvert p_{im}-P_m \rvert] / (2T P_m (1-P_m))$	yes	yes	no
Interaction index	Exposure	${}_mP_n^* = \Sigma[(t_i p_{im}/TP_m)(p_{in})]$	no	no	no
Duncan's delta index	Concentration	$DEL = \Sigma [\lvert(t_i p_{im}/TP_m) - (a_i/A)\rvert] / 2$	no	no	no
Absolute centralization index	Centralization	$ACE = \Sigma[X_{i-1p}A_i] - \Sigma[X_{ip}A_{i-1}]$ tracts sorted by land area $X_{ip} = \Sigma[t_i p_{im}]$, tracts from *0* to *i* $A_{ip} = \Sigma[a_i]$, tracts from *0* to *i*	no	no	yes
Spatial proximity index	Clustering	$SP = (TP_m P_{mm} + TP_n P_{nn})/NP_{tt}$ $P_{mn} = \Sigma \Sigma [(t_i p_{im} t_j p_{jn} c_{ij})/TP_m TP_n]$ $c_{ij} = e^{-dij}$ d_{ij} = distance between tract *i* and tract *j*.	no	no	yes

T = number of metro area residents
t_i = number of residents in tract *i*.
P_m = proportion of metro area residents of racial/ethnic group *m*.
p_{im} = proportion of tract *i*'s residents of racial/ethnic group *m*.
A = land area of metro area
a_i = land area of tract *i*.

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Separate and Unequal: Residential Segregation and Estimated Cancer Risks Associated with Ambient Air Toxics in U.S. Metropolitan Areas

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This study examines links between racial residential segregation and estimated ambient air toxics exposures and their associated cancer risks using modeled concentration estimates from the U.S. Environmental Protection Agency's National Air Toxics Assessment. We combined pollutant concentration estimates with potencies to calculate cancer risks by census tract for 309 metropolitan areas in the United States. This information was combined with socioeconomic status (SES) measures from the 1990 Census. Estimated cancer risks associated with ambient air toxics were highest in tracts located in metropolitan areas that were highly segregated. Disparities between racial/ethnic groups were also wider in more segregated metropolitan areas. Multivariate modeling showed that, after controlling for tract-level SES measures, increasing segregation amplified the cancer risks associated with ambient air toxics for all racial groups combined [highly segregated areas: relative cancer risk (RCR) = 1.04; 95% confidence interval (CI), 1.01–107; extremely segregated areas: RCR = 1.32; 95% CI, 1.28–1.36]. This segregation effect was strongest for Hispanics (highly segregated areas: RCR = 1.09; 95% CI, 1.01–1.17; extremely segregated areas: RCR = 1.74; 95% CI, 1.61–1.88) and weaker among whites (highly segregated areas: RCR = 1.04; 95% CI, 1.01–1.08; extremely segregated areas: RCR = 1.28; 95% CI, 1.24–1.33), African Americans (highly segregated areas: RCR = 1.09; 95% CI, 0.98–1.21; extremely segregated areas: RCR = 1.38; 95% CI, 1.24–1.53), and Asians (highly segregated areas: RCR = 1.10; 95% CI, 0.97–1.24; extremely segregated areas: RCR = 1.32; 95% CI, 1.16–1.51). Results suggest that disparities associated with ambient air toxics are affected by segregation and that these exposures may have health significance for populations across racial lines. *Key words:* air toxics, cancer risk, environmental justice, health disparity, racial disparity, segregation. *Environ Health Perspect* 114:386–393 (2006). doi:10.1289/ehp.8500 available via *http://dx.doi.org/* [Online 19 October 2005]

Nearly 80% of the approximately 280 million people living in the United States reside in metropolitan areas (U.S. Bureau of the Census 2004). Environmental health researchers and public health practitioners have recently begun to focus on the links between the urban built environment, social inequality, and community health and well-being (Frumkin 2002, 2003; Jackson 2002; Northridge et al. 2003). Despite the proliferation of research on this issue, there is a lack of scientific consensus about what it is about neighborhood and other area-level variables that affect health. Neighborhood-level factors affect individual health by influencing access to quality foods, especially fresh fruits and vegetables and affordable supermarkets, and access to crucial services, such as health care, parks, and open space (Diez-Roux 2003; Morland et al. 2002; Transportation and Land Use Coalition 2002). Other key neighborhood factors that affect health include the social environment (social capital, cohesion, and crime rates) (Kawachi and Berkman 2003; Wallace and Wallace 1998; Wallace 1988) and the physical environment (traffic density, housing quality, and abandoned properties) (Reynolds et al. 2002; Shenassa et al. 2004; Wallace 1990).

Environmental health researchers, sociologists, policy makers, and advocates concerned about environmental justice have argued that residents of color who are concentrated in neighborhoods with high levels of poverty are also disproportionately exposed to physical environments that adversely affect their health and well-being. Research on race and class differences in exposures to toxics varies widely, and although by no means unequivocal, much of the evidence suggests a pattern of disproportionate exposures to toxics and associated health risks among communities of color and the poor, with racial differences often persisting across economic strata (Burke 1993; Morello-Frosch et al. 2001, 2002a, 2002b; Pastor et al. 2001; Perlin et al. 2001; Sadd et al. 1999). Such evidence has important implications for policy making, but few studies elucidate links between social inequality and residential segregation with exposures to environmental hazards (Morello-Frosch 2002; Morello-Frosch et al. 2001).

Wide-ranging and complex political and socioeconomic forces, coupled with patterns of industrialization and development, have segregated people of color, particularly African Americans, into neighborhoods with some of the highest indices of urban poverty and deprivation (Peet 1984; Schultz et al. 2002; Walker 1985; Williams and Collins 2001, 2004). Indeed, uneven industrial development, real estate speculation, discrimination in government and private financing, workplace discrimination, and exclusionary zoning have led to systemic racial segregation among diverse communities with important implications for community health and individual well-being (Logan 1978; Logan and Molotch 1987; Morello-Frosch 2002; Sinton 1997; Wilson 1996). Studies connecting residential segregation to health outcomes and health disparities represent a relatively new direction of research. Much of this work has focused on the health impacts of residential segregation on African Americans (LaVeist 1989, 1992, 1993; Polednak 1991, 1993, 1996a, 1996b, 1997). Results of this research generally show that residential segregation is associated with elevated risks of adult and infant mortality (Collins and Williams 1999; LaVeist 1989, 1992, 1993; Polednak 1991, 1993, 1996a, 1996b, 1997; Williams and Collins 2001) and tuberculosis (Acevedo-Garcia 2001).

Although elements for understanding the relationship between residential segregation and community environmental health can be found separately in the literature of both sociology and environmental justice, only one previous investigation has attempted to combine these two lines of inquiry to analyze the relationship between outdoor air pollution exposure and segregation (Lopez 2002). Some researchers have recently argued that residential segregation is a crucial place to start for understanding the origins and persistence of environmental health disparities (Gee and Payne-Sturges 2004; Lopez 2002; Morello-Frosch 2002; Morello-Frosch et al. 2001; Pulido 1994, 2000; Pulido et al. 1996). Gee and Payne-Sturges (2004) propose a conceptual framework for understanding how race-based segregation may lead to a disproportionate burden of cumulative exposures to potential environmental hazards among certain communities while enhancing their vulnerability or susceptibility to the toxic effects of

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exposures due to individual and area-level stressors, and lack of neighborhood resources. In this study we seek to operationalize parts of this conceptual framework by examining links between racial residential segregation and estimated cancer risks associated with modeled ambient air toxics exposures. Recent analysis of modeled national estimates suggests that ambient concentrations of hazardous air pollutants (HAPs) exceed benchmark risk levels for cancer and noncancer end points in many areas of the country (Apelberg et al. 2005; Morello-Frosch et al. 2000; Woodruff et al. 1998). Follow-up studies on air quality as well as stationary and mobile sources of air pollution have found a disproportionate burden of exposures and associated cancer and noncancer health risks for communities of color and poor residents. These studies have examined transportation corridors with high traffic density (Gunier et al. 2003), location of Toxics Release Inventory (TRI) and other treatment, storage, and disposal facilities (Morello-Frosch et al. 2002a; Pastor et al. 2001, 2002; Perlin et al. 1999, 2001), and modeled estimates of air toxics from the U.S. Environmental Protection Agency (EPA) Cumulative Exposure Project (CEP) and National Air Toxics Assessment (NATA) (Lopez 2002; Morello-Frosch et al. 2002a, 2002b; Pastor et al. 2002, 2004). For this study, we assessed whether racial and economic disparities in estimated cancer risk associated with air toxics are modified by levels of residential segregation in U.S. metropolitan areas.

Materials and Methods

To analyze the relationship between pollution and health risk burdens with race-based residential segregation, we obtained modeled ambient air toxics concentration estimates from the U.S. EPA's NATA and combined these data with cancer potency information. We then integrated these cancer risk estimates with socioeconomic and demographic information derived from the 1990 U.S. Census (U.S. Census Bureau 1991, 1993) for all tracts within 309 metropolitan areas in the continental United States. All data linking, data management, and statistical analysis were performed using SAS (version 8.2; SAS Institute Inc., Cary, NC).

Modeled estimates of outdoor air toxics concentrations. The U.S. EPA's most recent publicly accessible national-scale air toxics assessment was conducted for 1996 and estimates the annual average concentration for a subset of the 188 HAPs listed in section 112 of the 1990 Clean Air Act Amendments (33 pollutants, including diesel particulate matter). The methods used to generate census-tract–level estimates of risk are described in detail by the U.S. EPA and others (Rosenbaum et al. 1999; U.S. EPA 2005a). Using an algorithm based on the Assessment System for Population Exposure Nationwide (ASPEN) model, NATA generates concentration estimates using a Gaussian dispersion modeling approach that accounts for meteorologic conditions, wind speed, and atmospheric chemistry, including processes such as reactive decay, secondary pollutant formation, and deposition. NATA then applies the model algorithm to the U.S. EPA's National Toxics Inventory, which is compiled using five primary information sources: state and local toxic air pollutant inventories, existing databases related to the U.S. EPA's air toxics regulatory program, the U.S. EPA's TRI database, estimates using mobile source methodology (developed by the U.S. EPA's Office of Transportation and Air Quality), and emission estimates generated from emission factors and activity data (U.S. EPA 2005a).

The model then allocates air toxics concentration estimates in statewide grids that can be used to create data surfaces and for interpolation and allocation to census tracts (U.S. EPA 2005a). The model estimates long-term HAP concentrations attributable to anthropogenic sources within 50 km of each census tract centroid. Each pollutant concentration is a spatial average that approximates the population-weighted average of outdoor HAP concentrations experienced within a census tract over the course of a year. There are > 60,000 census tracts in the continental United States, with each averaging between 4,000 and 5,000 residents. Specifics of the model are discussed elsewhere (Rosenbaum et al. 1999; U.S. EPA 2005a). We assessed air toxics concentrations for stationary emissions sources, which include point-source emissions (from facilities required to report emissions to the TRI, including large chemical manufacturers, refineries, and electrical power plants) and smaller area sources (including dry cleaners, auto body shops, and chrome plating facilities); and for mobile emissions sources, which include on-road vehicles (e.g., trucks and cars) and nonroad sources (e.g., airplanes, trains, construction equipment, and farm equipment) (U.S. EPA 2005a). Estimated outdoor concentrations also included a background portion attributable to long-range transport, resuspension of historical emissions, and natural sources derived from measurements taken at clean air locations remote from known emissions sources. These values were treated as a constant across all census tracts and added to the modeled concentration estimates from mobile and stationary emissions sources.

Assessment of cancer risks. We combined modeled HAP concentration estimates with cancer potency information to estimate the distribution of cumulative cancer health risks in accordance with California's "hot spots" guidelines [Office of Environmental Health Hazard Assessment (OEHHA) 2003]. The guidelines provide procedures for use in the preparation of cancer and noncancer health risk assessments required under California's Air Toxics "Hot Spots" Information and Assessment Act (1987). This law established a statewide program for the inventory of air toxics emissions from individual facilities as well as requirements for risk assessment and public notification of potential health risk (OEHHA 2003).

We assessed cancer risks using inhalation unit risk (IUR) estimates in micrograms per cubic meter for each carcinogenic compound. Inhalation unit risk estimates are defined as the individual lifetime excess risk due to a chronic lifetime exposure to one unit of pollutant concentration (U.S. EPA 2003). Potency estimates generally assume nonthreshold, low-dose linearity unless there is compelling evidence to the contrary, and are derived from occupational or animal studies. The unit risk calculated from occupational studies is based on a maximum-likelihood estimate of the dose–response data. Potencies derived from animal data represent a 95% upper bound estimate of the probability of contracting cancer.

The U.S. EPA, the California Environmental Protection Agency (Cal-EPA), and the International Agency for Research on Cancer (IARC) identify carcinogens based on the scientific weight of evidence for carcinogenicity, which is derived from human and animal data. The weight-of-evidence descriptors for carcinogenicity used by various agencies vary somewhat, and the U.S. EPA is in the process of revising their cancer risk assessment guidelines (U.S. EPA 2003), but the categories used are similar. Currently, the U.S. EPA is proposing to classify potential carcinogens based on the following weight-of-evidence categories: *a*) carcinogenic to humans, *b*) likely to be carcinogenic to humans, *c*) suggestive evidence of carcinogenic potential, *d*) inadequate information to assess carcinogenic potential, *e*) not likely to be carcinogenic to humans. Air toxics classified in any of the first three descriptor categories were evaluated in this analysis (U.S. EPA 2003). We also used the California OEHHA (2002) IUR estimate for diesel particulates to calculate an estimated lifetime cancer risk for diesel particulates. Although the U.S. EPA does not have an IUR for diesel, Cal-EPA has derived a potency estimate for this mixture of compounds and has classified it as a carcinogen under Proposition 65 (OEHHA 2005). Similarly, IARC has classified diesel particulates as a probable carcinogen (IARC 2005).

Estimated cancer risks for each pollutant in each census tract were derived with the following formula:

$$R_{ij} = C_{ij} \times \text{IUR}_j, \quad [1]$$

where R_{ij} is the estimate of individual lifetime cancer risk from pollutant j in census tract i, C_{ij} is the concentration of HAP j in micrograms per cubic meter in census tract i, and IUR is the IUR estimate for pollutant j in micrograms per cubic meter. The cancer risks of different air toxics were assumed to be additive and were summed together in each census tract to estimate a total individual lifetime cancer risk in each tract. To roughly estimate the number of cancer cases from lifetime exposures, we multiplied the total cancer risk in each census tract by the total tract population.

1990 census data. The tract-level health risk data were matched with area level socioeconomic and demographic information from the 1990 Census (summary tapes file 1 and 3; U.S. Census Bureau 1991, 1993). These data were used to derive the following variables used in our analysis.

Segregation. Massey and Denton have identified several conceptual dimensions of segregation, all of which were conceived with a particular context in mind: that of urban segregation of blacks from whites in the United States (Massey and Denton 1988, 1989; Massey et al. 1996; U.S. Bureau of the Census 2004). These concepts and measures have been expanded to consider the segregation of Hispanic-American and Asian-American populations from whites (Massey 2004; Massey and Fong 1990). To maximize congruence with the theory and development of the segregation indices, we have also constrained our analysis to metropolitan areas of the United States.

Of the various conceptual dimensions of segregation, evenness as measured by the dissimilarity index has most often been employed in health studies (Acevedo-Garcia et al. 2003; Collins and Williams 1999). Chiefly for this reason, we limited our measure of segregation to (un)evenness. Evenness measures the degree to which the proportion of a particular racial or ethnic group living in residential areas (e.g., census tracts) approximates that group's relative percentage of an entire metropolitan area. It is measured using the dissimilarity index (D), which is interpreted as the proportion of the racial group of interest that would need to relocate to another census tract to achieve an even distribution throughout a metropolitan area. Although most health studies involving measurement of segregation are limited to dyadic comparisons, such as black/white segregation, we elected to incorporate the multigroup dissimilarity index (Dm), a version of the dissimilarity index generalized to capture concurrent segregation between multiple racial/ethnic groups (Iceland 2004; Sakoda 1981). The Dm has been developed to characterize segregation in the more typically multiethnic contemporary metropolis. We estimated multigroup segregation using the following formula:

$$\text{Dm} = \Sigma(t_i \Sigma|p_{im} - P_m|)/[2T\Sigma P_m(1-P_m)], \quad [2]$$

where t_i is the number of residents in tract i, p_{im} is the proportion of people in subgroup m in census tract i, T is the total number of residents in the metropolitan area, and P_m is the proportion of people in subgroup m in the metropolitan area. The denominator sums the maximum segregation possible given the relative proportion of each racial/ethnic group in the metropolitan area. In sum, the numerator of the Dm is the minimum number of people who would need to move from one neighborhood to another so that the distribution of each racial/ethnic group in every neighborhood matches that of the metropolis as a whole. The denominator is the minimum number of people who would need to move to achieve this goal, starting from a context of complete segregation. Thus, the index varies from a value of 0, meaning no segregation exists (i.e., all neighborhoods have exactly the same distribution of people by race/ethnicity), to 1, complete segregation (i.e., each neighborhood is populated by only one racial/ethnic group). Intermediate values indicate a continuous range of racial/ethnic stratification of neighborhoods within a metropolis. One final note is that Dm is not composition dependent; consequently, this measure can be used to compare a diverse array of metropolitan areas, and it is not affected by the relative proportion of the demographic groups being examined.

Because air toxics concentration estimates were available only for the continental United States, we restricted our investigation to metropolitan areas within the same geographic reach. These metropolitan areas, as defined by the Office of Management and Budget based on data from the 1990 U.S. Census, are aggregations of counties that may (and often do) cross state boundaries. They are intended to describe an area dominated by a central city (with a population of at least 50,000) and surrounded by communities linked by housing and employment patterns (U.S. Bureau of the Census 1994). Because the HAP concentration data are available at the census tract level (1990 tract definitions), we used 1990 census tracts as a proxy for "neighborhood." These areas are defined in advance of the decennial censuses and are nonoverlapping, mutually exclusive divisions of territory. Census tracts are nested within county boundaries and are intended to describe areas that are roughly comparable in population size (most tracts contain between 1,000 and 8,000 residents) and roughly consistent internally with respect to socioeconomic conditions. Some limitations of using census tracts as an approximation for neighborhoods have been described (Krieger et al. 2003). In addition, census tracts are the only construct approximating neighborhoods defined with a consistent methodology across all metropolitan areas of the United States.

We based our calculations on numbers of people in six exhaustive and nonoverlapping racial/ethnic groups as defined in the 1990 U.S. Census (U.S. Census Bureau 1991, 1993): Hispanics of any race, non-Hispanic whites, non-Hispanic blacks, Asians and Pacific Islanders, American Indians and Alaska Natives, and persons of "other" races. We recalculated these indices excluding persons of "other" races. Finding no substantive differences from our earlier calculations, we elected to retain this group in order to capture 100% of the population in each metropolitan area. We stratified the metropolitan areas into three segregation groups for further analysis: low to moderately segregated (Dm = 0.16–0.39), highly segregated (Dm = 0.40–0.60), and extremely segregated (Dm ≥ 0.60).

Regional grouping of states. Because previous research has documented regional variation in both the level of racial/ethnic segregation and its causes (Frey and Farley 1996), we developed six broad regional classifications of the continental United States to control for these differences (Figure 1): western states, the three states bordering the Pacific Ocean; border states, the three states sharing a border with Mexico (other than California); southern states, those that ceded to form the Confederate States of America during the Civil War (other than Texas); northeastern states, those north of the Mason-Dixon line and predominantly east of the Appalachian mountains (Pennsylvania, Maryland, the District of Columbia, and points northeast); midwestern states, from the western slopes of the Appalachians to the Mississippi River Valley (Ohio, West Virginia, and Kentucky west to Missouri, Iowa, and Minnesota); and mountains and plains states, those dominated by the central plains and Rocky Mountains (other than the border states).

Population density. We estimated population density by dividing the number of residents in an area by the square kilometers of that area, as reported in the 1990 Census (U.S. Census Bureau 1991, 1993). Population density is often underestimated by this method because of the inclusion of large areas of uninhabited (and often uninhabitable) land area. To more accurately reflect the density of human habitation in each census tract, we disaggregated each tract into its constituent block groups (one to nine block groups per tract), estimated the population density for each block group, and then created a population-weighted sum of these population densities to estimate the average population density at which tract residents live.

Population size. Researchers have noted that residential segregation of whites from blacks tends to be higher in metropolitan areas that are older and have larger populations and less recent growth in housing stock (Farley 1977). The influence of a city's age on the level of black/white segregation is not independent of population size. Of these three measures, the population size of a metropolitan area has the clearest link to the volume and concentration of air pollution, even though this link is probably not independent of the local area population density described above. We categorized metropolitan areas into seven categories of population size defined by the Census Bureau, ranging from at least 50,000 to > 5 million (U.S. Census Bureau 1991, 1993).

Poverty and material deprivation. To some degree, area level poverty may explain observed relationships between racial/ethnic segregation and estimated cancer risks associated with ambient air toxics exposures. Therefore, we examined poverty status as determined by 1990 U.S. Census household income and composition, in three categories: below the poverty level, above the poverty level but less than twice the poverty level, and at least twice the poverty level. The poverty level (which varies by household size and age composition) equaled $12,647 in 1989 for a family of two adults and two children (U.S. Bureau of the Census 2004). In addition to area-level poverty, we developed a census-tract measure of material deprivation by calculating a version of the Townsend index (Krieger et al. 2003; Townsend et al. 1988) adapted for U.S. census data by summing four Z-scores for the proportion of home owners, the proportion of car owners, the proportion of residents living in crowded conditions (at least one person per room), and the proportion of unemployed persons among workers.

Civic engagement. Metropolitan areas characterized by racial/ethnic segregation may result in relative disenfranchisement of racial/ethnic minority groups. In a highly segregated metropolitan context, political influence and decision-making power are likely to be stratified across racial/ethnic lines and concentrated to serve the interests of racial majority communities (LaVeist 1992, 1993). This alignment of power could have implications for land-use decision making, transportation planning, and regulatory activities at a regional level in ways that affect ambient air quality in different neighborhoods (LaVeist 1992, 1993; Morello-Frosch 2002; Morello-Frosch et al. 2001; Pastor et al. 2001). We used a measure of voter turnout as a proxy for civic engagement, based on the number of votes cast in the 1996 presidential election (U.S. Bureau of the Census 1998) divided by the adult population in 1990. The finest geographic resolution for this data available across all metropolitan areas was at the county level.

Statistical methods. We calculated a descriptive statistic, population risk index (PRI), to assess potential environmental inequities across race/ethnicity, poverty level, and segregation categories. The PRI is a weighted average of the census-tract–level total cancer risk associated with ambient air toxics (Morello-Frosch et al. 2001; Perlin et al. 1995). The risk index is computed according to the following formula:

$$\mathrm{PRI}_j = \Sigma R_i n_{im} / N_{Im}, \qquad [3]$$

where R_i equals the individual lifetime cancer risk estimate in census tract i, n_{im} is the number of people in subpopulation m in census tract i, I is the set of all census tracts considered in the analysis ($I = \Sigma i$), and N_{Im} is the total number of people in subpopulation m who reside in all tracts I. The population risk indices for different demographic groups can be compared with each other to graphically assess the extent to which environmental inequities may be occurring.

Because our exposure estimates are based on the ecologic unit of 1990 census tracts, we selected the Poisson regression technique to conduct multivariate modeling. To model relative exposure to carcinogenic air pollutants, we estimated rates of the expected number of lifetime cancer cases associated with modeled estimated ambient air toxics levels, by combining modeled concentration estimates with cancer potency information (IURs), and the population at risk in a given census tract. We divided the population of each tract into six categories based on race/ethnicity: Hispanics (of all races), non-Hispanic whites, non-Hispanic blacks, non-Hispanic Asians and Pacific Islanders, non-Hispanic American Indians and Alaska Natives, and non-Hispanics of other races. The outcome for our Poisson regression models was thus the expected number of cancer cases for members of each race/ethnic group in each census tract. A Poisson linear regression model with a robust standard error was used to estimate the average change in estimated cancer incidence associated with changes in segregation level and other covariates.

Results

This analysis included 309 metropolitan areas encompassing 45,710 tracts and > 79% of the population of the United States, including 76% of non-Hispanic whites, 85% of non-Hispanic blacks, 91% of Hispanics (of any race), 87% of Asian/Pacific Islanders, and 53% of American Indians/Native Alaskans. The average individual lifetime cancer risk estimates for each metropolitan statistical area ranged across several orders of magnitude, with some of the highest risk estimates found in southern California and in the midwestern region (data not shown).

Table 1 presents the distribution of estimated cancer risk from air toxics in the U.S. census tracts. The average estimated cancer risk per million from all emissions sources combined was 631.9. This estimate declines significantly after removing diesel (115.5 per million; Table 2). Generally, cancer risk estimates exceeded the regulatory goal of one in a million by several orders of magnitude (Clean Air Act Amendments 1990). Among source contributions, mobile sources make the most significant contribution to estimated cancer risk (on average, 88.3% of total risk with diesel particulates included and 35.7% excluding diesel particulates). This is followed by area sources (7% including diesel particulates and 36% excluding diesel particulates) and then major point sources that contribute less on average to the overall cancer risk burden (1.3% including diesel particulates and 7% excluding diesel particulates).

Figure 1 maps patterns of racial segregation across the 309 metropolitan areas included in this analysis. The background colors indicate how we classified states into regional categories: western, border, southern, northeastern, midwestern, and mountains and plains states. The smaller, darker shapes are metropolitan areas. The map indicates that the northeastern, southern, and midwestern regions have some of the highest levels of multiethnic/racial segregation in the country, whereas the western and mountain and plains states tend to have lower levels of segregation. Table 3 displays the distribution of metropolitan areas, tracts, total population, and racial/ethnic groups by three segregation categories (moderate/low, highly, or extremely segregated). About 75% of metropolitan areas were either highly or extremely segregated (Dm ≥ 0.40), and nearly 40% of the census tracts included in this analysis were extremely segregated (Dm ≥ 0.60). Nationally, nearly 50% of non-Hispanic blacks, 37% of whites, more than 20% of Hispanics, and 24% of Asians live in extremely segregated metropolitan areas. These patterns vary significantly by geographic region, particularly in the northeastern and midwestern states, where segregation levels are highest.

Figure 2 shows the racial/ethnic distribution of estimated cancer risk associated with air toxics across segregation categories. The y-axis shows a population-weighted individual excess cancer risk estimate for each racial/ethnic group and segregation category. Each line in the graph represents one of the five racial/ethnic groups, with one line representing the total population. The data points to the left are average cancer risk estimates for each racial/ethnic group for all segregation categories combined. The graph shows two patterns: that cancer risks across all metropolitan areas increase with increasing segregation levels for all racial/ethnic groups, and that overall, Hispanics and Asians, followed by African Americans, have some of the highest cancer risk burdens in metropolitan areas with higher segregation levels compared with the average risk across all groups and compared with whites and Native Americans. Figure 3 shows the racial breakdown of cancer risk burden by poverty level. Although there is a persistent racial/ethnic gap in cancer risk across all levels of poverty, there is no gradient that increases with rising area-level poverty, which suggests that the effect of segregation is independent of the impact of poverty on the exposure burdens across racial categories. The data were further examined to assess the racial/ethnic distribution of cancer risk across three segregation levels for each of the three area-level poverty categories. The same positive segregation gradient persisted for each racial group, regardless of poverty category (data not shown). This suggests that although segregation concentrates poverty (Massey and Fischer 2000; Massey et al. 1991), area-level poverty functions independently of segregation to affect estimated cancer risks associated with ambient pollutants. These distributional patterns were very similar when area and mobile source emissions were examined separately. For point-source emissions alone, the gradient across segregation categories was not observed (data not shown).

To examine these variables in a multivariate analysis, we assessed the relationship between segregation and estimated cancer risk, stratifying by race/ethnicity, and calculating risk ratios for each level of segregation, using low/moderate segregation as the referent group. Table 4 shows the unadjusted model without controlling for key area-level socioeconomic measures. This model shows a strong cancer risk gradient by segregation category for the total population [highly segregated: relative cancer risk (RCR) = 1.73; extremely segregated: RCR = 2.63] and indicates gradients for each racial/ethnic category with the strongest gradient observed for Hispanics (highly segregated: RCR = 2.44; extremely segregated: RCR = 6.40) and Asians (highly segregated: RCR = 2.25; extremely segregated: RCR = 3.90). Table 5 displays the adjusted model controlling for state regional grouping (six regions), metropolitan area population size, county-level voter turnout, tract-level poverty, tract-level material deprivation score (Townsend index), and tract-level population density. Results indicate that even after controlling for tract-level socioeconomic status (SES) measures, increasing segregation amplifies the cancer risks associated with ambient air toxics for all racial groups combined (highly segregated: RCR = 1.04; extremely segregated: RCR = 1.32). This effect of segregation is strongest for Hispanics (highly segregated: RCR = 1.09; extremely segregated: RCR = 1.74) but is also evident, albeit somewhat weaker, among whites, African Americans, and Asians. The models were also run for the source categories separately and showed strong gradients for mobile and area emission sources and nonsignificant effects for point sources (data not shown).

Discussion

In this analysis we examined the relationship between estimated cancer risks from ambient air toxics, tract-level socioeconomic characteristics, and metropolitan-area racial segregation in the continental United States. Much of the average cancer risk is due to emissions from mobile sources, even when diesel particulates are removed from the analysis. We found a persistent relationship between increasing levels of racial/ethnic segregation and increased estimated cancer risk associated with ambient air toxics. Moreover, racial disparities in risk burdens widen with increasing levels of segregation. In examining race and tract-level poverty concurrently, we found a persistent disparity in population-weighted cancer risk among racial/ethnic groups across poverty levels. However, we observed no increasing gradient with increasing poverty, suggesting that segregation affects pollutant burdens in a manner

Table 1. Distribution of estimated cancer risks in continental U.S. metropolitan areas, per million.

	Mean	5th percentile	Interquartile range	95th percentile
All sources	631.9	129.3	272.4–696.5	1619.1
Background	23.0	23.0	23.0–23.0	23.0
Point (major) sources	7.9	0.1	0.6–6.2	26.3
Area sources	43.3	5.4	13.3–50.9	135.6
Mobile sources	557.6	94.8	223.9–605.7	1465.8
On-road mobile sources	178.5	39.3	90.9–227.9	422.8
Nonroad mobile sources	379.2	48.7	122.1–368.4	1097.8

Table 2. Distribution of estimated cancer risks in continental U.S. metropolitan areas (excluding diesel particulate matter), per million.

	Mean	5th percentile	Interquartile range	95th percentile
All sources	115.5	37.7	61.0–137.9	277.0
Background	23.0	23.0	23.0–23.0	23.0
Point (major) sources	7.9	0.1	0.6–6.2	26.3
Area sources	43.3	5.4	13.3–50.9	135.6
Mobile sources	41.3	6.7	18.7–51.2	102.9
On-road mobile sources	25.4	4.4	12.3–33.3	61.2
Nonroad mobile sources	15.9	1.8	5.6–17.5	44.7

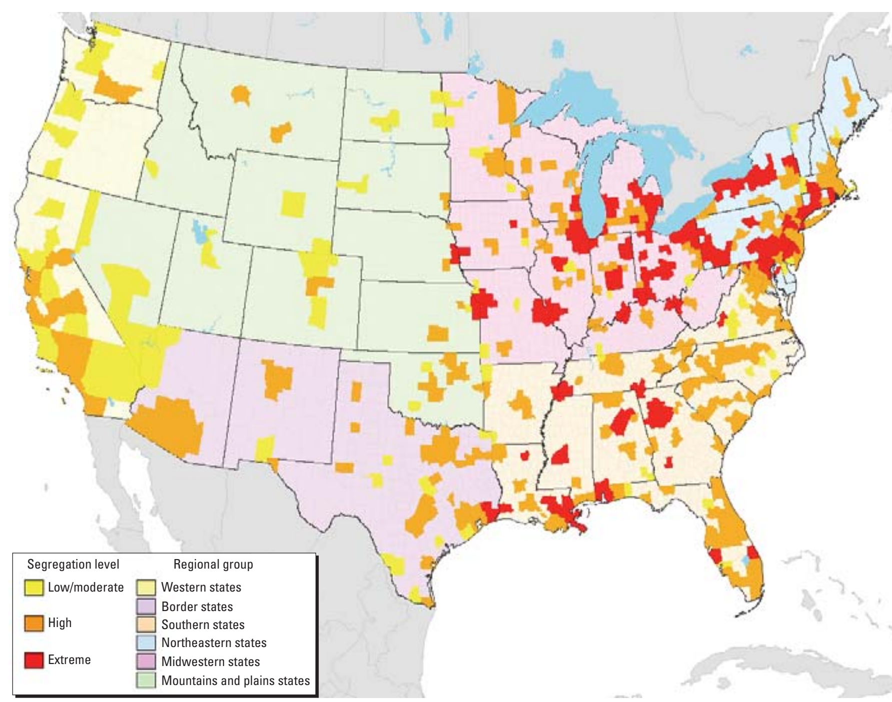

Figure 1. National map of multigroup racial/ethnic segregation in the United States (1990 Census; U.S. Census Bureau 1991, 1993).

independent of area-level poverty. Multivariate modeling controlling for tract-level SES variables showed that cancer risk burdens increased by increasing levels of segregation for all racial groups combined and that this positive relationship was most pronounced for Hispanics, whites, and blacks. Separate modeling by source category showed similar results for mobile and area emission sources, but not for point sources, where persistent segregation gradients for the total population and for each racial group were not observed.

Previous analyses of the U.S. EPA's CEP and 1996 NATA data confirm the distribution of emissions source allocations for estimated cancer risk that are primarily driven by mobile sources (Apelberg et al. 2005; Morello-Frosch et al. 2000, 2001, 2002a, 2002b). Much of this difference in source contributions to estimated cancer risk for this study is driven by the overwhelming effect of diesel that is emitted by mobile sources. However, when diesel is removed from the analysis, mobile source emissions still account for 36% of estimated cancer risk. It is also possible that the difference in source contributions to estimated cancer risk is due to a lack of cancer potency information for those pollutants that tend to be released from stationary facilities (Morello-Frosch et al. 2000). The modeling results also confirm emerging evidence of racial disparities in exposure to air pollutants from mobile emission sources, including two studies in California examining traffic density and the demographic makeup of schools near major traffic corridors (Green et al. 2004; Gunier et al. 2003).

The segregation results in this study are consistent with those of one previous national study that examined the relationship between black/white residential segregation and ambient air toxics exposure in U.S. metropolitan areas using data from the U.S. EPA's CEP (Lopez 2002). Results showed that increased black/white segregation was associated with wider disparities in potential air toxics exposure, after controlling for a series of area-level SES measures. We used a different methodologic approach in our study in terms of how we measured segregation, derived area-level SES measures, and developed our statistical models, yet the consistency of results between these two segregation studies is noteworthy. To our knowledge, our analysis is the only study to use a generalized multiethnic segregation

Table 3. Distribution of racial/ethnic groups by level of metropolitan area segregation.

		Segregation [Dm (%)]		
	Total (*n*)	Low and moderate 0.16–0.39	High 0.40–0.59	Extreme 0.60–0.82
Metropolitan areas	309	25	53	21
Census tracts	45,710	10	50	40
National	196,848,140	11	52	37
Hispanics of all races	20,386,166	13	66	21
Non-Hispanic whites	144,397,690	12	51	37
Non-Hispanic blacks	24,873,268	5	45	50
Non-Hispanic American Indians and Alaska Natives	894,954	21	60	19
Non-Hispanic Asians and Pacific Islanders	6,069,605	12	64	24
Western states	34,819,823	33	67	—
Hispanics of all races	7,756,347	20	80	—
Non-Hispanic whites	21,565,910	42	58	—
Non-Hispanic blacks	2,256,761	21	79	—
Non-Hispanic American Indians and Alaska Natives	233,259	50	50	—
Non-Hispanic Asians and Pacific Islanders	2,947,432	18	82	—
Southern states	39,028,191	5	71	24
Hispanics of all races	1,983,575	2	89	9
Non-Hispanic whites	28,404,970	5	72	23
Non-Hispanic blacks	7,995,229	5	63	32
Non-Hispanic American Indians and Alaska Natives	110,127	10	72	18
Non-Hispanic Asians and Pacific Islanders	514,659	5	74	20
Mountains and plains states	10,125,466	44	45	11
Hispanics of all races	685,376	51	43	5
Non-Hispanic whites	8,507,657	44	44	12
Non-Hispanic blacks	565,269	26	54	19
Non-Hispanic American Indians and Alaska Natives	174,238	26	71	3
Non-Hispanic Asians and Pacific Islanders	184,341	52	40	8
Border states	18,113,094	9	89	2
Hispanics of all races	4,620,933	14	85	0
Non-Hispanic whites	11,126,767	7	91	2
Non-Hispanic blacks	1,853,246	5	90	5
Non-Hispanic American Indians and Alaska Natives	135,802	4	95	1
Non-Hispanic Asians and Pacific Islanders	351,491	4	94	2
Midwestern states	43,620,713	3	26	72
Hispanics of all races	1,475,572	1	12	87
Non-Hispanic whites	35,856,980	3	29	68
Non-Hispanic blacks	5,463,371	1	10	90
Non-Hispanic American Indians and Alaska Natives	138,166	4	41	55
Non-Hispanic Asians and Pacific Islanders	656,826	3	25	72
Northeastern states	51,140,853	1	40	59
Hispanics of all races	3,864,361	0	29	70
Non-Hispanic whites	38,935,406	2	43	56
Non-Hispanic blacks	6,739,392	0	29	71
Non-Hispanic American Indians and Alaska Natives	103,362	3	35	63
Non-Hispanic Asians and Pacific Islanders	1,414,856	0	38	61

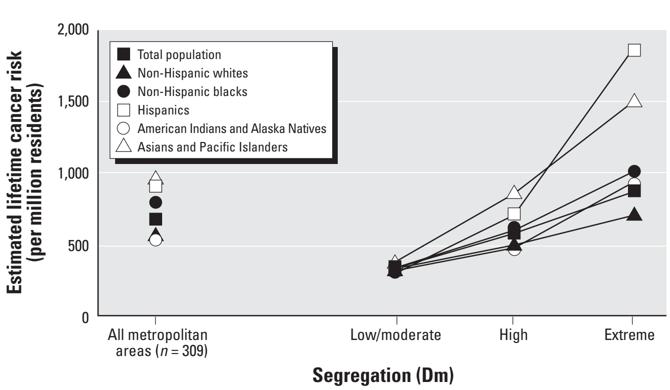

Figure 2. Estimated cancer risk associated with ambient air toxics by race/ethnicity and racial/residential segregation, continental U.S. metropolitan areas.

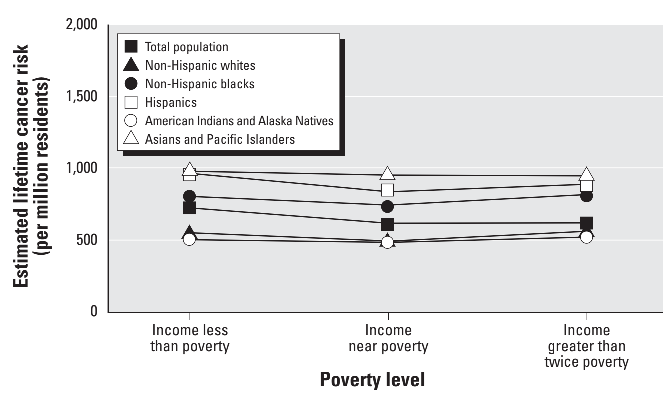

Figure 3. Estimated cancer risk associated with ambient air toxics by race/ethnicity and poverty status, continental U.S. metropolitan areas.

measure for the evaluation of environmental health disparities.

Apelberg et al. (2005) recently conducted an analysis of racial and socioeconomic disparities in cancer risk associated with air toxics in Maryland using the NATA data and found substantial risk disparities for on-road, area, and nonroad sources by socioeconomic measures such as income, homeownership, education, and disparities in exposures from on-road and area sources by race (measured as percent black residents in a tract). Racial disparities in cancer risk were strongest at the lowest income levels (Apelberg et al. 2005). In our national study, we found persistent racial disparities across income categories, but this may be the result of differences in methodology in the estimation of race-based risks or in the demographic makeup of the different study areas. Moreover, we concentrated on segregation rather than on the proportion of specific racial groups in census tracts. Indeed, most environmental inequality studies use measures of racial composition or the existence of census tracts with a high proportion of specific minority groups to assess potential disparities. This measure of tract-level racial composition is often interpreted as a measure of the magnitude of segregation in a metropolitan area. However, racial composition may not always be a true reflection of segregation per se, because segregation is a contextual measure that depends on the relationship between racial groups in neighborhoods (e.g., census tracts) across a larger geographic area (e.g., a metropolitan area). Thus, whereas percent minority measures reflect the composition of a particular neighborhood, they do not assess whether a metropolitan area's organization reflects broader patterns of racial inequality. Indeed, our results indicate that segregation, when operationalized as a measure of metropolitan area evenness, is associated with a higher average cancer risk overall and that it also amplifies disparities across racial groups, suggesting that this regional measure of inequality functions independently of neighborhood or tract-level SES measures.

There are some inherent limitations to this analysis, particularly related to the use of the NATA data. First, the characterization of health risks posed by air toxics focuses on additive cancer risks but says nothing about how some of these substances may interact synergistically with each other. Second, this analysis focuses on one route of potential exposure (inhalation through outdoor ambient exposures) and does not account for other exposure pathways through other media. Moreover, risk estimates do not take into account indoor and personal exposures to air toxics from other sources, such as consumer products, or the penetration of outdoor pollutants into indoor environments that can result in exposure levels that are significantly higher than estimated exposures from outdoor pollution sources. For example, ASPEN model estimates for volatile organic compounds used for NATA were generally lower than measured personal exposures and the estimated cancer risks (Payne-Sturges et al. 2004). Moreover, a comparison of the modeled air quality estimates with geographically limited ambient air monitoring data throughout the country found that the modeled estimates for the handful of pollutants examined by the NATA were typically lower than the measured ambient annual average concentrations (U.S. EPA 2005b). Another potential source of uncertainty arises from the comparison of 1996 risk estimates with racial and socioeconomic measures from the 1990 Census. We chose to use the 1990 Census to avoid having to arbitrarily exclude individuals who did not self-identify exclusively into one racial category. In terms of changes in pollution distributions, although emissions are likely to have changed during this period because of regulatory efforts, it is also likely that certain emissions—particularly the proliferation of mobile sources and the steady increase in the average number of vehicle miles driven in certain regions—could be counteracting previous gains from tougher emission standards from other sources (Apelberg et al. 2005).

Table 4. Relative estimated lifetime cancer incidence associated with ambient air toxics [RCR (95% CI)], continental U.S. metropolitan areas.[a]

	Highly segregated	Extremely segregated
Total population	1.73 (1.69–1.77)	2.63 (2.57–2.70)
Non-Hispanic whites	1.55 (1.51–1.60)	2.19 (2.13–2.25)
Non-Hispanic blacks	1.90 (1.71–2.10)	3.18 (2.86–3.52)
Hispanics (all races)	2.44 (2.27–2.63)	6.40 (5.94–6.89)
Non-Hispanic American Indians and Alaska Natives	1.39 (1.05–1.85)	2.51 (1.85–3.39)
Non-Hispanic Asians and Pacific Islanders	2.25 (1.99–2.55)	3.90 (3.43–4.42)

CI, confidence interval. R^2 = 5%.
[a]Unadjusted estimates.

Table 5. Relative estimated lifetime cancer incidence associated with ambient air toxics [RCR (95% CI)], continental U.S. metropolitan areas.[a]

	Highly segregated	Extremely segregated
Total population	1.04 (1.01–1.07)	1.32 (1.28–1.36)
Non-Hispanic whites	1.04 (1.01–1.08)	1.28 (1.24–1.33)
Non-Hispanic blacks	1.09 (0.98–1.21)	1.38 (1.24–1.53)
Hispanics (all races)	1.09 (1.01–1.17)	1.74 (1.61–1.88)
Non-Hispanic American Indians and Alaska Natives	1.02 (0.77–1.35)	1.21 (0.90–1.64)
Non-Hispanic Asians and Pacific Islanders	1.10 (0.97–1.24)	1.32 (1.16–1.51)

CI, confidence interval. R^2 = 38%.
[a]Adjusted for state regional grouping; metropolitan area population size; county voter turnout; census-tract population density, poverty rate, and material deprivation.

Conclusion

Although the literature on segregation and health has expanded significantly in recent years, studies that specifically address segregation in the context of environmental health disparities are in their infancy. Communities concerned about environmental inequities have encouraged scientists, policy makers, and the regulatory community to consider the junctures of socioeconomic inequality, environmental protection, and public health. This study suggests that disparities in exposures to cancer risks associated with ambient air toxics are affected by the degree of racial residential segregation, and that these exposures may have environmental health significance for populations across racial/ethnic lines. Furthermore, the observed increase in cancer risk in more segregated urban areas is not modified by area-level poverty. Future research, incorporating new and better models of exposure, should include segregation as a key factor in the analysis. Moreover, although most research has focused on the health consequences of black/white segregation in metropolitan areas, other minority groups may be similarly affected. Finally, examining segregation among metropolitan areas promotes a regional perspective for understanding the dynamics that shape environmental health disparities. The rationale for taking such a regional perspective is based on previous research that strongly suggests that it is more fruitful to assess potential drivers of environmental health disparities at the regional level because economic trends, transportation planning, and industrial clusters tend to be regional in nature, and zoning, siting, and urban planning decisions tend to be local (Maantay 2002; Morello-Frosch 2002; Morello-Frosch et al. 2001). Therefore, future work that examines how health inequities play out across metropolitan areas could have implications for the development of localized interventions and policy initiatives that ameliorate fundamental drivers of environmental inequities among diverse communities.

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THE AIR IS ALWAYS CLEANER ON THE OTHER SIDE: RACE, SPACE, AND AMBIENT AIR TOXICS EXPOSURES IN CALIFORNIA

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ABSTRACT: *Environmental justice advocates have recently focused attention on cumulative exposure in minority neighborhoods due to multiple sources of pollution. This article uses U.S. EPA's National Air Toxics Assessment (NATA) for 1996 to examine environmental inequality in California, a state that has been a recent innovator in environmental justice policy. We first estimate potential lifetime cancer risks from mobile and stationary sources. We then consider the distribution of these risks using both simple comparisons and a multivariate model in which we control for income, land use, and other explanatory factors, as well as spatial correlation. We find large racial disparities in California's "riskscape" as well as inequalities by other factors and suggest several implications for environmental and land use policy.*

In 2000, Sunlaw Energy, a company seeking to build a new natural gas-powered power plant, approached the city of South Gate, an industrial suburb along the Alameda Corridor in Los Angeles County. While such plants often trigger resistance, partly because of fears of air pollution, the company promised to make use of a new cleaner pollution-control system that had only been deployed thus far in mini-generators. As this was to be the first test of whether the technology could be brought up to scale in a larger plant, many environmentalists from around the region and the state were supportive, particularly given that the statewide energy crisis in California was creating pressure for a rapid build-out of the power grid. Labor unions were also interested in the jobs that could be generated along with the electricity.

Some local community members and city leaders were not so enthusiastic. Invoking the notion of *cumulative exposure*, they argued that a new plant, no matter how clean, was an

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unfair burden in a heavily Latino community that was already the site of numerous pollution-emitting facilities and heavy truck traffic from local industry and nearby freeways. The company, eager to move forward, proposed that the matter be put to a citywide referendum, confident that the combination of environmentalist and labor support, and promises to fund neighborhood improvements, provide local scholarships, and pay local taxes would yield a positive response from local voters. Despite an expensive long-term campaign that included ads, community picnics, and even a float in the city's Christmas parade, the referendum on March 6, 2001 produced a 2–1 landslide against the new plant; faced with this resounding "no," the company lived up to its earlier statements and withdrew its construction plans (Martin, 2001a, 2001b).

In recent years, advocates of environmental justice have suggested that such considerations of cumulative and inequitable exposure should figure into decisions about facility siting, freeway expansion, and other environmental disamenities. Such advocates have gained particular ground in California where 1999 legislation mandated environmental justice as a consideration for relevant state agencies and subsequent laws and agency actions have tried to better address community concerns about environmental disparities in the state. In this article, we determine whether the advocates have had a point, looking at the distribution of outdoor air toxic exposures and their estimated associated cancer risks in California. Simple comparisons indicate disparity by race and income, and multivariate analysis suggests an important association of race and income with the level of air toxics health measures even after controlling for other important factors, such as manufacturing presence, land use, population density, and region, that might explain the general level of air toxics. The results suggest that California policy makers and advocates have been right to be concerned about the intersection of cumulative exposure and environmental injustice.

There are several innovations in this article. First, we are among a very small group of authors using health risks based on estimated exposure rather than simply using proximity to particular point sources of pollution. Moreover, these health risks are based on pollution exposures from both point and mobile emission sources. Second, we control for land use, a variable that is usually eschewed in such analysis because of the difficulties of obtaining geographically broad and reliable coverage. Third, we subject the usual regressions to spatial tests to see whether the findings have been driven purely by geographic clustering; they are not, providing all the more reason to be concerned about potential issues of environmental inequity.

ENVIRONMENTAL JUSTICE FINDINGS

Environmental justice (EJ) research now has a long pedigree. Early ground-breaking studies on the siting of hazardous waste sites conducted by the GAO (U.S. General Accounting Office, 1983) and the United Church of Christ (United Church of Christ, 1987) seemed to suggest a disparity in proximity to hazards. In the mid-1990s, however, this pattern was disputed by a series of studies that seemed methodologically superior in both the choice of geographic scale (tracts versus zip codes) and the use of multivariate regression techniques to control for the other determinants that might influence hazard location (Anderton, Anderson, Oakes, & Fraser, 1994, Anderton et al., 1994). These early critiques prompted the adoption of increasingly sophisticated approaches in the field, including more careful choices around the regression methods and data (Been, 1995), consideration of the other sorts of hazards such as the emissions recorded in the Toxic Release Inventory (Sadd, Pastor, Boer, & Snyder, 1999), and the use of temporal analyses to see whether hazards were placed in minority communities or minorities moved in afterwards (Been & Gupta, 1997; Pastor, Sadd, & Hipp, 2001).

Many of these second-generation efforts have tended to square with the insights of environmental justice advocates, and a recent broad national study launched by three researchers initially skeptical of EJ claims also found evidence of disparities by race and class, depending on the geographic scale used (Lester, Allen, & Hill, 2001). Numerous other efforts have failed to find such a correlation. In an encyclopedic and very useful review of the field, Bowen (2001) points to a range of studies showing regional differences in patterns of environmental inequity, including Yandle and Burton's (1996) work on Texas and his own collaborative study of Ohio (Bowen, Salling, Haynes, & Cyran, 1995). Ash and Fetter (2002) also point to the importance of region, noting that disparities may exist within regions even if they do not show up in the broad national studies that aggregate populations from all over the country. Regardless of one's perspective on the national pattern, however, many have concluded that there does seem to be a consistent pattern of disparity in California, the area of focus in this article, and this may be one of the reasons why the state has become a leader in environmental justice activism and policy (Kelly, 2003).

Still, methodological disputes are rampant in the field. One important debate has to do with the consequences of pollution or proximity to exposure, with some arguing that a more explicit focus on risk should dominate the analysis (Foreman, 1998). This suggests the need to go beyond a focus on stationary sources and include analysis of the mobile sources and smaller emitters that may contribute a large share to the overall burdens of pollution and risk (Glickman & Hersh, 1995; Perlin, Setzer, Woodrow, Creason, & Sexton, 1995). Recent research on California does indicate that transportation emissions make significant contributions to estimated health risks associated with ambient pollutant concentrations, suggesting that a focus on stationary sources alone will likely distort any estimate of the distribution of environmental burdens (Morello-Frosch, Woodruff, Axelrad, & Caldwell, 2000, Morello-Frosch, Pastor, & Sadd, 2001). A risk modeling approach that considers all sources of pollution, including mobile sources, is also more consistent with the emerging policy focus on cumulative exposure.

Another methodological issue, brought to the debate with particular eloquence by Bowen (2001), is the need to pay more attention to potential spatial dependence into the analysis. That is because land uses tend to cluster together, and race and other variables are also clustered (due to socioeconomic drivers as well as the dynamics of residential choice and housing discrimination), correlations between hazards and race may be spurious. This suggests that regression techniques should introduce some control for spatial processes in order to clarify whether race and other socioeconomic and political variables are truly robust in multivariate analyses.

In other work, we have taken up some of these challenges. In Morello-Frosch, Pastor, and Sadd (2001), for example, we obtained cancer risk estimates from modeled concentrations of air pollutants, including mobile and small point sources, and explored the risk patterns for Southern California utilizing race, income, and land use. Using 1990 census data, we found that minority residents were far more likely to be living in areas of higher potential cancer risk from ambient air pollution than non-Latino white residents. More recently, we have conducted an analysis of proximity to facilities listed in the Toxic Release Inventory of the U.S. Environmental Protection Agency that attempted to control for spatial clustering through the use of spatial lag regressions (Pastor, Sadd, & Morello-Frosch, 2004). We found that race mattered in the distribution of environmental disamenties, although we were unable at that point to include a very important spatial characteristic, land use.

The goal in this analysis is to integrate risk data with census information and a new data set on land use, and then examine the patterns of environmental disparities in contemporary California. We also introduce some controls for the presence of immigrants based on the notion that newcomers might be either less aware of the effects of pollution or less willing or able to politically engage to resist the placement of environmental disamenities in their communities. Finally, we consider the spatial issues directly by introducing first regional dummy variables then attempting to control for spatially autocorrelated error terms. We turn below to the data and the methods before focusing on the results.

DATA SOURCES AND METHODS

The Dependent Variable: Air Toxics and Cancer Risks

To create measures of cumulative exposure and risk, we used annual average air toxics concentration estimates from the U.S. EPA's National Air Toxics Assessment (NATA) for 1996 (U.S. EPA, 2004). The underlying data on toxics comes from five primary information sources including: state and local toxic air pollutant inventories, existing databases related to EPA's air toxics regulatory program, EPA's Toxic Release Inventory (TRI) database, estimates using mobile source emissions estimates (developed by EPA's Office of Transportation and Air Quality), and other emission estimates generated from emission factors and activity data. Using the emissions data as inputs, an air dispersion model is used to estimate the annual average ambient concentration of each air toxic pollutant at the centroid of each census tract. The model is calculated after taking into account the impacts of atmospheric processes (winds, temperature, atmospheric stability, etc.) on pollutants. The 1996 NATA database includes estimates of concentrations for diesel particulates and 32 of the 188 air toxics listed under the 1990 Clean Air Act Amendments and takes account of both mobile and stationary sources.

We combined these air toxics concentration estimates with inhalation unit risk estimates for each carcinogenic compound to estimate overall cancer risks. First, estimated cancer risks for each pollutant in each census tract were derived with the formula

$$R_{ij} = C_{ij} \times IUR_j,$$

where R_{ij} is the estimate of individual lifetime cancer risk from pollutant j in census tract i, C_{ij} is the concentration in micrograms of pollutant per cubic meter of air ($\mu g/m^3$) of the air toxic j in census tract i, and IUR_j is the inhalation unit risk estimate for pollutant j. In accordance with California's AB2588 "Hot Spots" Guidelines (OEHHA, 2003) and EPA's cancer risk guidelines (U.S. EPA, 1986, 1990), cancer risks of each pollutant were assumed to be additive and were summed together in each tract to derive a total individual lifetime cancer risk. Source allocation estimates indicate that on average, mobile source emissions account for the largest proportion of estimated cancer risks (approximately 85%) followed by stationary sources (approximately 15%). Similarly, cumulative lifetime cancer risks were attributable to a handful of pollutants, especially diesel particulates (around 70%) followed by chromium, butadiene, polycyclic organic matter, formaldehyde, benzene, and carbon tetrachloride (approximately 30%).

The result of this work might be termed a *risk surface*. It offers a picture by tract of the estimated lifetime cancer risk associated with cumulative exposures to ambient air toxics with the hills and valleys of the risk surface indicating areas of higher or lower risk for residents. These risk estimates assume that residents live in the same area over their lifetime and do not represent actual cancer cases. However, the estimates allow for a broad scale geographical analysis of the potentially disparate health risks associated with air pollution borne by diverse communities in the state.

Before undertaking any analysis, however, we first needed to *reshape* the surface. That is, the 1996 risk surface from the NATA data is generated for the 1990 census tract shapes but any tests against demographics and income would probably be more appropriately performed using the 2000 census data. After all, the income variables in the 2000 census are actually from 1999, only three years newer than the risk data, and the demographics of 2000 are likely to be closer to 1996 than the 1990 data. We, therefore, intersected the 1990 and 2000 tracts and calculated risk values as attributes of the 2000 tracts based on the proportion of common area with 1990 tracts. This method makes the simplifying assumption that the 1990 risk value for any given tract is homogeneously distributed within that area, but 2000 tracts overlay two or more 1990 tracts in California in a relatively small number of cases. To our knowledge this is the first attempt at conducting an environmental justice analysis that combines U.S. EPA's 1996 NATA data with 2000 Census variables.

Independent Variables: Land Use, Market Dynamics, and Socioeconomics

We then derived a set of independent variables which corresponded to one of three non-exclusive explanations for the geographic pattern: land use considerations, market dynamics, and political power. The land use explanation suggests that excess pollution is the result of zoning, reflecting a potentially rational planning strategy of clustering uses together (such as industry, commerce, and transportation) to minimize impact on residents. The market explanation suggests that environmental pollution may reflect a mix of consumer and industry choices. Because the foregone income for poorer residents from illness is lower, one might expect such residents to be more likely to be near hazards and one might also, for reasons of market convenience, expect industrial firms and industrial workers to cluster together. A power-based explanation may accept or reject aspects of the rational planning and market choice view, but it forthrightly argues that marginalized groups will be less able to resist hazard placement, and companies and governments, seeking the path of least resistance, may seek to locate plants and environmental disamenities in their communities (Hamilton, 1995).

Land Use Variables

One of the most common variables utilized in the rational land use explanation is population density. This is based upon the notion being that denser areas will generate more traffic and pollution generating activities which increase cancer risk estimates. Such population density is measured as persons per square mile in the descriptive statistics below but in the regressions we follow the lead of Mennis (2002) and consider a natural log specification of population density. We do not expect that the shift from one person per square mile to 1000 per square mile to have the same effect on the likelihood of estimated cancer risk from ambient air pollution as the movement from 4000 to 5000 in the same square-mile area; there is a diminishing effect which is better captured by the log form. Alternative specifications (such as categorical variables for density) were explored but these did not improve the fits, are not standard in the literature, and did not square with our theoretical priors about the superior nature of the log form.

We also consider land use more explicitly. The first measure is indirect: we entered a dummy variable indicating whether a tract was urban (as indicated by whether more than 50% of the land area in each tract was designated urban by the Census). The assumption underlying the model was that urban tracts would have higher levels of air pollution. We were also fortunate to have direct estimates of land use. This is important because we have shown in earlier work that population density can actually be a stand-in for more direct measures of land use and so will decline in coefficient value and statistical significance once an appropriate proxy for actual land use is introduced into a regression (see Boer, Pastor, Sadd, & Snyder, 1997; Morello-Frosch, Woodruff, Axelrad, & Caldwell, 2000).

The first of our direct land use variables was the percentage of land devoted to industry, commerce, and transportation. The rationale behind this is that the former set of uses should be associated with higher levels of pollution from large point sources, small stationary sources (such as dry cleaners), and mobile sources. We also had a measure for the degree of land devoted to high density residential use. The assumption was that denser concentrations of residents will lead to more transport and more commerce, both of which will then yield more air pollution. This is also captured by population density; our regressions suggest that there is indeed some competition for significance and explanatory power due to collinearity. Because the density measure for residential housing is less exact than the actual population density from the Census (the former is interpreted from satellite imagery while the latter is directly calculated by using figures on people and land area from the Census), we expected that the general population density measure might dominate as an explanatory variable and found that to be the case.

The land use measures are taken from the 2001 U.S. Geologic Survey (USGS) Land Cover Characterization Program, an effort that uses aerial photo and satellite imagery interpretation to generate a 21-category classification of land use at a spatial resolution of 30 meters. To check accuracy, we compared a Southern California subset of this land use characterization with a higher resolution dataset generated by the Southern California Association of Governments (SCAG) that was based on city land use and zoning maps, as well as digital aerial imagery from three separate years. The match between the two datasets was quite good, although the USGS data tends to underestimate residential and commercial/industrial/transportation cover in a more urban setting. Still, the variables derived from each data source performed similarly in regression exercises limited to Southern California. Because we are interested in a statewide view, we present below only the results for the state that necessarily rely on the broader USGS dataset.

Market Dynamics Variables

The market dynamics view suggests that risk may be higher in areas of lower income, perhaps because lower-income residents are more willing to trade off health for less expensive housing. This suggests the need to introduce income into the analysis, a point we take up in more detail below. This view also suggests that firms may make locational decisions based on the proximity to large pools of workers. Anderton et al. (1994) first pointed the way to this insight by introducing a measure controlling for the percentage of census tract residents employed in manufacturing, and we follow suit in our analysis here (see also Been, 1993, 1995).

The income dynamics are, however, more complex than many first believe. While the usual assumption is that there will be a linear relationship between income and degree of risk, we have argued and demonstrated elsewhere that the relationship may be more

U-shaped (Boer et al., 1997). At very low levels of income, there may be few economic activities or assets and, therefore, no nearby sources of pollution from industry, commerce, or transport. On the other hand, at very high levels of income, residents may have the political power to resist riskier land uses and mitigation costs would be higher for polluters. Thus, we might expect the likelihood of both site location and air pollution to be higher at levels of income somewhere in the middle of the distribution. As it turns out, this pattern shows up in both our raw data and eventually in our regression analysis.

Power Variables

Finally, what about modeling empowerment? While income is one such measure of power, the more direct power measures used in traditional environmental justice analysis include race and home ownership. Race is, of course, exactly the focal point of many environmental justice advocates. From an analytical perspective, the notion is that if race is important, even after controlling for income, then perhaps calculations of differing political power and strength factor into hazard location (see Bullard, 1994; Hamilton, 1995; Pulido, 1996, 2000). We thus consider both the overall presence of people of color (derived by subtracting the percentage of the population that is non-Latino white) and separate measures for the percentage African American, Latino, and Asian Pacific, with the idea being that discriminatory intents or effects might be different depending on the group.

The home ownership variable attempts to pick up on the distinction between wealth and income, an issue that has emerged as important in the epidemiological literature but has been less well-addressed in the environmental justice research (Krieger & Fee, 1994). While income tends to reflect disposable cash, wealth measures family assets and hence a household's safety net in case of economic emergencies (Williams, 1996; Williams & Collins, 1995). Most game theory models suggest that those who have higher levels of economic security (due to existing assets) may be more willing and able to bargain strongly against, say, the location of a polluting facilities. In short, it is not just the flow of income but the stock of assets that matters. The Census has virtually no reliable measures of family wealth at the tract level but home ownership can be used as a crude indicator of wealth and assets (Krieger & Fee, 1994). We have also suggested that because homeowners tend to be more active politically, this variable may also serve as a crude measure of political engagement (Morello-Frosch, et al., 2001).

In this work, we also consider another variable in this category of power-based explanations–the presence of relatively recent immigrants. The notion is that newly arrived immigrants will tend to be less engaged in the political process by virtue of either their immigration status, which prevents them from voting, or simply because of their nascent experience with the US political system. A statistical problem is that the measure we use (the percentage of residents that arrived as immigrants in the 1980s and 1990s) is quite collinear with the percentage of residents that are Latino and Asian Pacific, particularly in California. To take account of this, we also constructed a dummy variable that took the value of one for census tracts where the presence of new immigrants was much higher than would have been expected. To determine this, we regressed the percentage of recent immigrants in a tract on the percentage of Latinos and Asian Pacifics in a tract then assigned the third of the state's tracts with the largest residuals (that is, where the actual presence of immigrants was much higher than the predicted value) a value of one. While an analytically superior strategy might have been to determine the percentage of Latinos and Asians that were recent immigrants, this is not available in the summary data available at the tract level. In any case, the resulting measure helps us to sort out the differential impact of race and ethnicity from immigration in our statistical model.

Regional Controls and Spatial Techniques

Finally, we also are concerned with spatial effects in terms of regional impacts and spatial autocorrelation. To look at these, we eventually turn to the use of spatial regression techniques. However, our first cut is simply to introduce dummy variables for various regions in California, specifically the five counties that make up the largest members of the Southern California Association of Governments (SCAG); the nine counties that make up the Association of Bay Area Governments (ABAG); California's most southern counties, San Diego and Imperial; the six counties around Sacramento; the eight counties that constitute the bulk of the San Joaquin Valley; the five counties on the state's central coast; the 11 counties that are in the eastern-most portion of the state and straddle the Sierra Nevada; and finally, the rest of the state.

Inclusion of such regional controls does change the coefficients and significance of some variables of interest as shown below. This led us to consider a different and more sophisticated way of modeling spatial effects, specifically attempting to control for spatial autocorrelation. Spatial autocorrelation refers to the tendency of variables to be influenced by their neighbors, a fact that will cause the errors in the regression analysis to not satisfy the independence conditions generally associated with ordinary least squares regression. Tests for such autocorrelations are much like the Durbin-Watson used in time series analysis; neighboring observations are defined in this case by space and not time. While there is generally one proximate lagged time period used in the temporal consideration of autocorrelation, there can be many such spatial neighbors. When such spatial autocorrelation is present, researchers tend to adopt either a spatial lag approach or a spatial errors approach with the latter usually considered methodologically superior for complex models such as that developed here.

Controlling for such spatial dependence requires that we construct an appropriate set of neighbor relationships. The archetypical strategy involves either a rook or the queen relationship–in the former case, units sharing boundaries are considered neighbors while in the latter case, any geographic unit that touches another unit is deemed to have an effect. In most testing, this also involves row standardization to determine weights–a unit with four neighbors will find that each has a one-fourth influence on the error. However, rook-style or queen-style relationships are most appropriate to square grids in which space is neatly arranged, hardly the geography typified by census tracts. Hence, we created a set of inverse distance weights such that neighbor effects, which are still required by row-standardization to sum up to one, decline with distance. Distance was measured from tract center to tract center with care taken to trim the tract shapes to account for coast lines. We specifically chose a power function of one with the maximum distance for a neighbor effect being 2.5 miles. This is a radius typically used as the maximum in the environmental justice literature and our results are robust to other reasonable choices of distance.

Finally, we should acknowledge that we are not offering a model with a wide and exhaustive range of variables. This, however, is intentional. Some earlier research, especially the path-breaking Anderton et al. (Anderton, Anderson, Oakes, et al., 1994; Anderton, Anderson, Rossi, et al., 1994) studies, tended to include many variables that were measuring nearly the same phenomenon and hence were likely to be highly collinear; the subsequent finding that some of these variables were not statistically significant was hardly surprising. By contrast, our strategy is to develop a parsimonious model that contains measures that capture and identify the important elements of various arguments about environmental justice.

RESULTS

Descriptive Statistics

How does the pattern of air toxics and cancer risk in California play out against the variables of interest described above? To understand the pattern visually, we utilize a two-by-two breakdown to split the state into census tracts of four types: (1) tracts where the estimated cancer risk is above the median for the state's tracts and the percentage minority is above the median for the state's tracts, (2) tracts where the estimated cancer risk is above the median and the percentage minority is below the median, (3) tracts where the estimated cancer risk is below the median and the percentage minority is above the median, and finally (4) tracts where the estimated cancer risk is below the median and the percentage minority is below the median. The resulting pattern is shown in Figure 1 and reveals the geographic clustering that leads us to consider spatial controls later in the analysis. As for demographics, about half the state's population lives in the tracts with above median-risk; those tracts contain only 39% of the state's Anglo population but 58% of the state's minority population.

Another approach to the demography involves considering various bands of tracts based on their risk estimates. While the breakout for Figure 1 considered only two sorts of tracts by level of pollution in order to simplify the mapping, we are less constrained by the challenges in visual representation when making tables and charts and therefore broke the state tracts into thirds, labeling the third with the lowest estimated cancer risk the *least polluted*, those in the middle third *moderately polluted*, and those in the top third *most polluted*. Tracts in the sample include only the 7,015 tracts (of the state's 7,049 tracts) for which we have all data eventually employed in our regression analysis; this constraint is imposed to maintain consistency through the analysis and the pattern is nearly identical if we change the sample for each variable to include all tracts where that variable is available.

Figure 2 shows the racial pattern in our three different pollution bands. As can be seen, the pattern is consistent with the usual suppositions of environmental justice advocates although in a slightly more complex way that is usually imagined. The percentage non-Latino white declines as we move from the least polluted tracts to the most polluted tracts but interestingly, the African American presence seems to rise as we move from the least polluted to the moderately polluted and stabilizes thereafter. Latino presence rises only slightly between least and moderately polluted areas but then move up rapidly as we drift into the most polluted areas. The Asian Pacific population is more similar to the African American pattern but there is still a sizable increase as we move from the moderately to the most polluted areas. In any case, the disproportionate presence of Latinos in highly areas with high pollution burdens may help to explain why California's environmental justice advocates have found such a ready audience in that community (see Pastor, Morello-Frosch, & Sadd, 2004).

Table 1 illustrates other variables of interest, including home ownership, household income, presence of manufacturing employees, percentage immigrants, and the various land use variables. We report the average value for each of these variables in the pollution bands described above. The exception is the population density measure for

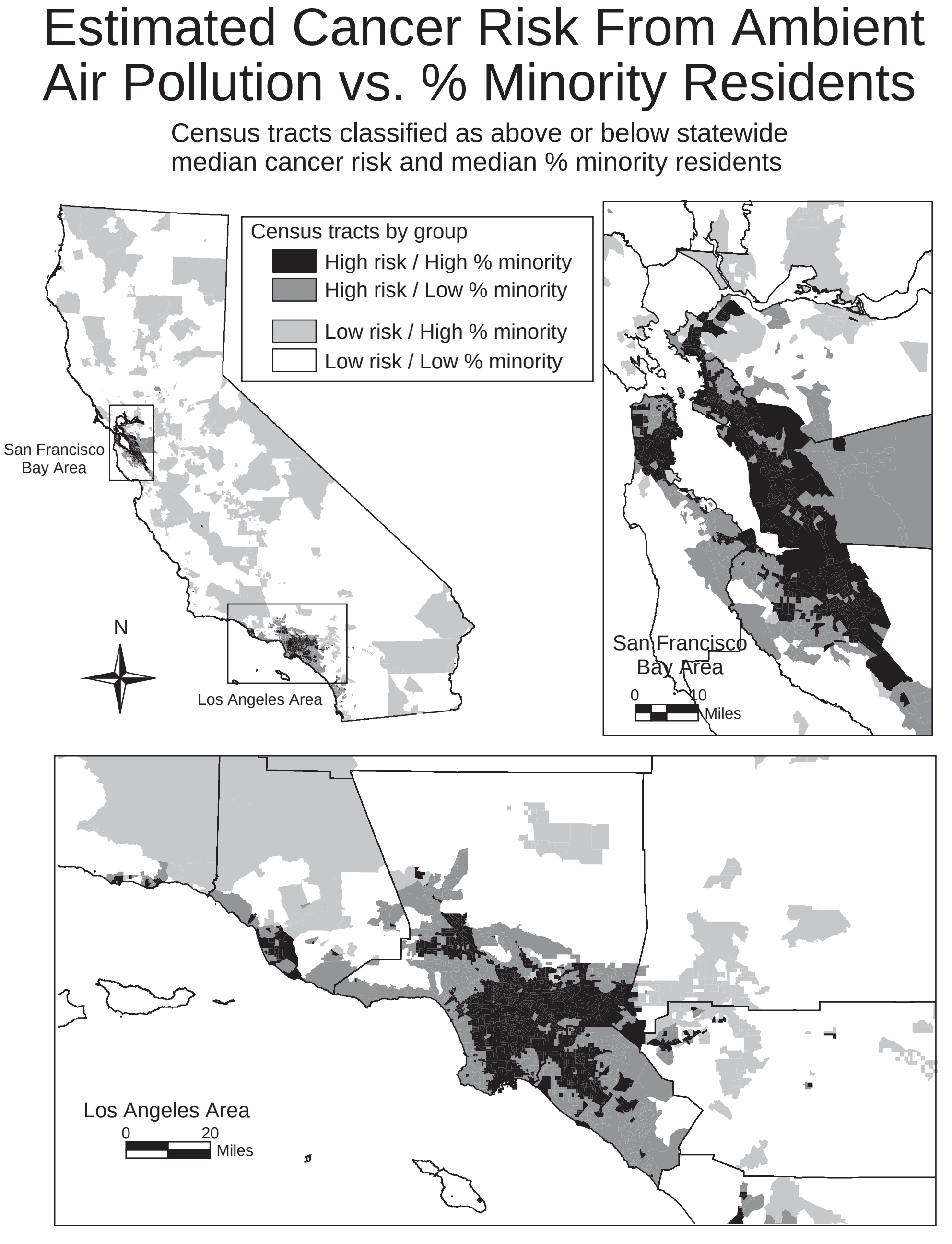

FIGURE 1

Estimated Cancer Risk and Demography in California

which we instead utilized the median in each pollution band given the potential for population density averages to be distorted by a few highly dense or very underpopulated outlier tracts. As might be expected, the proportion of home ownership declines as we move to the most polluted tracts, the percentage of the local labor

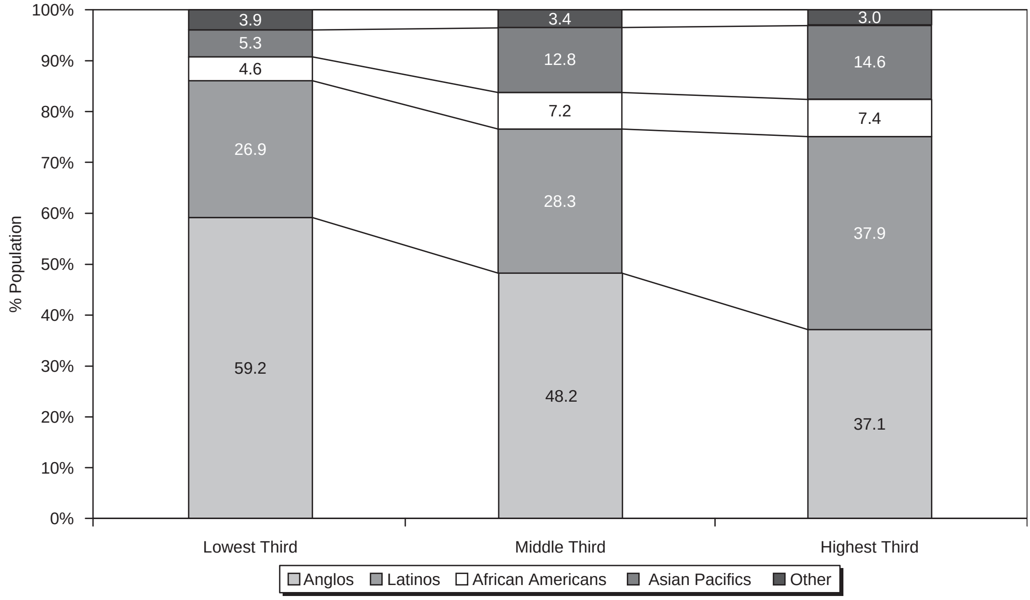

FIGURE 2

Racial/Ethnic Composition of California Census Tracts by Degree of Estimated Cancer Risk from Ambient Air Toxics

force in manufacturing rises, the percentage of immigrants rises dramatically, and population density is higher as is the degree of urbanization, the percentage of land devoted to industry, commerce, and transportation, and the percentage of land hosting high-density housing.

The exception to this monotonic pattern is median household income: as suggested above, it actually peaks in the middle band and is, in fact, somewhat higher for those living in the most polluted conditions than it is for those living in the least polluted conditions. While the latter finding might seem to contradict the usual assumptions about patterns of income inequities, it is important to keep in mind that these simple statistics have not yet been subjected to either multivariate analysis or spatial controls. It is possible that we are simply finding that denser, urban areas have more pollution and also have higher income levels than less urban areas. To explore these relationships in more detail, we must turn to multivariate analysis. The comparative examination does suggest that a U-shaped relationship might the most appropriate functional form.

The basic multivariate model regresses the log of estimated cancer risk on the independent variables discussed above; we use the log because this reduces extreme outliers and yields a normal-style distribution of the dependent variable that is more conducive to the standard regression requirements. Table 2 begins the analysis with a basic model that includes the following independent variables: the percentage people of color, the percentage home owners, median household income and its square (to reflect the assumption of a U-shaped relationship) (see Boer, et al., 1997), the percentage of the labor force in manufacturing, the log of population density, and a variable that takes the values of one if the tract is urban. All variables are signed as expected and the significance levels are high, with the lowest *t*-score being that for the urban dummy.

TABLE 1

Income, Density, and Other Characteristics of California Census Tracts by Degree of Estimated Cancer Risk from Ambient Air Pollution

	Percentage Home Owners	Relative Median Household Income (100 = state median)	Percentage of Labor Force in Manufacturing	Percentage Immigrated in the 1980s and 1990s	Population per Square Mile	Percentage Tracts Labeled Urban	Percentage Land Used by Industry, Commerce, or Transportation	Percentage Land Used by High Density Residential
Least polluted	64	95.3	9.2	10.5	2,174	62.6	6.7	3.1
Moderately polluted	58.1	122.1	13.6	18.7	6,800	92.1	12.9	10.4
Most polluted	50.3	108.8	16.6	23.5	9,672	97.9	17.2	18

The next column of Table 2 shows the basic model with a measure of commercial, industrial, and transportation land use. Compared to column one, we see that inclusion of this variable increases explanatory power (as measured by the adjusted R^2), appropriately reduces the coefficients on the measure for race, home ownership, income, and the percentage of the labor force in manufacturing, and causes the dummy variable indicating urbanization to be completely insignificant. Apparently, land use is important to consider in these analyses and failure to include it could lead to an attribution to racial and other dynamics that might be inappropriate. In the third column, we introduce our variable for high-density residential land use. As can be seen, this reduces the coefficient and significance for our population density measure, as might be expected, and the urbanization variable creeps up to quite anemic significance.

In Table 3, we introduce our first set of spatial controls: regional dummies set for various areas in the state. In the first column the coefficients for race and income fall dramatically as does the effect of the percentage of the labor force in manufacturing and the commercial/industrial/transportation land use variable. This suggests that the strong effects of those variables might be the result of spatial clustering for other reasons. Interestingly, this first use of spatial controls sharply reduces the statistical significance of the high-density residential variable. When we drop both it and the urban dummy in the second column, there are only very modest changes in coefficient values and significance levels for the other variables. Column three rounds out the picture by dropping the regional dummies and the urban and high-density residential variables, an exercise conducted in order to show how a very parsimonious regression would perform. Still, the most important implication from this table is the potential importance of spatial controls given their impact on the coefficients of other variables of interest.

Before investigating spatial effects more directly, we introduce the analysis of separate ethnic groups and immigration. The first column of Table 4, for example, shows the results when we enter the percentage African American, percentage Latino, and percentage Asian Pacific separately, including all land use measures. All of these measures are significant, although the coefficient for African American is much larger than for the other groups, suggesting a particular potential burden for that population. The second column introduces the percentage recent immigrants but the variable is only significant at the most marginal of levels. However, we suspect significant collinearity with percentage Latinos and Asians, a pattern reflected in the fact that the coefficients for Latinos and Asians decline when the immigration variable is introduced.

Given this issue, we instead created a variable, discussed earlier, which takes the value of one if the tract has a recent immigrant presence well beyond that usually associated with the presence of Latinos and Asians. We suggest that in such cases the tract is likely to be among those serving as receivers for newly arrived residents. This variable is quite significant in the regression analysis and its inclusion has only modest effects on other coefficients. Once we introduce regional controls, however, the measure of recent migration loses statistical significance, suggesting that it may be capturing a difference between regions rather than within regions. As before, the urban dummy and percentage high-residential decline in significance substantially when the regional controls are introduced.

What about a more systematic approach to controlling for spatial effects? The two standard regression approaches to spatial autocorrelation involve use of a spatial lag. This approach assumes that the autocorrelation is in the dependent variable. The spatial errors model assumes, as is more likely to be the case here, that the independent variables exhibit spatial dependence and the regression errors will be spatially dependent as well. While it is

TABLE 2

Determinants of the Level of Estimated Cancer Risk from Ambient Air Pollution: Testing Land Use Measures

	Basic Model		Model with Industrial, Commerce, and Transport Land Use		Model with Industrial and High-Density Residential Land Use	
Variables	Coefficient	*T*-stat	Coefficient	*T*-stat	Coefficient	*T*-stat
% People of color	0.608	17.23****	0.558	16.24****	0.538	15.82****
% Home owners	−1.073	−25.84****	−0.849	−20.31****	−0.753	−17.92****
Relative median household income (100 = state median)	0.016	29.84****	0.017	32.04****	0.017	33.84****
Relative median household income squared	−2.7E-05	−17.72****	−2.8E-05	−19.20****	−3.0E-05	−20.78****
% Labor force in manufacturing	1.422	14.37****	1.263	13.10****	1.149	12.00****
Log of population density	0.188	25.86****	0.190	26.85****	0.159	21.55****
Urban tract (yes or no)	0.090	2.86****	−0.024	−0.78	0.038	1.22*
% Land for industry, commerce, and transport			1.344	20.65****	1.324	20.57****
% Land used by high density residential					0.702	12.41****
Adjusted *R*-squared	0.540		0.567		0.576	
N	7015		7015		7015	
F-statistic	1179.6****		1148.2****		1060.0****	

*p < .20. **p < .10. ***p < .05. ****p < .01.

TABLE 3

Determinants of the Level of Estimated Cancer Risk from Ambient Air Pollution: Testing Land Use Measures and Introducing Regional Dummy Variables

	Model with Industrial and High-Density Residential Land Use, and Regional Controls		Model with Industrial Land Use, No Urban Dummy, and Regional Controls		Model with Industrial Land Use, No Urban Dummy, and no Regional Controls	
Variables	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
% People of color	0.299	9.59****	0.303	9.77****	0.561	16.41****
% Home owners	−0.680	−17.31****	−0.697	−18.47****	−0.853	−20.60****
Relative median household income (100 = state median)	0.011	23.22****	0.011	23.20****	0.017	32.07****
Relative median household income squared	−2.0E-05	−14.92****	−1.9E-05	−14.87****	−2.8E-05	−19.23****
% Labor force in manufacturing	0.663	7.82****	0.673	7.95****	1.266	13.16****
Log of population density	0.143	21.60****	0.143	34.63****	0.185	40.30****
Urban tract (yes or no)	−0.009	−0.34				
% Land used by industry, commerce, or transportation	0.989	17.12****	0.979	17.21****	1.335	20.85****
% Land used by high density residential	0.076	1.39*				
SCAG 5 County Area	0.952	21.21****	0.956	21.33****		
ABAG 9 County Area	0.783	16.44****	0.778	16.41****		
San Diego-Imperial Counties	0.632	13.43****	0.634	13.46****		
Sacramento 6 County Area	0.314	6.58****	0.309	6.50****		
San Joaquin 8 County Area	0.061	1.35*	0.057	1.26*		
Central Coast 5 Counties	0.109	2.14***	0.110	2.15***		
Sierra Nevada 11	0.064	1.05	0.064	1.06		
Adjusted *R*-squared	0.679		0.679		0.567	
N	7015		7015		7015	
F-statistic	926.7****		1058.8****		1312.2****	

*p < .20. **p < .10. ***p < .05. ****p < .01.

TABLE 4

Determinants of the Level of Estimated Cancer Risk from Ambient Air Pollution: Introducing Different Ethnicities and Immigration

	Model with Industrial and High-Density Residential Land Use, No Immigration		Model with Industrial and High-Density Residential Land Use, Simple Immigration Measure		Model with Industrial and High-Density Residential Land Use, Complex Immigration Dummy		Model with Industrial and High-Density Land Use, Complex Immigration Dummy, and Regional Controls	
Variables	Coefficient	*T*-stat	Coefficient	*T*-stat	Coefficient	*T*-stat	Coefficient	*T*-stat
% Latino	0.357	9.19****	0.315	6.41****	0.367	9.45****	0.143	4.00****
% African American	0.940	15.33****	0.943	15.38****	0.924	15.07****	0.431	7.77****
% Asian Pacific American	0.640	11.18****	0.565	7.24****	0.650	11.36****	0.584	11.41****
% Immigrated in the 1980s and 1990s			0.149	1.39*				
Higher than expected percentage recent immigrants					0.067	4.27****	0.007	0.51
% Home owners	−0.742	−17.62****	−0.718	−15.83****	−0.675	−15.06****	−0.666	−16.17****
Relative median household income (100 = state median)	0.017	31.67****	0.017	31.67****	0.017	31.31****	0.011	20.56****
Relative median household income squared	−3.0E-05	−20.10****	−3.0E-05	−20.14****	−2.9E-05	−20.04****	0.000	−13.47****
% Labor force in manufacturing	1.374	13.72****	1.353	13.35****	1.345	13.42****	7.9E-01	8.84****
Log of population density	0.153	20.68****	0.152	20.53****	0.151	20.47****	0.139	20.95****
Urban tract (yes or no)	0.040	1.29*	0.044	1.41**	0.046	1.48**	−0.009	−0.35
% Land used by industry, commerce, or transportation	1.302	20.35****	1.299	20.29****	1.294	20.24****	0.953	16.55****
% Land used by high density residential	0.758	13.38****	0.745	12.96****	0.743	13.10****	0.080	1.46*
SCAG 5 County Area							0.980	21.69****
ABAG 9 County Area							0.774	16.23****
San Diego-Imperial Counties							0.661	13.99****
Sacramento 6 County Area							0.320	6.72****
San Joaquin 8 County Area							0.094	2.08***
Central Coast 5 Counties							0.152	2.96****
Sierra Nevada 11							0.060	0.99
Adjusted *R*-squared	0.582		0.582		0.583		0.682	
N	7015		7015		7015		7015	
F-statistic	888.1****		814.4****		817.7****		793.3****	

*p < .20. **p < .10. ***p < .05. ****p < .01.

generally assumed that the spatial errors model is more appropriate in most circumstances, we began by testing the spatial lag; significance levels for our independent variables were nearly the same but the residuals still exhibited autocorrelation and so we turned to the spatial errors approach.

The results are shown in Table 5. Note that all regressions were conducted using a generalized moments procedure based on the approach of Kelejian and Prucha (1997). The first column shows the results for a full model, including all land use measures; the comparison regression conducted using OLS is in the third column of Table 2. In this spatial errors regression, coefficient values fall by about 35% for race, about 50% for home ownership and income, about 20% for manufacturing employee presence, and about 40% for commercial/industrial/transportation land use. The *t*-scores for these variables decline as well, however, all of these variables are easily significant at the .01 level. The adjusted R^2 also declines although it is unclear how much weight should be given to this measure after the iterated transformations necessary for this procedure. In any case, the decline in the coefficient values for the main variables noted above is exactly what we would have expected from introducing controls for spatial clustering and it is of analytical, if not social, comfort that the race variable still matters.

Interestingly, the percentage high-density residential is now insignificant, similar to that variable's performance when we introduced regional dummies as the spatial controls. The significance has clearly slipped over to the population density measure–its *t*-value has actually risen even though the coefficient fell. The dummy variable for urbanization is now significant at the 0.10 level and so the next regression (depicted in the second column) drops the high-density measure but retains the urban dummy. As can be seen, the pattern for all the other variables is essentially unchanged and so this is our base for further testing.

The next three columns enter the various ethnic groups separately then add first the percentage recent immigrants and then the recent immigrants dummy discussed above. We do not enter the regional dummies in any of these regressions because such spatial tags are generally considered inappropriate in a spatial regression. As with the general percentage people of color variables, coefficient values drop from the previous OLS model but the significance levels are surprisingly similar. The immigrant variable enters significantly, reducing the coefficient values for the Latino and Asian variables when entered as a direct measure. When entered as a dummy to avoid collinearity, the significance level rises and the other coefficients remain more stable. The bottom line of the analysis, however, is quite straightforward–even after controlling for spatial autocorrelation, we find a significant association of race with the estimated cancer risk in a particular tract.

CONCLUSIONS: IMPLICATIONS FOR POLICY-MAKING AND RESEARCH

This article has sought to advance the current state of environmental justice research by reexamining the distribution of environmental risk in the state of California using econometric and environmental health risk assessment tools. Utilizing pollutant concentration estimates, we estimated cancer risk from ambient air toxics and found a pattern of disproportionate exposure by race that persists even after controlling for other variables that predict ambient pollution burdens, such as land use, household income, population density, home ownership, and other variables normally used in the environmental justice literature. The pattern holds, moreover, even when we try to control for spatial factors through either the use of regional dummy variables or more sophisticated techniques that try to account for the presence of spatial autocorrelation.

TABLE 5

Determinants of the Level of Estimated Cancer Risk from Ambient Air Pollution: Results When Controlling for Spatial Autocorrelation, Full Set of Models

	Basic Full Model, Including All Land Use Variables, Spatial Error Specification		Basic Full Model, Including Industrial Land Use and Urban Dummy, Spatial Error Specification		Model with Ethnic Groups, Industrial Land Use and Urban Dummy, Spatial Error Specification		Model with Ethnic Groups, Industrial Land Use and Urban Dummy, Immigration Variable, Spatial Error Specification		Model with Ethnic Groups, Industrial Land Use and Urban Dummy, Immigration Dummy, Spatial Error Specification	
Variables	Coefficient	*T*-stat	Coefficient	*T*-stat	Coefficient	*T*-stat	Coefficient	*T*-stat	Coefficient	*T*-stat
% People of color	0.351	*10.80*****	0.351	*10.81*****						
% Home owners	−0.377	*−11.96*****	−0.377	*−12.13*****	−0.368	*−11.83*****	−0.349	*−10.65*****	−0.336	*−10.52*****
Relative median household income (100 = state median)	0.008	*21.80*****	0.008	*21.94*****	0.008	*21.15*****	0.008	*21.21*****	0.008	*21.04*****
Relative median household income squared	−1.2E-05	*−11.69*****	−1.2E-05	*−11.73*****	−1.2E-05	*−11.46*****	−1.2E-05	*−11.53*****	−1.2E-05	*−11.39*****
% Labor force in manufacturing	0.928	*10.32*****	0.928	*10.33*****	0.981	*10.75*****	0.959	*10.41*****	0.966	*10.58*****
Log of population density	0.144	*29.54*****	0.144	*30.88*****	0.141	*30.17*****	0.141	*30.03*****	0.141	*30.12*****
Urban tract (yes or no)	0.038	*1.94***	0.038	*1.93***	0.039	*1.98****	0.040	*2.06****	0.040	*2.04****
% Land used by industry, commerce, or transportation	0.792	*16.69*****	0.791	*16.80*****	0.785	*16.71*****	0.786	*16.72*****	0.786	*16.76*****
% Land used by high density residential	0.010	*0.19*								
% Latino					0.281	*8.01*****	0.226	*4.89*****	0.273	*7.81*****
% African American					0.640	*8.96*****	0.650	*9.08*****	0.641	*8.99*****
% Asian Pacific American					0.504	*8.20*****	0.424	*5.60*****	0.504	*8.21*****
% Immigrated in the 1980s and 1990s							0.162	*1.81***		
Higher than expected percentage recent immigrants									0.048	*4.40*****
Adjusted *R*-squared	0.270		0.269		0.279		0.281		0.282	
N	7015		7015		7015		7015		7015	

*p < .20. **p < .10. ***p < .05. ****p < .01.

It is important to note two empirical caveats before discussing the policy implications of this analysis. First, this is a pure cross-sectional analysis: we do not discuss whether environmental health conditions are worsening or improving over time nor can we establish with the data at hand whether the current allocation of pollutant burdens is a result of residential choice or the placement of polluting facilities and roadways in minority neighborhoods. While some of our earlier statistical work has been more consistent with the facility placement hypothesis (see Pastor, Sadd, & Hipp, 2001), historical analysis suggests that there are probably both facility placement and residential change dynamics affecting the inequitable pattern of environmental disamenities in Southern California (Boone & Modarres, 1999; Pulido, Sidawi, & Vos, 1996). However, we should stress that inclusion of income and land use does not explain away the racially disparate pattern of cancer risks associated with air toxics, suggesting that the pattern may not be related to a simple explanation of market dynamics or so-called "minority move-in."

The second caveat is that we do not offer a straightforward causal model of the cross-sectional pattern. Like much of the other research in this field, we are essentially establishing a multivariate mapping of potential explanatory factors. Still, the fact that the racial pattern persists in a multivariate setting does offer some insight into the potential casual factors at play. Specifically, the tendency for race and other variables most often associated with a power-based explanation of environmental risk to be highly significant and robust to various specifications (including spatial controls) suggests that more attention may need to be paid to insuring that the voices of underrepresented communities are present in future policy debates over environmental regulation and zoning decisions.

In any case, the results have several implications for politics and policy. First, this analysis contributes to the mounting body of evidence regarding environmental inequities in pollution burdens in California. This adds fuel to a movement that has recently secured a series of legislative and administrative changes in the state, including several state assembly and senate bills dealing with environmental justice, children's health, healthy schools, persistent bioaccumulative pollutants, and other issues. It specifically suggests the importance of addressing cumulative impacts, because our results are based on considering toxics from both mobile and stationary sources. Although data gaps pose challenges for estimating the cumulative health risks associated with multiple pollutants and emission sources, some researchers and regulatory agencies have at least begun to think about how to integrate existing information on multiple environmental hazards in certain neighborhoods (Morello-Frosch & Jesdale, 2003). More research is clearly needed in this arena, particularly so that cumulative estimates could be better developed and considering when making decisions about facility siting, freeway expansion, and other measures likely to worsen exposure.

Second, the results suggest the importance of considering land use. While we have demonstrated that race, income, and other variables matter even when one controls for land use, zoning is itself a decision that is not neutral in its process or outcome. For example, decisions that lead an area to be designated as an industrial zone may set the stage for elevated risks. Currently, environmental health and justice concerns do not figure significantly in land-use planning protocols. Some environmental justice advocates have consistently argued that any development project or siting decision that would worsen environmental inequities should at least trigger a more comprehensive review that could be incorporated into an Environmental Impact Statement (EIS). In addition to assessing the existing cumulative pollution exposures and associated health risks in an impacted area, such an EIS analysis would also require consideration of the demographic composition and linguistic capabilities of the surrounding community as well as data on land use patterns and proximity of schools, hospitals, and other facilities used by populations that are particularly vulnerable to environmental pollution. These integrated approaches will not only improve environmental regulation but can also better inform the development of land-use policy instruments that would include more systematic consideration of equity issues in zoning decisions and land-use planning (for related policy ideas, see Jackson, 2002, Northridge, Sclar, & Biswas, 2003; McCann & Ewing, 2003; Ewing, Schmid, Killingsworth, Zlot, & Rauderbush, 2003).

Finally, the analysis suggests that efforts to increase public participation in environmental decision-making should focus on those groups, including immigrants, which seem most likely to be disproportionately burdened by pollution sources. In this regard, outreach efforts should address barriers of language and community capacity to effectively engage in the policy arena. These approaches to leveling the playing field in terms of power and voice could benefit everyone: preliminary research indicates that disparities in political power and residential segregation affect not only those who bear the net costs and benefits of environmentally degrading activities, but also the overall magnitude of environmental degradation (e.g., air pollution) (Boyce, Klemer, Templet, & Willis, 1999) and health risks (e.g., individual estimated lifetime cancer risk). Our own research confirms this, suggesting that increased urban segregation (both in the nation and the state of California) exacerbates racial inequalities in cancer risks associated with air toxics and results in higher pollution levels overall across all demographic groups with risk gradients increasing for each racial group by increasing levels of segregation (Morello-Frosch & Jesdale, 2003).

The state of California does seem to be moving in several of the policy directions suggested above, many of which are embodied in a new set of recommendation for the California Environmental Protection Agency issued by an Advisory Committee on Environmental Justice (Cal-EPA, 2003). In particular, the state is considering improving community participation and assessing cumulative exposure and impact. Related legislation has also taken up the issue of the best way to incorporate environmental justice concerns into revisions of the local general plans that govern land use. In all these areas, the agency, advocates, and industry stakeholders are calling for more research to be conducted so that the patterns demonstrated here can be appropriately benchmarked and addressed.

As the research proceeds, it is likely that continuing debates about risk estimates, spatial controls, and independent variables will occupy the attention of the academic community. Nevertheless, it is important to remember that behind these methodological debates lies what we believe to be a shared goal: how best to facilitate a fair distribution of environmental amenities and disamenties. For many communities in contemporary California, the grass is always greener and the air is always cleaner on the other side; the hope for the state's future is that new policies and practices will ensure an opportunity for all residents to have access to a healthy environment.

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WHICH CAME FIRST? TOXIC FACILITIES, MINORITY MOVE-IN, AND ENVIRONMENTAL JUSTICE

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ABSTRACT: *Previous research suggests that minority residential areas have a disproportionate likelihood of hosting various environmental hazards. Some critics have responded that the contemporary correlation of race and hazards may reflect post-siting minority move-in, perhaps because of a risk effect on housing costs, rather than discrimination in siting. This article examines the disproportionate siting and minority move-in hypotheses in Los Angeles County by reconciling tract geography and data over three decades with firm-level information on the initial siting dates for toxic storage and disposal facilities. Using simple t-tests, logit analysis, and a novel simultaneous model, we find that disproportionate siting matters more than disproportionate minority move-in in the sample area. Racial transition is also an important predictor of siting, suggesting a role for multiracial organizing in resisting new facilities.*

In recent years, policy makers have become increasingly responsive to the perception of racially inequitable exposure to various environmental hazards concerns. As early as 1994, a Presidential Executive Order directed all federal agencies to take into account the potentially disproportionate burdens of pollution or hazards existing in US minority communities. In 1998, the Southern California Air Quality Management District—charged with cleaning up the country's dirtiest air—decided, under pressure from grassroots activists, to create its own task force on environmental justice. One year later, the California legislature adopted a law directing the state's Office of Policy Research to develop environmental justice guidelines for California's

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various agencies, forcing a scramble among policy makers to better define both the problem and appropriate remedies.

Despite the ongoing response at the policy level, the research on disproportionate exposure by race has yielded mixed results. Making use of simple cross-tabulations, basic correlation analysis, and case studies, the earliest work in this field found that minority neighborhoods hosted a disproportionate share of the environmental hazards and toxins produced by an industrialized society (Bullard, 1990; UCC, 1987). Subsequently, some researchers found that race was not a significant factor when controlling for income, employee proximity, and other reasonable variables (Anderton, Anderson, Oakes, & Fraser, 1994; Anderton, Anderson, Rossi, et al., 1994). However, a more recent wave of research, also controlling for other explanatory factors, has tended to confirm the racial disproportionality hypothesis (see, for example, Been, 1995).

Virtually all of this research has amounted to a "snapshot in time" of the distribution of environmental hazards. Recognizing where hazards are and whom they might affect is of immediate utility to those public officials calculating health risks, planning emergency measures, or seeking to redevelop contaminated land. But such a cross-section analysis does not fully address a question of central concern to policy makers: Were the hazards disproportionately sited in minority communities or did minority residents move in after hazards were sited?

The debate between the "disproportionate siting" and "minority move-in" hypotheses matters greatly for urban and environmental policy. If the problem of disproportionate exposure by race is due to siting, then it would be appropriate for policy makers to revise zoning and permitting procedures to eliminate any elements of discrimination. But suppose the pattern emerges because the siting of hazards detracts from neighborhood livability and thereby diminishes land values, inducing an exodus of middle-class (often Anglo) homeowners and an influx of lower-class (often minority) residents. While health precautions would still call for buffers between industrial and residential uses as well as other safeguards, the notion that the process is market-driven may lead some to suggest that individuals are simply choosing to trade increased neighborhood health risks for slightly larger or better (in other ways) housing.

The role for policy in this view might be confined to: (1) ensuring access to data about neighborhood health risks so that individuals who choose to trade risk for affordable housing are not acting on incomplete information (see Burby & Strong, 1997), and (2) continuing the enforcement of existing statutes that limit the steering of minority house-seekers to particular neighborhoods. Indeed, if information is complete and housing discrimination is limited, then some might argue that there is little reason to be concerned about a contemporary pattern of disproportionate exposure; after all, market dynamics suggest that those neighborhoods with hazards will eventually become predominantly minority anyway.

Is the current pattern of environmental inequity a field of bad dreams: Build it and minorities will come? This article contributes to disentangling the role of disproportionate siting and minority move-in with a study of the temporal dynamics in Los Angeles County, a region where there is clear evidence of disproportionate contemporary exposure to toxic storage and disposal facilities (TSDFs), toxic air releases, and other environmental negatives (Boer, Pastor, Sadd, & Snyder, 1997; Burke, 1993; Sadd, Pastor, Boer, & Snyder 1999; Szasz, Meuser, Aronson, & Fukurai, 1993). We focus on TSDFs, facilities that operate under a U.S. EPA permit to store hazardous wastes (any non-petroleum substance which is ignitable, corrosive, reactive, or toxic) as defined in the Resource Conservation and Recovery Act of 1976. Most TSDFs are private, for-profit businesses that accept waste from other generating facilities.

We link the siting dates and addresses of Los Angeles' high-capacity TSDFs (those which handle more than 50 tons a year) to a database that tracks changes in selected socio-economic variables through the period 1970 to 1990, with all data geographically indexed to the 1990 census tract shapes. We subject the resulting data to a variety of tests, including logistic regressions to predict future siting and a simultaneous model that accounts for both minority move-in and disproportionate siting. The results indicate that disproportionate siting matters more than minority move-in within the sample area. The results also suggest that areas undergoing ethnic transition may be as vulnerable to siting as areas with older or more established minority populations. This finding reinforces the activist argument that residents should organize on a multiracial basis to resist increased exposure to environmental hazards.

The article proceeds as follows. The first section reviews previous studies and outlines our approach. The second section discusses basic trends in the data. The third section offers logit-style regressions that attempt to predict the likelihood that a hazardous site will be located in a particular area. The fourth section tests for the possibility of minority-move-in, both after the siting and during the period of siting. The final section concludes with possible lessons for both policy makers and activists.

LITERATURE REVIEW AND METHODOLOGY

There is now a burgeoning literature examining the pattern of contemporary location of environmental hazards (see the extensive review in Szasz & Meuser, 1997). While the evidence is often more mixed than many activists have believed, the bulk of the research does seem to point to disproportionate exposure to hazards in minority communities. The most recent work about California is strongly supportive of disproportionality in the Golden State. Morello-Frosch (1997), for example, focuses on hazardous air pollutants (HAP) at the county and census tract level and finds a consistent association between the percentage of minorities and both HAP concentrations and estimated likelihoods of pollutant-related cancer risk. Our own previous work (Boer et al., 1997; Sadd et al., 1999) explores the distribution of hazardous waste storage and disposal facilities (TSDF) and toxic air releases in Southern California and finds strong evidence of a racial pattern, even when controlling for reasonable variables such as land use, manufacturing employment, and income.

Many have assumed that contemporary inequity is the result of discriminatory siting practices. The general argument is that low levels of political power in minority communities may induce polluters to locate hazards in these areas (Hamilton, 1995). Such a political argument is often implicitly based on notions of social capital and community efficacy: Where residents have more ability to organize and affect policy, perhaps because of their income or racial status in a stratified society, they will be more able to resist the placement of a hazardous facility. Of course, social capital may in fact be affected by other factors, such as the level of education of residents or the ability to bridge differences between minority groups, a topic we explore below (see also Briggs, 1998; Temkin & Rohe, 1998).

An alternative argument suggests that disproportionate exposure simply reflects the market: Both minorities and undesirable land uses will be attracted to areas with lower housing values, and in fact, minorities may move in after the arrival of a new locally undesirable land use (Been & Gupta, 1997). In our view, this market-based account of minority move-in is unlikely, at least in Southern California; after all, if race still matters when income is held constant in a cross-section regression, then any disproportionate move-in of ethnic residents would seem to reflect different consumer tastes for exposure to this type of risk. In fact, however, one survey suggests that minority residents may be even more concerned about environmental risk, particularly in the contemporary period in which environmental justice has become a key organizing buzzword in selected communities (Burby & Strong, 1997). Still, the minority move-in argument persists and a more sophisticated version can incorporate the potential role of housing discrimination in limiting the locational opportunities for minorities.

Despite the importance of the issue, there is very little solid research on the dynamics of disproportionate siting versus minority move-in. Yandle and Burton (1996) provided an early longitudinal look at hazardous landfills in metropolitan areas in Texas but their work has been sharply criticized on methodological grounds (see, for example, Anderton, 1996; Mohai, 1996). More recently, Shaikh and Loomis (1999) looked at the decadal percentage change in minorities in Denver neighborhoods after the siting of a stationary source of air pollution. Not only did they find no evidence of minority move-in but they also found some evidence suggesting that communities without polluting sites experienced larger increases in the percentage of minorities; however, the areal units in their study are zip codes, a less uniform geography which has largely been eschewed in favor of census tracts in most recent research efforts.

Thus, the two most significant and reputable longitudinal studies are Oakes, Anderton, & Anderson (1996) and Been & Gupta (1997). The Oakes, et al. (1996) study uses the 1992 Environmental Services Directory to determine beginning dates for commercial TSDFs nationwide. Comparing tracts that received TSDFs over the 1970 to 1990 period to the rest of the county, the authors found no evidence of either disproportionate siting by race—or of a subsequent move-in of minorities that exceeds the pattern for areas with similar industrial characteristics. They then conducted a more formal multivariate regression analysis on the TSDF tracts and a stratified sample of non-TSDF tracts: neither race nor poverty was significant and the only variable with real predictive power was the percentage of local residents involved in industrial employment. As for post-siting changes, a TSDF tends to have a negative (not positive) impact on African American or Latino in-migration, albeit at an insignificant level. Thus, in both the simple comparisons and the multivariate setting, neither disproportionate siting nor minority move-in are shown to exist.

In a similar nationwide longitudinal study, Been and Gupta (1997) arrived at slightly different results. Like Oakes et al. (1996), they used a national sample and conducted multivariate regressions on tracts that received TSDFs and a stratified sample of tracts that did not. They also found no evidence for a market dynamics story of minority move-in subsequent to the siting of a TSDF. However, they did find that the percentage of Latinos had a significant impact on the likelihood of receiving a TSDF (as did the percentage of local industrial employees and population density). While this overall pattern of results tends to offer some weak support to the usual claims of environmental justice proponents, there is no evidence that the percentage of African American residents has an impact on siting and the percentage of residents in poverty is actually found to have a negative impact on 1980s sitings.

Our own approach involves several modifications from the previous studies. First, we look only at one region, Los Angeles County. This limited geographic scope is partly due to our view that the nature of hazards is related to the industrial clusters of a region—Los Angeles's furniture making and metal plating industries are not likely to drift north to Seattle, and Microsoft is not likely to move south to Los Angeles—so it is the distribution of hazards within a region that matters. Logistically, this regional focus also allowed us to obtain siting information from original business records and permit applications, as well as to accurately locate and verify each TSDF by conducting visits to actual facility locations. Focusing on one region also allowed us to employ a California Department of Finance (DOF) database that allocates certain variables from the 1970 and 1980 censuses, including ethnicity, to the 1990s tract boundaries. Therefore, we could consider all host and non-host tracts rather than a stratified sample as in earlier work.

A second difference is our use of geocoded site location and GIS procedures to determine affected tracts. Both Been and Gupta (1997) and Oakes, et al. (1996) focused on the demographic characteristics of tracts that contained TSDFs. Yet as Anderton, Anderson, Rossi, et al. (1994) and Anderton, Anderson, Oakes, et al. (1994) pointed out, TSDFs are often located near a tract boundary and a simple tagging of only the host tract will ignore the impact on immediately adjacent neighborhoods. Therefore we pinpointed the actual facility and used a circular buffer distance of one-quarter mile and one mile to define the potentially affected tracts and residential population. As a result of this procedure, there are slightly more affected tracts than there are TSDFs at the one-quarter mile level and, of course, even more affected tracts when we extend out to the one-mile circle.

Third, we go beyond previous work in considering the post-siting dynamics. With little theoretical justification, other researchers have tended to employ the same variable set to predict move-in as they did to predict siting; we instead nest our analysis of post-siting effects in a simple model of neighborhood demographic change. We also advance the field by constructing and testing a simultaneous (or two-stage least squares) model. After all, disproportionate siting and minority move-in often occur at the same time and a regression strategy that accounts for this may be the best way to estimate the separate effects.

Fourth, we focus on the effects of a new dimension of ethnic change. Previous work has stressed the percentage of minorities. But while a 40% increase in Latinos that is matched by a corresponding 40% decrease in African Americans may leave the percentage of minorities unchanged, the neighborhood will in fact be transformed. Such ethnic transitions may weaken the usual social bonds constituted by race and make an area more susceptible to siting. We investigate this "social capital" effect below, finding that it does indeed have an effect on the likelihood of receiving a TSDF.

Before presenting the methods and results, we should acknowledge several clear limits to our work and that of others. One is that we are testing for effects at the neighborhood level. Such a focus on the social ecology of an area does not mean that particular subpopulations or individuals are necessarily exposed in the same rate as their census tract; actual exposure can vary depending on a variety of factors. This neighborhood effects approach, however, is characteristic of almost all environmental justice studies, primarily for reasons of data collection (for an exception based on an original survey, see Burby, 1999; Burby & Strong, 1997). In addition, some epidemiological studies have demonstrated a significant relationship between residential proximity to hazardous waste storage facilities and increased health risk and disease, especially among pregnant mothers and infants (Berry & Bove 1997; Croen, Shaw, Sanbonmatsu, Selvin, & Buffler, 1997; Goldman, Paigen, Magnant, & Highland, 1985; Knox & Gilman 1997; see also Shaw, Schulman, Frisch, Cummins, & Harris, 1992).

A second related limit is that we do not really establish the actual risk associated with living near a TSDF. Once again, there are few efforts in the environmental justice literature that tackle actual risk; an exception is Morello-Frosch's effort to use public health methodologies to transform cumulative exposure to hazardous air pollutants into estimated cancer risk. However, few people believe that living near a TSDF enhances their quality of life and, as Burby and Strong (1997) argue, proximity to environmental negatives does seem to have a significant impact on perceptions of neighborhood quality. People are more likely to be alarmed about hazards when their sense is that they are being exposed involuntarily or that exposure is unfair. In short, the distribution of perceived risk and perceived fairness also matters.

Finally, while this study was conducted with as much rigor as possible, it still requires all the qualifications necessarily associated with the statistical work in this field. Most specifically, associating race with siting decisions, even in multivariate exercises, may establish pattern but it does not establish intent. The real rationales for location will need to be uncovered by specific case studies, of which there are a few excellent examples (see Boone & Modarres, 1999; Pulido, 1996). This study simply offers a framework of plausibility for the more detailed and qualitative work ahead for other researchers.

DATA SET AND BASIC TRENDS

The data set we use merges selected variables from the 1970, 1980, and 1990 censuses, all recalculated to the 1990 tract shapes, with information on the location and siting dates of TSDFs in Los Angeles County. Because many facilities obtained permits long after siting (partly because they were sited prior to current regulations or operated with interim permits), the recorded permit dates used in many studies are often inaccurate. To correct this, we filed a series of public records act requests to obtain the original forms identifying when any particular facility began operation. We focused on the high-capacity TSDFs—those that process or store at least 50 tons of hazardous substances annually. Although slightly less than half (39 of 83) of the TSDFs in the study area are classified as high capacity, these facilities handle nearly all of the hazardous waste among TSDFs in the region (644,136 of 644,511 total tons). Of these 39, our records search proved unable to identify the siting date of one of these facilities. Given the circular buffers, we ultimately examined 55 tracts in the quarter mile radius (for which there was at least 50 tons allocated to the tract when casting a circle of effect around the facility), and 245 tracts in the one-mile radius as of 1990, all within a county with 1,652 tracts.

Figure 1 shows all TSDFs in the county; Figures 2 and 3 plot two possible date-location combinations for the high capacity TSDFs (existed prior to 1970, or was placed 1970 to 1990) against median household income and percentage of minorities in 1990. There is a definite visual correlation between these socio-economic variables and the contemporary location of high-capacity TSDFs. This association is confirmed in the t-tests shown in Table 1. The focus in this article is on the high-capacity TSDFs so all references in the statistical tables and the following discussion are to the high-capacity variety only.

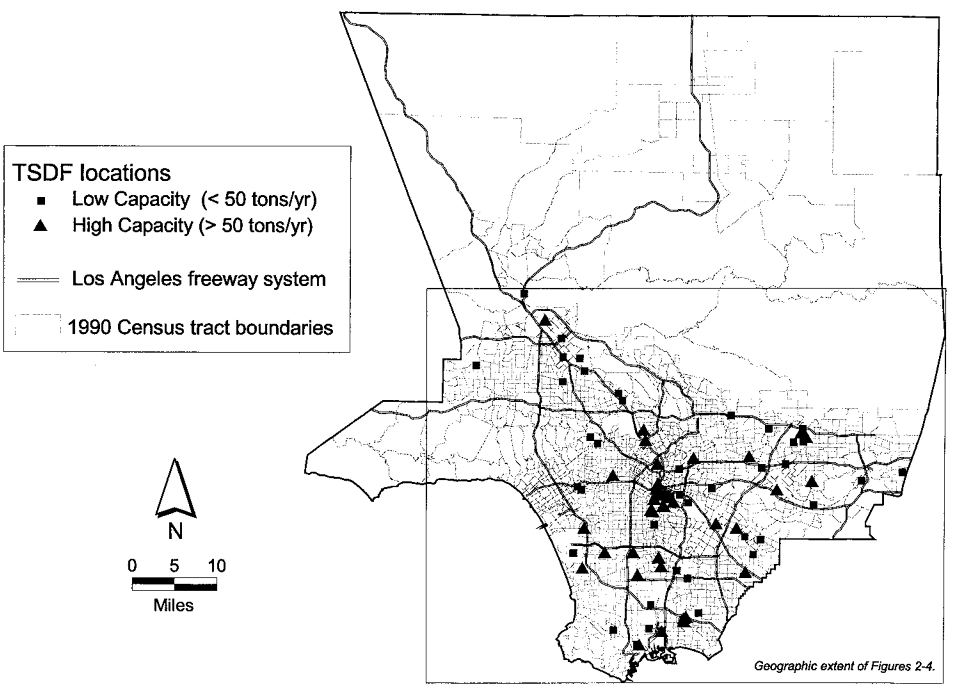

FIGURE 1

Locations of Hazardous Waste TSDFs in Los Angeles County, California (1993).

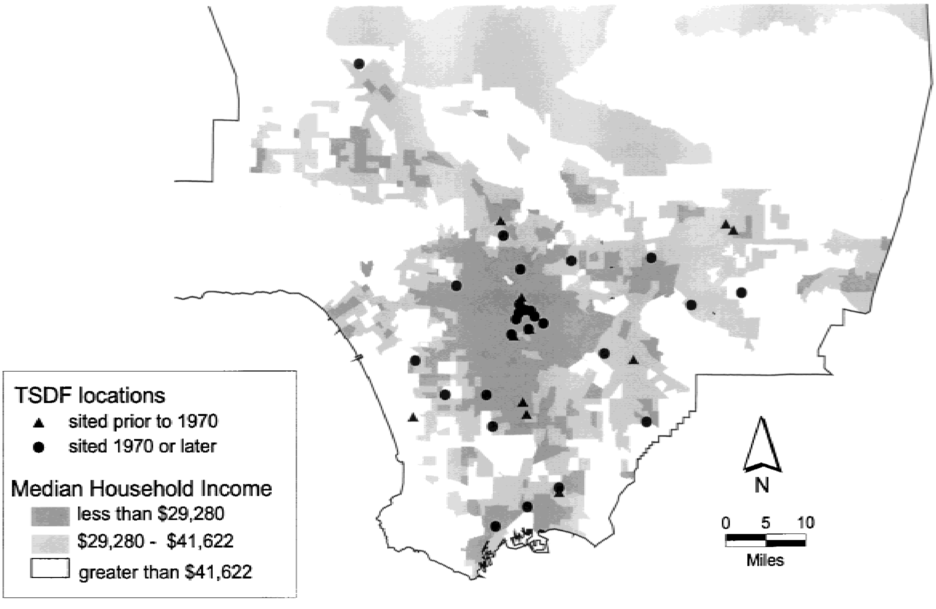

FIGURE 2

High Capacity Hazardous Waste TSDFs and Median Household Income, 1990, Los Angeles County, California

Note: Each category contains one-third of all Los Angeles County census tracts.

Note that Table 1 first offers the county average for the examined variables, then the difference between the values of those variables in affected and non-affected tracts, with significance levels for the differences immediately to the right; Tables 2 through 4 use a similar structure to present results. In 1990, tracts that contained or were proximate to TSDFs tended

TABLE 1

Comparing Tracts With and Without TSDFs in Los Angeles County as of 1990

Variable	Average	Within 1/4 mile of TSDF, 1980 (Difference)	Within 1 mile of TSDF, 1990 (Difference)
% Minority	56.3	25.5***	27.2***
% African American	11.0	7.6**	7.8***
% Latino	34.7	18.6***	18.5***
Household Income	$38,369	−$11,379***	−$9,796***
Home Value	$243,257	−$73,559***	−$70,571***
Median Rent	$629	−$137***	−$113***
% College Educated	22.0	−11.8***	−11.2***
% Single Family Housing	59.8	−6.9*	−2.8
Population Density	11,031.3	−2,192.4*	1,083.2*
% Blue Collar	40.7	15.3***	13.4***
% Manufacturing Emp.	20.4	5.7***	6.2***
N (depends on variable)	1636–1641	54–55	252–253

*p < .10. **p < .05. ***p < .01.

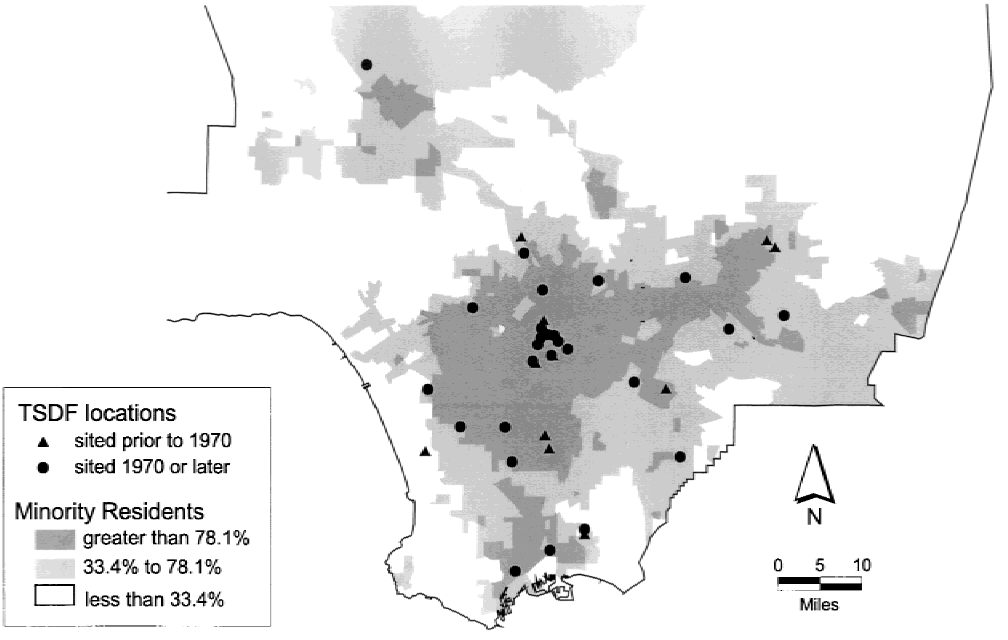

FIGURE 3

High Capacity Hazardous Waste TSDFs and Presence of Minority Residents, 1990, Los Angeles County, California

Note: Reported as percentage of African American, Asian-American, and Latino. Each category contains one-third of all Los Angeles County census tracts.

TABLE 2

Comparison of the Characteristics of Tracts That Would Receive a TSDF in 1970–90 With All Other Tracts in Los Angeles County in 1970

Variable	1970 Average	TSDF Sited Within 1/4 Mile Between 1970–90 (Difference)	TSDF Sited Within 1 Mile Between 1970–90 (Difference)
% Minority	31.8	22.2***	22.2***
% African American	10.8	15.4**	11.0***
% Latino	18.0	4.3	9.0***
Household Income	$10,032	−$1,908***	−$1,603***
Home Value	$26,042	−$4,621***	−$4,270***
Median Rent	$138	−23.0***	−21.3***
% College Educated	12.6	−4.9***	−5.2***
% Single Family Housing	64.4	−9.2**	−1.4
Population Density	8,724.1	−1933.9*	446.0
% Blue Collar	46.1	9.8***	9.4***
N (depends on variable)	1604–1640	34–35	161–164

*p < .10. **p < .05. ***p < .01.

TABLE 3

Demographic Changes in Tracts Following a TSDF Siting Versus Tracts Without a TSDF (over two decades following a siting)

		Received a TSDF between 1960–70	
Change from 1970–90	Average	Within 1/4 mile (Difference)	Within 1-mile (Difference)
Change in % Minority	24.6	0.2	−0.9
Change in % African American	0.2	−5.9	−3.9*
Change in % Latino	16.7	8.1	2.4
Increase in Household Income	275.5%	−9.5%	3.0%
Increase in Home Value	817.7%	−102.2%	−9.8%
Increase in Median Rent	361.9%	16.3%	11.8%
Change in % College Educated	9.4	−3.9**	0.1
Change in % Single Family Housing	−4.7	3.0	1.0
Change in % Blue Collar	−5.3	0.3	−3.0*
N (depends on variable)	1604–1640	10	46–47

*p < .10. **p < .05. ***p < .01.

to contain a higher percentage of minority and poor residents. They also had lower rents and house values. The proximate areas also were less educated and more blue-collar. The percentage of single-family housing units—used as a proxy for home ownership, a measure unavailable in the DOF database—is negatively correlated with TSDFs at the one-quarter mile radius. Population density is negative and significant in the quarter mile sample but is actually positive and significant in the one-mile sample; the finding is not consistent with the common sense notion that TSDFs might best be placed in less populous areas.

Of course, the real issue is whether the tracts were significantly different prior to TSDF siting. Table 2 uses the tract characteristics of 1970 to show that the areas that were to receive TSDFs over the 20 years contained more minority, poor, and blue-collar residents; note that the percentage of Latino residents was not significant at the one-quarter mile, achieving a significance level close to but not within the usual .10 cut-off. Receiving tracts were also less likely to have homeowners, at least in the one-quarter mile buffer. These areas also had lower initial home values and rents along with a lower percentage of college-educated residents, suggesting the important role that educational skills might play in resisting hazards. Population density was negative and significant for the one-quarter mile zone but positive (albeit insignificant) at the one-mile level. In short, many of the patterns reflected in the 1990 snapshot were present in the soon-to-be-affected 1970 tracts, a result consistent with a story of disproportionate siting.

What happened in tracts after a hazard arrived? Using our dating scheme, we looked at the changes from 1970 to 1990 in tracts that received or were near hazardous sites located in the 1960 to 1970 period, benchmarking against areas that did not receive such sites. As seen in Table 3, there is virtually no evidence of move-in: using the standard .10 cutoff, the only significant changes were a less rapid increase in the percentage of college educated residents in the one-quarter mile buffer, a decline in the percentage of African Americans, and a sharper fall in the percentage of blue-collar workers in the one-mile radius. While generally insignificant, the sign pattern does suggest that Latinos may have been replacing African Americans in these newly toxic areas.

However, since one might expect these and any other shifts to emerge rapidly, Table 4 examines changes in the next decade, first for those areas receiving sites in the 1960s and then

TABLE 4

Demographic Changes in Tracts Following a TSDF Siting Versus Tracts Without a TSDF (over decade following a siting)

		Received a TSDF between 1960–70	
Change from 1970–80	Average	Within 1/4 mile (Difference)	Within 1-mile (Difference)
Change in % Minority	14.2	3.1	2.5
Change in % African American	2.0	−1.0	1.4
Change in % Latino	8.1	4.0	0.2
Increase in Household Income	91.6%	−8.3%	−2.2%
Increase in Home Value	254.0%	−34.5%*	−16.9%*
Increase in Median Rent	99.7%	−10.26	−6.0%
Change in % College Educated	5.1	−3.0*	−0.6
Change in % Single Family Housing	−2.4	−0.9	0.7
Change in % Blue Collar	−1.8	1.8	−2.2*
N (depends on variable)	1604–1639	18	46–47
		Received a TSDF between 1970–80	
Change from 1980–90	Average	Within 1/4 mile (Difference)	Within 1-mile (Difference)
Change in % Minority	10.3	0.6	1.7**
Change in % African American	−1.8	0.1	0.2
Change in % Latino	8.6	1.2	0.6
Increase in Household Income	96.9%	−9.8%*	−3.2%
Increase in Home Value	159.1%	15.9%	8.1%**
Increase in Median Rent	133.7%	−0.1%	3.6%
Change in % College Educated	4.3	−2.6**	−2.4***
Change in % Single Family Housing	−2.3	−4.8	−0.6
Change in % Blue Collar	−3.5	0.6	0.8
N (depends on variable)	1616–1640	28–30	128–132

*p < .10. **p < .05. ***p < .01.

for those receiving sites in the 1970s. For the first group, there are a few moderately significant changes in the next decade at the one-mile level: Housing values did rise less rapidly for both radii while the percentages of college educated and blue-collar workers fell in relative terms for the one-quarter mile and one-mile buffers respectively. In the tracts that received hazardous sites in the 1970s, the next decade brought less rapid increases in household income at the one-quarter mile, declines in the relative presence of college-educated in both buffers, and a relative increase in the percentage of minorities at the one-mile level. Strikingly, however, household values actually rose more rapidly for those homes falling in the one-mile zone.

As suggested above, a focus on the percentage increase in minorities can ignore interethnic shifts. Black to Brown shifts have been especially prevalent in South Los Angeles, an area laden with hazardous or toxic facilities and air pollution. The sign pattern in the 20-year profile (positive for Latinos, negative for African Americans) suggests that some of these changes may have been occurring in tracts closer to high-capacity TSDFs. Such shifting neighborhood patterns can cause tensions between minority groups, weakening neighborhood social capital and increasing the area's vulnerability to siting locally undesirable land uses. To avoid missing this important phenomenon, we devised a measure that calculates the absolute sum of ethnic changes—for example, an increase in Latinos of 20% of the total population and a decrease in African Americans by the same amount yields a value of 40% rather than the zero obtained when calculating the percentage increase in minorities. We label this measure of dynamics within a census tract “ethnic churning.”

We only have measures for such churning for the 1970s and the 1980s. Starting with the one-quarter mile sites, we find that there is significant ethnic churning during the decade of a TSDF siting (in the 1970s or the 1980s) but no significant evidence of churning in either the decade before or the decade after. A more interesting pattern emerges when we utilize a one-mile radius. We find a significant degree of ethnic churning in the soon-to-be affected tracts in the decade before the siting (for 1980s sites, as this is the only group for which we have ethnic change data for the previous decade). In the decade of the siting, the one-mile tracts have more ethnic churning than the unaffected tracts. By the decade after the siting, the difference between affected and unaffected tracts has fallen in value and is significant only for sitings in the 1970s. By the second decade after the siting (for facilities placed in the 1960s) there is virtually no difference in the ethnic churning occurring between affected and unaffected tracts. The overall pattern seems to indicate that such demographic transition actually begins in the decade prior to the siting and then slowly fades as the tract transforms ethnically to a new character, a finding that is consistent with our presumption that such transitions may make areas politically weak and hence vulnerable to the siting of TSDFs. To address this possibility, we explore the issue more formally in the multivariate regressions below.

To sum, while there is some evidence for the move-in hypotheses—a significant increase in minorities in one of the ten-year periods, a slower increase in housing values in another of the time periods examined, and some degree of ethnic churning—both the general pattern of insignificance and certain contradictory results (including a relative decrease in blue collar workers, a relative increase in housing values in one period, and a move-out of African Americans over the 20-year period) suggest problems with the market dynamics story. In general, the disproportionate siting hypothesis holds up much better in these simple t-tests, lending more credence to the proponents of environmental justice than to the market dynamic doubters.

MULTIVARIATE ANALYSIS OF SITING

While the bivariate analyses are suggestive, the fact that areas that received TSDFs were both poor and minority makes it difficult to determine whether race had an independent effect. To estimate this separate effect, we need a multivariate procedure in which various characteristics of a tract in 1970 are used to jointly predict the arrival of a hazard in a subsequent period. Building on a model developed by Boer et al. (1997) to test for contemporaneous correlation, we performed a logit regression in which the dependent variable took the value of one if a tract was to receive a nearby TSDF in the 1970 to 1990 period. We considered only areas that were not yet hosting TSDFs at the beginning of the period, implying that the sample is reduced further for the one-mile radius (as we must exclude tracts that were within one mile of existing TSDFs). An alternative strategy of considering all tracts yields nearly identical results and is used, for example, when we attempt to determine if the preexistence of a hazard has a positive effect on attracting another hazard.

The independent or explanatory variables were drawn from the 1970 census material. To avoid collinearity, we pared down the explanatory variables to the percentage of single family housing, population density, median household income, and the percentage of minorities. The first variable is a proxy for home ownership, with our hypothesis that homeowners, having made financial and social investments in a neighborhood, are more likely to resist the siting of a TSDF; as such, it is an indirect measure of one dimension of social capital. Population density is expected to have a negative effect, both because reasonable public health strategies would suggest that dense areas should be avoided and because density can be a (negatively correlated) stand-in for industrial land use, a variable unavailable to us in the 1970 sample. As for income, we expected a U-shaped function: Often, the lowest income areas lack pollution because they lack economic activity, the wealthiest areas avoid pollution because of political power, and the burden falls most heavily on working-class areas (Been, 1995; Szasz & Meuser, 1997). Finally, the percentage of minorities is, according to environmental justice advocates, expected to have a positive impact.

As seen in Table 5, all of our variables were appropriately signed and reasonably significant (although the income variables attained only a .20 significance level at the one-quarter mile radius, a fact not indicated in the table as the standard cut-off for significance is .10). The percentages of African Americans and Latinos were significant when entered separately (as noted in the columns marked Model 2). To check whether a location that had already been polluted by previous siting was more attractive (or offered less resistance to) future sites, we also conducted regressions in which we entered a dummy variable for the pre-existence of another TSDF. To economize on space the results are not shown in the table. Previous presence was significant but this produced only modest shifts in coefficient values and had no effect on the pattern of significance for the other variables, including the percentage of minorities. The overall pattern seems to support those who have contended that siting may have been disproportionately concentrated in minority areas.

We also experimented with a quadratic specification for African Americans and Latinos, in which, consistent with our specification of income, the ethnic variables assume a curvilinear relationship with a peak value. In logit regressions using 1970 data to predict siting in the next 20 years, the Latino quadratic specification was always significant but the African American attained mixed significance. At the one-quarter mile radii, peak vulnerability during the 1970s occurred when a tract was 44% African American and 48% Latino. This is consistent with homophily hypothesis of sociology, which predicts that ties are most likely to form among individuals with similar characteristics (Blau, 1977). In historically or uniformly ethnic areas, this particular social capital can be deployed to resist siting; in areas where minority presence

TABLE 5

Logit Results Predicting Siting of a TSDF

Variables (as of 1970):	TSDF placed Within 1/4 mile 1970–90 (Model 1)	TSDF placed Within 1/4 mile 1970–90 (Model 2)	TSDF placed Within one mile 1970–90 (Model 1)	TSDF placed Within one mile 1970–90 (Model 2)
% Single Family Housing	−0.0292***	−0.0307***	−0.0092**	−0.0109**
Population Density	−0.0002***	−0.0002***	−0.00006***	−0.00006***
Household Income	0.0588	0.0606	0.0812***	0.0810***
Household Income squared	−0.0003	−0.0003	−0.0004***	−0.0004***
% Minority	0.0327***		0.0295***	
% African Americans		0.0332**		0.0274***
% Latinos		0.0270*		0.0340***
Observations	1610	1610	1540	1540
Log Likelihood	293.2	295.1	939.7	947.6
Nagelkerke R^2	0.164	0.158	0.129	0.119

*p < .10. **p < .05. ***p < .01.

is high but split and changing between African American and Latino groups, there may be little communication and more vulnerability.

Minority Move-In versus Disproportionate Siting

What about the effects of siting on minority move-in? To determine the pattern, we first devised a simple model of tract-level increases in the percentage of minorities. For right-hand side variables, we included the Anglo percentage of the population and a quadratic for Anglo population. The curvilinear relationship arises because tracts with few Anglos have little room left to add minorities; tracts highly populated by Anglos tend to resist minority move-in through various mechanisms, and peak minority movement occurs somewhere between these two extremes (Massey & Denton, 1993). We also included home value and median rent, expecting lower values of each of these to attract minority movers, partly because such movers have low income and partly because lower values might reflect the impacts of housing discrimination. We also included a measure of residential stability (proxied by those residing in the same house five years previously), expecting a negative relationship because areas with more stability will generate fewer vacancies.

Table 6 indicates that the basic model performs quite well, yielding a reasonable R^2 and high significance for all the variables. We then added an independent variable that takes a value of one if the tracts received a TSDF before 1970, and zero otherwise (within one-quarter or one-mile radii as appropriate; see Models 2 and 3 in Table 6). At the one-quarter level, the variable enters negatively, albeit insignificantly: Controlling for other factors, the existence of a TSDF seemed to lead to some modest minority move-out, a result similar to Oakes, et al. (1996). The variable is actually positive but insignificant at the one-mile level.

Consistent with the earlier t-tests, we then looked at the effects in the decade immediately following siting on the presumption that effects might show up rapidly. For the 1970s, the sign for 1960s siting is insignificant and, therefore, is not reported. In the 1980s, receiving a TSDF within one-quarter mile during the 1970s had a negative and insignificant impact while receiving a TSDF within one mile had a positive but insignificant effect on minority move-in (see Table 7). When we control for the previous decade's change in the percentage of minor-

TABLE 6

Regression Results Predicting Minority Move-In from 1970–90

Variable	Change in Minorities 1970–90 (Model 1)	Change in Minorities 1970–90 (Model 2)	Change in Minorities 1970–90 (Model 3)
% Anglo population-beginning of decade	1.425***	1.426***	1.425***
Anglo population squared-beginning of decade	−0.011***	−0.011***	−0.011***
Median Home Value-beginning of decade	−0.135***	−0.135***	−0.134***
Median Rent-beginning of decade	−0.096***	−0.096***	−0.096***
% Reside Same House-end of previous decade	−0.179***	−0.180***	−0.179***
TSDF within 1/4 mile in 1970		−1.578	
TSDF within one mile in 1970			0.237
Observations	1584	1584	1584
F-Test	219.607***	182.943***	182.895***
Adjusted R^2	0.408	0.408	0.408

*p < .10. **p < .05. ***p < .01.

TABLE 7

Regression Results Predicting Minority Move-In from 1980–1990

Variable	Change in Minorities 1980–90 (Model 1)	Change in Minorities 1980–90 (Model 2)	Change in Minorities 1980–90 (Model 3)	Change in Minorities 1980–90 (Model 4)
% Anglo population-beginning of decade	0.764***	0.760***	0.597***	0.596***
Anglo population squared-beginning of decade	−0.007***	−0.007***	−0.005***	−0.005***
Median Home Value-beginning of decade	−0.051***	−0.052***	−0.058***	−0.059***
Median Rent-beginning of decade	−0.010	−0.009	−0.017**	−0.017**
% Reside Same House-end of previous decade	−0.035***	−0.035***	0.002	0.002
TSDF siting within 1/4 mile during 1970's	−0.288		0.039	
TSDF siting within one mile during 1970's		0.859		0.499
Change in minorities-previous decade			0.195***	0.195***
Observations	1618	1618	1617	1617
F-Test	227.193***	227.772***	235.214***	235.419***
Adjusted R^2	0.456	0.457	0.504	0.504

*p < .10. **p < .05. ***p < .01.

ities, siting has a positive effect but the coefficient values are quite small while the change in minority percentage in the previous decade is quite significant, a pattern which suggests that neighborhoods may become more open to minority house seekers as a result of an earlier move-in—or that the prior processes of disproportionate siting and demographic transition were simultaneous.

To estimate such a simultaneous model involves two-stage least squares regressions. Because our predictive equation for the effects of minorities on siting was a binomial logit, we first calculated it as a linear probability model to determine whether the relationship would be amenable to the two-stage approach; as expected, the adjusted R^2 fell since the linear probability fit is much less exact but the variables were signed correctly and the minority variables were actually stronger. We then estimated the determinants of TSDF siting over the 20-year period, including as a factor the change in the percentage of minorities over that same period; we simultaneously estimated minority move-in, adding in a variable indicating the siting of a TSDF over the same period. We ran variants of this model, including one in which the prior siting of a TSDF was allowed to influence the future siting of a TSDF, and one in which we considered only those tracts receiving a TSDF for the first time. As the results were broadly similar, we focus on the latter results to maintain consistency with the previous tables.

Table 8 presents the results of this exercise. Note that we now use the pre-existing percentage minority and percentage minority squared in the move-in regression (rather than Anglo percentage) to maintain consistency with the siting regression. As evident in Table 8, an increase in percentage minority tends to attract a TSDF in both the one-quarter and one-mile radius (again, the R^2s are low because we have moved from a binomial to a linear probability model) while the siting of a TSDF, holding other factors constant, actually tends to lead to minority move-out not move-in. Given the earlier t-test comparisons on Latinos, we also estimated a model in which the key variable was the change in percentage Latino and non-Latino; the results also did not indicate move-in in the context of controlling for other factors. The overall pattern is not supportive of the market dynamics account of the contemporary location of TSDFs.

To see whether a change in the ethnic composition of an area—even if it remains minority—weakens social capital and makes areas more vulnerable to disproportionate siting, we re-estimated the model by using ethnic churning during the 1970s and 1980s and TSDF siting over the same period. Table 9 shows the results parallel those reported earlier for the change in the percentage of minorities: Ethnic churning during these two decades is a strong predictor of a concurrent siting of a TSDF, with the one-quarter mile effect of ethnic change on siting only narrowly missing significance (it is significant at the .104 level) while the income specification is significant at the .20 level (not shown in Table 9 because of the standard .10 cut-off). The churning variable is highly significant at predicting TSDF siting at the one-mile level while TSDF siting has a negative effect on ethnic churning for both radii. The representation of this can be seen in a map of Los Angeles County (Figure 4) which overlays the location of TSDFs over the 1970s and 1980s with a breakdown of tracts by their degree of ethnic churning. There is a remarkable visual correlation between the two.

POLICY IMPLICATIONS

This study examined the issue of whether the pattern of disproportionate exposure of minorities to toxic storage and disposal facilities (TSDFs) reflects the disproportionate siting of such TSDFs or whether the contemporary situation results from a subsequent move-in of minority residents, at least in Los Angeles County. Initial t-tests suggest that areas that were soon to receive TSDFs were low-income, minority, and disproportionately renters; after they received these hazards, their gain in minority residents did not generally outpace that of the rest

TABLE 8

Inflow of Minorities and Siting of TSDFs in a Simultaneous Model

Variables (beginning of period)	TSDF siting w/in 1/4 mile 1970–90	Change in % Minorities 1970–90	TSDF siting w/in 1/4 mile 1970–90	Change in % Minorities 1970–90
% Single Family Housing	−0.0007***		−0.0008**	
Population Density	−0.000004***		−0.000005***	
Household Income	0.0006		0.0025***	
Household Income Squared	−0.000001		−0.000006***	
Median Home Value		−0.1337***		−0.1289***
Median Rent		−0.0958***		−0.1020***
Reside Same House Past 5 years		−0.1792***		−0.1202**
% Minority	0.0011***	0.8895***	0.0042***	1.0852***
Minorities squared		−0.0118***		−0.0131***
Change in % minorities, 1970–90	0.0008*		0.0034***	
Siting of a TSDF, 1/4 mile, 1970–90		−85.704***		
Siting of a TSDF, 1 mile, 1970–90				−51.039**
Observations	1566	1566	1499	1499
Adjusted R^2	0.027	0.290	0.068	0.219
F-Value	8.297***	107.652***	19.190***	70.979***

*p < .10. **p < .05. ***p < .01.

TABLE 9

Ethnic Churning and Siting of TSDFs in a Simultaneous Model

Variables (beginning of period)	TSDF siting within 1/4 mile 1970–90	Ethnic Churning 1970–90	TSDF siting within 1/4 mile 1970–90	Ethnic Churning 1970–90
% Single Family Housing	−0.0007***		−0.0007***	
Population Density	−0.000004***		−0.000005***	
Household Income	0.0008		0.0033***	
Household Income Squared	−0.000002		−0.000008***	
Median Home Value		−0.3026***		−0.2850***
Median Rent		−0.1855***		−0.2008***
Reside Same House Past 5 years		−0.5166***		−0.3772***
% Minority	0.0009***	1.1067***	0.0035***	1.6932***
Minorities squared		−0.0115***		−0.0157***
Dynamic Variables				
Change in ethnic comp., 1970–90	0.0006***		0.0023***	
Siting of a TSDF, 1/4 mile, 1970–90		−148.686***		
Siting of a TSDF, 1 mile, 1970–90				−117.041***
Observations	1566	1566	1499	1499
Adjusted R^2	0.027	0.178	0.064	0.112
F-Value	8.100***	57.502***	18.211***	32.531***

*p < .10. **p < .05. ***p < .01.

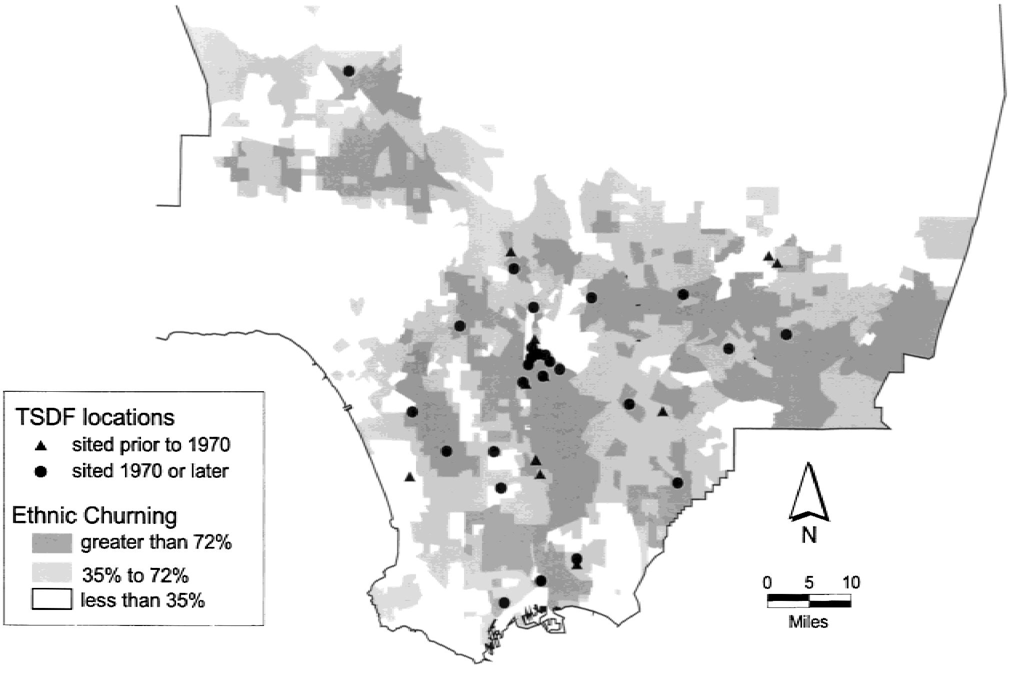

FIGURE 4

High Capacity Hazardous Waste TSDFs and Ethnic Churning, 1970–1990, Los Angeles County, CA Note: Derived from 1970, 1980, and 1990 census data. Each category contains one-third of all Los Angeles County census tracts.

of the sample. Logit regressions confirmed that demographic variables seemed to matter in the future siting of a TSDF; linear regressions on the changing demographics of census tracts suggest that TSDFs do not generally tend to induce minority move-in. Finally, a simultaneous model that tries to account for the contemporary siting of a hazard and the move-in of minorities also suggests that demographics matter in siting while siting generally has an unexpected effect on demographics, disproportionately repelling rather than attracting minority residents.

The central lesson from our various statistical tests is consistent: Controlling for other factors, minorities attract TSDFs but TSDFs do not generally attract minorities. Of course, even if minority move-in is not the primary determinant of the current pattern of hazards in Los Angeles, we see little harm in ensuring that full information about toxic or potentially hazardous sites is provided to homeowners (perhaps as part of real estate disclosure forms that are required by law to indicate flood zones in most states, and on-site environmental hazards in California) so that their decisions are fully informed. There is obviously also a need to combat housing discrimination and the steering of minority homebuyers and renters.

However, to the extent that other studies confirm disproportionate siting as a causal factor, it may be useful to re-examine zoning and other practices along several different dimensions. The first is simply public participation in the siting process. While one leading critic of the environmental justice movement has suggested that community participation can lead to "theatrics" (Foreman 1998, p. 45), Cole (1992) argues that it can be effective at generating compromises and ensuring that an informed community can monitor post-siting environmental hazards.

In California, there is a mechanism for participation in siting TSDFs under the 1986 Tanner Act that mandated that governments develop local assessment committees reflecting the makeup of the community that would interact with facility proponents early in the siting approval process (Schwartz & Wolfe, 1999). However, critics argue that such committees are often unrepresentative of the immediately affected population, in part because committee selection is determined by a larger government unit (for example the county) which may be poised to capture the economic benefits even though the costs will be concentrated in particular neighborhoods (Cole, 1999).

Schwartz and Wolfe (1999), therefore, recommend changing the process to ensure that more members come from the immediately adjacent neighborhood. We concur but also stress that public participation presents a conundrum: Expecting the currently unorganized communities most likely to receive hazards to be able to conduct an effective public campaign to protect their interests is optimistic. Moreover, hazard-by-hazard organizing is time-consuming and can put communities in a reactive rather than proactive mode. This suggests the need to develop some baseline standards that can protect those least able to defend their own interests.

Suppose, for example, that new TSDFs were disallowed in any location where the effect would be to worsen the existing distribution of hazards by race or income. This is a minimal standard. Since 1990, the census tracts within one-quarter mile of a TSDF had, on average, a population about 25% more minority than in the rest of the county. By this standard, therefore, the only areas greenlined should be those that were more than 25% above the rest of the county. Thus, such a rule would not significantly reverse existing inequities but simply prevent them from getting worse.

To explore the impacts of this greenlining rule, we took the average income and percentage of minorities for the tracts with existing TSDFs in 1970 and designated tracts with either a lower income or more minorities as areas to be avoided during the 1970s. We then did the same calculation for 1980 to arrive at the greenlined areas for that decade. By this standard, just over half of the TSDFs sited in the two decades were in avoidance areas and might have been disallowed.

Given the current strict regulatory environment and increased public opposition to such perceived hazards, whether real, potential, or perceived, no new high-capacity TSDFs have been sited in southern California since 1988. This essentially locks in the current disproportionate pattern of location of these potential hazards. The emphasis now is on clean up and rehabilitation, with brownfields efforts receiving support from federal, state, and local governments. In these efforts, special attention could be paid to the greenlined areas as a way to remedy a past pattern of disproportionate siting. In a similar vein, Burby and Strong (1997) recommend targeting information to those who may most need it, such as communities that are the most distrustful because of a past experience with disproportionate siting.

This study offers a lesson consistent with the experience many environmental justice advocates: Demographics reflecting political weakness—including a higher presence of minorities, a lower presence of home owners, or a significant degree of ethnic churning—seem to be the real attractors of TSDFs. A special challenge is posed by the fact that areas undergoing transition and unable to lay claim to pre-existing racially based social capital may be especially vulnerable. If this is so, then the current strategy of most of the environmental justice movement—building social capital across ethnic lines by an explicit commitment to a people of color movement—may be an effective way to combat the environmental degradation often found in urban minority communities.

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In the Wake of the Storm

Environment, Disaster, and Race After Katrina

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In the Wake of the Storm: Environment, Disaster, and Race After Katrina

Executive Summary

Hurricane Katrina opened a window on a world of hurt often ignored by media, policymakers, and the public. Facing enhanced environmental vulnerability and stranded by a lack of public transit, residents of the poorest and blackest neighborhoods of New Orleans quickly educated America that disasters and rescues are not equal opportunity affairs.

Among the few not shocked by the stark images splashing across television screens were scholars and activists in the field of environmental justice (EJ). These researchers study chronic risk, generally finding that lower-income minority communities, like those of New Orleans' Lower Ninth Ward, are disproportionately exposed to hazards and other disamenities. Katrina, it seemed, simply reflected environmental injustice in an accelerated and accentuated mode.

Does environmental disparities by race and class really exist? Researchers have gone back and forth, with early studies supplanted by newer studies supplanted by still newer studies. Although the evidence is still emerging, the best assessment is that disparities are common, and researchers increasingly suspect that some observed differences in health outcomes are attributable to environmental factors, particularly in combination with social stressors related to poverty and lesser access to health care. And it is not just income: race seems to be a more significant predictor in many studies, suggesting the importance of deeply rooted systems of privilege and discrimination.

Minority and low-income Americans are also more likely to be underserved by government and private relief agencies before, during, and after environmental calamities such as Katrina. Before a disaster, minorities are more likely to be underprepared and underinsured, and to be living in unsafe, substandard housing. During a disaster, minorities and the poor are often—due to economic and language barriers—less exposed to disaster warnings, and more likely to encounter ethnic insensitivity from relief workers and government officials. After a disaster, minorities and low-income individuals suffer slow recoveries not only because they have less insurance and lower incomes, but also because they receive less information, fewer loans, and less government relief, and encounter bias in the search for long-term housing.

This sort of "second disaster" for those with scantier economic and political resources seems to be playing out in the aftermath of Katrina. Many in the low-income neighborhoods ravaged by the hurricane are concerned that federal, state, and local officials will not prioritize their communities for cleanup and reconstruction, and worry that New Orleans will become little more than a theme park for tourists. Responding proactively to the impacts of Hurricane Katrina requires an eco-social approach—one that makes explicit the connections between public health, the environment, and social inequality.

Beyond Katrina, we need to revamp both disaster preparedness and environmental policy. There has been some progress; public and private agencies have disseminated information in more languages, hired diversity experts to educate their officials and staff, and provided increased support for disaster research. But little of that seems to have rubbed off on Federal Emergency Management Agency (FEMA) in its response to Katrina, and the U.S. Department of Housing and Urban Development has not stepped up to offer the housing vouchers for poor victims that were so effective in the wake of the 1994 Northridge California quake.

Likewise, progress on a more inclusive environmental policy has been made at the state level but seems to be stalling at the national level. The U.S. Environmental Protection Agency (EPA) has re-

versed course from the two previous administrations and sought to both take the focus off race in regulatory enforcement activities and diminish the annual collection of pollution emission data that researchers, communities, and industries use to monitor firm-level environmental performance.

If there is a will to do better, there are ways. Seizing the opportunity opened by Katrina is possible. The differential effects of this disaster were neither natural nor an accident. They were consistent with a pervasive continuum in which low-income and minority communities suffer from both higher socioeconomic stress and greater environmental exposures to air toxins, hazardous wastes, and other environmental disamenities.

Furthermore, it is not just poor and minority communities that are at risk. A hazardous facility can be sited in someone else's backyard, but research shows that the effects soon spill over into other neighborhoods. Establishing fairness as a guidepost for disaster and environmental planning is not just the right thing to do—it may be the best thing for protecting the well-being of all Americans.

Katrina did open a window on a dark side of America—the economic and environmental vulnerability of low-income people and minority communities. We can close that window, or we can use the new view to chart a better, healthier, and more equitable future for us all.

In the Wake of the Storm: Environment, Disaster, and Race After Katrina

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Introduction: Lifting the Veil

On Monday, August 29, 2005, the gale force winds of Hurricane Katrina swept across the Gulf Coast. Although the hurricane's wind and water pummeled many parts of Louisiana, Mississippi and Alabama, the eyes of the nation were focused on New Orleans, a city where a complicated system of levees and canals had been designed to prevent any storm from flooding neighborhoods and districts. Unfortunately, as some analysts had warned, the levees were not up to the challenge of Katrina, and breaks quickly appeared, flooding the city, and creating a humanitarian crisis of extraordinary proportions.

Even as Katrina was sweeping away businesses, homes, and lives, a stark set of images of desperate and seemingly abandoned residents began to shatter many of the illusions Americans usually associate with disasters. The first of these was that the government would always be there as an effective safety net. Amidst the confusion of coordinating various governmental agencies and a slow and now much criticized federal response, stranded individuals and families were often left to fend—or not fend—for themselves. The inadequacy of federal, state, and local efforts led to a growing wave of criticism and cynicism about government capacity. Partly as a result, the director of the Federal Emergency Management Agency first stepped down from heading the Katrina relief effort and then resigned from the agency.

The second illusion that Katrina swept away was the traditional belief that natural disasters are a sort of equal opportunity affair—acts of God that affect us all. But as the government's emergency rescue and recovery efforts floundered, particularly in beleaguered New Orleans, the country began to realize that this was not the case. It was a largely African American and often poor populace that had lived in the areas most vulnerable to the collapse of the levees, that proved unable to secure transportation to evacuate the city, and that was now scrambling in frightening conditions to secure scarce aid for their families, their friends, and themselves. Both the impacts of and response to disaster, it seemed, were heavily affected by income and race.

Although this seemed a revelation to many reporters and politicians, one group of researchers and activists were far less surprised: those who had been laboring in the field of what is called environmental justice (EJ). Born of an intersection of emerging social movements, technological advances in geographic information systems and spatial statistics, and a growing policymaker interest in disproportionately affected communities, the environmental justice field has generally focused on the distribution of environmental costs and benefits. Although data issues and methodological disputes remain, an array of case studies and large-scale statistical analyses had long been suggesting that disparities in environmental conditions were a worrisome norm in many parts of the United States—including Louisiana, a place where a disproportionate share of African Americans were already living in a petrochemical corridor best known by a frightening nickname, "Cancer Alley."

What is environmental justice and how does it offer a prism for thinking about disaster vulnerability? How solid is the evidence of environmental disparity—and is the seeming inequity in exposure and effects from Katrina consistent with evidence from other disaster experiences? And, given these patterns, what are the policy implications for environmental regulation, emergency preparedness, and disaster recovery?

In this report, we offer a review of the existing literature and research on the relationship between race, the environment, and large-scale disasters. Our central points are simple. First, environmental inequities by race and often by income seem to be an established part of the American urban landscape—Katrina simply tore back the cover on this unfortunate fact. Second, disasters reflect what might be termed acute risks that, like the chronic risks targeted by environmental justice analysis, are often distributed in a way that reflects established chasms of power. Third, this uneven distribution of risk may impose heavy and unfair costs on certain populations and seems as well to lead to an overall underinvestment in prevention and preparedness, thus increasing burdens for the society as a whole. Making environmental justice principles part of preparedness and environmental policy, in short, is not simply the right thing to do—it is the prudent thing to do.

We begin our analysis by briefly reviewing the Katrina emergency using it as a platform for understanding the conceptual frameworks used in environmental justice research and the field of disaster studies. We suggest that disaster prevention is a classic "public good" with all the attendant issues: free riders who enjoy benefits but pay few costs, the consequent privatization of benefits and costs, and the skewed distribution of risk that results. The disaster studies field has long stressed the importance of socioeconomic factors in such skewed distributions, but the environmental justice framework offers new insights into the roles of race and power as well as of the market. Moreover, the broad view of the environment associated with the environmental justice paradigm—which includes not only exposure to lower air quality and proximity to hazards but also the distribution of transportation access and housing—makes the framework a good fit for understanding the impacts of disasters and their aftermath, including policies for preparedness, relief, and reconstruction.

We then look at the debate over the patterns of environmental disparities by race, class, and other factors. We note that proponents offer three main explanations for any disparities, with one explanation rooted in rational land use (and its unintended consequences), another rooted in market or income dynamics, and a third focused on the impact of differential political power. Of course, whether any of these theories account for patterns of difference depends on whether such patterns indeed exist. We therefore provide a review of the available studies, pointing to the evolution of research and concluding that the evidence is generally supportive of the hypothesis of disparity. Moreover, each of the market, power, and land use explanations finds some support in both the statistics and experience.

This essentially establishes that there is a problem. How that problem plays out in the context of disasters is seen as we review the intersection of disaster vulnerability with race and other socioeconomic variables. This evidentiary review relies more on case studies than on the large sample statistical tests used in environmental disparity research, in part because disasters are (fortunately) few and environmental degradation is (unfortunately) widespread. We break the analysis into considerations before, during, and after disasters, and find parallels with the findings of disparity that emerge from the environmental justice research. We close this section by exploring the implications of these disparities for risk reduction, particularly with regard to homeland security, a growing area of concern in light of the terrorist attacks of September 11, 2001.

We then present what we term the second disaster—the problems that often arise in rebuilding and recovery—and stress how the environmental justice lens can lead to an approach that helps ensure that disaster recovery and reconstruction will not contribute to further inequalities. We emphasize two concepts driving the edge of research and policy in the field of environmental equity: cumulative exposure and social vulnerability. Cumulative exposure refers to the agglomeration of environmental disamenities in certain communities, a problem that is often bypassed by pollution strategies based on facility-by-facility regulation, whereas social vulnerability refers to the capability of communities to weather the health and other risks of environmental disamenities or disasters, particularly with regard to their command over economic and other resources.

We conclude by stressing that the focus of environmental justice on disparities in hazards and disamenities is but a starting point in the work. Environmental justice activists and researchers have also offered a forward-looking view that both questions the nature of America's metropolitan landscapes and calls for a profound democratization in decision making. This emphasis on urban form and local voice can offer guidance to the rebuilding of New Orleans and the rest of the Gulf Coast. Moreover, an intriguing set of new studies suggests that environmental justice could actually be good for everyone: when the disparities between groups are lower, so is overall environmental risk. By contrast, being able to put hazards in "someone else's backyard" ends up creating more hazards for the society as a whole.

It is a lesson that should be familiar—the civil rights movement, after all, initially focused on addressing disparities faced by African Americans in hiring, housing, and voting. The resulting sea change in political opinion and the attendant changes in governmental policy led to changes that, though still short of what many wished, helped to make America a better and more productive nation. Taking the issues of environmental inequity seriously can likewise improve both environmental quality and disaster preparedness for all Americans.

Disasters, Risk, and Environmental Justice

Hurricane Katrina occurred in the southern United States—a region with a long history of coping with weather-related disasters that include droughts, floods, tornados, and hurricanes. Each year, communities along the Atlantic and Gulf Coast states are hit with tropical storms and hurricanes forcing millions to flee to higher ground. Historically, the Atlantic hurricane season produces ten storms, of which about six become hurricanes and two to three become major hurricanes. The 2005 hurricane season, however, produced a record twenty-seven named storms, topping the previous record of twenty-one set in 1933, and thirteen hurricanes, besting the old record of twelve set in 1969 (Tanneeru 2005).

The South is also host to the majority of the nation's African American population. Today, over 54 percent of the nation's blacks live in the South (McKinnon 2001). In the fifteen southern states, excluding Texas and Florida, blacks make up 23 percent of the population, versus about 12 percent for the nation as a whole. African Americans make up an even larger share of the three Gulf Coast states hardest hit by Katrina—Louisiana, Mississippi, and Alabama. They comprise 32 percent of the population in Louisiana, 36 percent in Mississippi, and 26 percent in Alabama.

The areas most affected by Katrina were even blacker and poorer. New Orleans was more than 67 percent black before Katrina (U.S. Bureau of Census 2000). The coastal Mississippi counties where Katrina struck ranged from 25 percent to 87 percent black. Poverty was also a common characteristic. Some 28 percent of New Orleans residents lived below the poverty level and more than 80 percent of those were black. The poverty rate was 17.7 percent in Gulfport, Mississippi, and 21.2 percent in Mobile, Alabama, in 2000, versus 11.3 percent in the nation as a whole (U.S. Census Bureau 2001).

Of course, those most likely to be left behind as the flood waters rose in New Orleans were from neighborhoods that were even poorer and more African American. Such increased vulnerability is typical of the South, a place where the history of slavery, Jim Crow, and white resistance has affected both race relations and the region's ecology. The plantation system exploited not only humans but also the land, and the South has often been thought of as a sacrifice zone, a sort of dump for the rest of the nation's toxic waste (Bullard 1990a, 1990b, 2000). This has been helped along by local governments and businesses that take economic and environmental advantage of those who are politically and socially powerless (Schueler 1992).

It should thus be no surprise that the environmental quality that Southerners experience is markedly different from that of other regions of the country. Lax enforcement of environmental regulations has left the region's air, water, and land the most industry-befouled in the United States. Louisiana typifies this pattern. Nearly three-fourths of Louisiana's population—more than 3 million people—get their drinking water from underground aquifers. Dozens of the aquifers are threatened by contamination from polluting industries (O'Byrne and Schleifstein 1991, A5).

New Orleans is also prototypical of environmental justice issues in the Gulf Coast region. The city's location along the Mississippi River Chemical Corridor, a place hosting more than 125 companies that manufacture a range of products including fertilizers, gasoline, paints, and plastics, increased its vulnerability to environmental threats (Roberts and Toffolon-Weiss 2001). New Orleans also had a highly significant childhood environmental lead poisoning problem. There were ongoing air quality impacts and the resulting high asthma and respiratory disease rates led to frequent visits to emergency rooms for treatment by both children and adults (Wright 2005).

In short, environmental health problems and issues related to environmental exposure were hot-button issues in New Orleans long before Katrina's floodwaters emptied the city. When the hurricane hit, the existing inequalities and the history of discrimination in the American South played out in tragic yet predictable ways. Evacuation strategies, for example, left the most vulnerable populations—the poor, minorities, the elderly—inadequately protected. A *Times-Picayune* reporter, Bruce Nolan, summed up the emergency transportation plan eloquently: "City, state and federal emergency officials are preparing to give the poorest of New Orleans' poor a historically blunt message: In the event of a major hurricane, you're on your own" (2005).

Katrina Hits—and Hits Hard

Storm Costs and Insurance

- Katrina is likely the most destructive hurricane in U.S. history, costing more than $70 billion in insured damage. The total economic losses from the storm are expected to exceed $125 billion (Chu 2005, A2). It was also one of the deadliest storms in decades, with a death toll of 1,325, and still counting.
- FEMA estimates that 12.7 percent of the households in Alabama, 15 percent in Mississippi, and 46 percent in Louisiana have flood insurance. Only 8 percent of the businesses in hurricane-affected counties in Alabama, 15 percent in Mississippi, and 30 percent in Louisiana have flood coverage (Chu 2005, A1).

Job Loss

- More than a million Louisiana residents fled Hurricane Katrina, of which an estimated 100,000 to 300,000 could end up permanently displaced. The powerful storm ravaged an eight-parish labor market that supported 617,300 jobs (Randolph 2005, 1A).
- In October 2005, a total of 281,745 Louisiana residents filed for unemployment benefits, citing Katrina as the cause for joblessness. This figure equated to 14 percent of the workers in the state or 47 percent of all the workers in the seven-parish New Orleans region (U.S. Bureau of Labor Statistics 2005). The unemployment rate for white Katrina evacuees was 24 percent, versus just under 50 percent for blacks and 42 percent for Hispanics (Economic Policy Institute 2005).

Katrina Toxic Contamination and Health Threats

- Katrina caused six major oil spills releasing 7.4 million gallons of oil, about 60 percent of that leaked in the Exxon Valdez incident in 1989 (Cone and Powers 2005).
- The storm hit sixty underground storage tanks, five Superfund sites, 466 industrial facilities that stored highly dangerous chemicals before the storm, and disabled more than 1,000 drinking-water systems, creating a toxic soup with E. coli in the floodwaters far exceeding EPA's safe levels (Cone 2005, A18).

Flooded Homes

- An estimated 140,000 to 160,000 homes in Louisiana may need to be demolished and disposed.
- More than 110,000 of New Orleans' 180,000 houses were flooded, and 90,000 sat for days or weeks in more than six feet of water. As many as 30,000 to 50,000 homes citywide may have to be demolished, and extensive repairs.

Flooded Schools

- Katrina displaced just under 350,000 school children in the Gulf Coast. An estimated 187,000 school children have been displaced in Louisiana, 160,000 in Mississippi, and 3,118 in Alabama (Hunter 2005).
- The powerful storm closed the entire New Orleans school system—116 schools and about 60,000 students—and left a trail of toxic muck in classrooms and playgrounds (Ritea 2006).

Local, state, and federal emergency planners had known for years the risks facing New Orleans' transit-dependent residents, particularly after the experience with Hurricane Georges in 1998 and Hurricane Ivan in 2004 (State of Louisiana 2000; Fischetti 2001; Bourne 2004; City of New Orleans 2005). Whereas 92 percent of American households own at least one motor vehicle, two in ten households (20 percent) in the Louisiana, Mississippi, and Alabama disaster area had none (Associated Press 2005a). More than 30 percent of African Americans in New Orleans do not own a car. Before Katrina, nearly 25 percent of New Orleans residents relied on public transportation (Katz, Fellowes, and Holmes 2005). The city already knew that at least "100,000 New Orleans citizens do not have means of personal transportation" to evacuate in case of a major storm (City of New Orleans 2005).

The city's emergency plan thus called for thousands of the city's most vulnerable population to be left behind in their homes, shelters, and hospitals (Schleifstein 2005). 'It also included the use of public buses to evacuate those without transportation: sixty-four buses and ten lift vans. The plan proved woefully inadequate, especially after nearly two hundred New Orleans Rapid Transit Authority (RTA) vehicles were lost to flooding (Eggler 2005, B1).

Let Them Eat Risk? Wealth, Rights, and Vulnerability

Why were so many left at risk? Many have pointed to the incompetence of various agencies, especially

Source: © Michael Ainsworth, Dallas Morning News, Corbis.
Note: Louis Jones, eighty-one, right, and Catherine McZeal, sixty-two, left, help each other walk down flooded Poydras Street as they went to the Superdome on Thursday, September 1, 2005, days after Hurricane Katrina flooded New Orleans. The couple got together to help each other through their crisis. "They wouldn't let our children help us," Mrs. McZeal said, referring to the fact that people were not allowed to drive into the area to get relatives.

FEMA. We think, however, that the answers lie in a deeper analysis of the way in which our society allocates risk and protection. This is not to excuse government failures—we join the chorus of condemnation in that regard—but rather to offer a framework that explains the continuum from the acute circumstances of disasters to the chronic risks imposed by environmental degradation. Equally important, we need to understand why it is that certain populations seem to suffer differential exposures to both crises such as Katrina and the slow-motion disasters that often plague communities suffering from high levels of air pollution, lead poisoning, or nearby toxic wastes.

Vulnerability to natural disasters such as Katrina and to man-made environmental hazards such as refineries is, to a large extent, a public bad: disasters and hazards typically hit communities, not isolated individuals. By the same token, measures to reduce vulnerability and hazards are public goods. That is, they cannot be purchased or otherwise secured by individuals acting alone: their provision requires proactive public policies.

Yet disaster-vulnerability reduction and environmental protection are seldom "pure" public goods. A pure public good is something that when provided to one is provided to all (a characteristic known as nonexcludability), and whose consumption by one does not diminish its availability to others (nonrivalness). In the twentieth century, the textbook case of a pure public good was national defense; in the twenty-first century, it may become policies to combat global warming.

Many risk-reduction measures are "impure" public goods: when provided to one, they are provided to others, but not equally to all. For example, flood-control projects provide location-specific benefits, restricted to those people who live or own assets in the protected area. By virtue of where they live, work, or own property, some members of society reap the benefits of such collective investments, and others do not.

This means that, in addition to the public policy question of how much risk-reduction to provide, policymakers and the public must grapple with the question of who should receive it. We face not only the classic economic problem of the allocation of scarce resources among competing ends, but also the classic political-economy problem of the allocation of scarce resources among competing individuals, groups, and classes.

This allocation question itself has two dimensions. One is normative, or prescriptive: to whom should resources for such risk reduction be allocated in principle? How, for example, should government resources be spent to prevent disasters, mitigate their effects, and compensate their victims? The other dimension is positive, or descriptive: to whom are risk-related resources allocated in practice? Who, in fact, receives a higher level of protection or recovery assistance, and what drives the pattern? And although these questions and their answers are most dramatic in the case of a crisis like Katrina, the issue of allocating risk permeates environmental practice and policy on an everyday basis.

There are two fundamentally different approaches to addressing risk distribution: the wealth- or market-based approach and the rights-based approach. The wealth-based approach—which is standard practice in most of the cost-benefit analyses that government agencies undertake—is founded on the idea that willingness of individuals to pay, to safeguard the environment or to protect themselves from hazards suggests the value of such protection. The wealth-based approach implies that the allocation of disaster-vulnerability reduction, like the allocation of goods and services in the marketplace, ought to be guided by explicit and implicit market signals: those who pay more deserve to get more.

If all individuals had roughly similar wealth and purchasing power, this approach to decision making would not translate into systematic disparities in disaster vulnerability. That is, there might be random differences in individual preferences for taking on the risks by, say, living on a fault line, but these should show little variance between rich and poor, or black and white. Disaster outcomes would thus be distributed more or less equally between groups. But in the real world, where wealth is quite unevenly distributed and racial bias exists in access to jobs and other income-earning opportunities, the wealth- or market-based approach means that richer individuals, and particular groups and classes, will get more of the impure public good of disaster-vulnerability reduction than their poorer or less powerful counterparts.

This is exactly why a wealth-based approach—which seems like a poor moral guideline for disasters—has such considerable descriptive relevance. As the world came to learn through images and then data, those left stranded and most vulnerable by Hurricane Katrina were disproportionately poor and disproportionately black.[1] These disparately affected groups lived in the lowest-lying areas of the city, and lacked the private means of transportation to flee as the storm approached. Similarly, casualties from the powerful earthquake that hit Guatemala in 1976 were distributed so unevenly across that country's population—with most of the 22,000 deaths among the poor and indigenous people—that the disaster was dubbed a "class-quake" (Wisner et al. 2004, 279–81). Their homes stood in landslide-susceptible ravines and gorges, and they could not afford the earthquake-resistant construction that would have saved their lives.

But the wealth- or market-based approach is by no means confined to the descriptive realm of what is. It also exerts a powerful influence, implicitly or explicitly, on many policymakers' prescriptions for what ought to be. One famous (or infamous) example is the 1992 memorandum in which then World Bank chief economist Lawrence Summers posed the question: "Just between you and me, shouldn't the World Bank be encouraging more migration of the dirty industries to the LDCs [less developed countries]?" Among the justifications for such a policy, Summers wrote, was that

> The measurement of the costs of health-impairing pollution depends on the forgone earnings from increased morbidity and mortality. From this point of view a given amount of health-impairing pollution should be done in the country with the lowest cost, which will be the country with the lowest wages. I think the economic logic of dumping a load of toxic waste in the lowest-wage country is impeccable and we should face up to that.

Summers's memorandum, which was leaked to *The Economist*, was noteworthy not so much for the viewpoint as for the frankness with which it was expressed. In much the same vein, the wealth- or market-based approach sometimes is invoked in the literature on environmental justice to argue that there is nothing wrong with disparate risk burdens, as long as they result from market dynamics and rational land-use decisions.

Rejecting willingness-to-pay as the underlying basis for social decisions on the allocation of risks does not mean rejecting cost-benefit criteria altogether. Weighing the costs and benefits of alternative courses of action is an inescapable task for public policy. Rather, it means choosing a different strategy to aggregate effects across the population. Instead of putting weights on different individuals on the implicit basis of their respective purchasing power, policymakers can use other, explicit principles to add total costs and benefits aggregated across all individuals. For example, they can assign equal weight to all, or even put greater weight on those who are in greatest need.[2]

An alternative approach is based on the notion that a clean and safe environment is a right held in common by all, not a privilege to be distributed on the basis of purchasing power (as indicated by either real-world markets or the shadow markets of benefit-cost analysis). Such a principle is, in fact, enshrined in many constitutions and laws around the world: the state constitution of Montana, for example, says that "all persons are born free and have certain inalienable rights. They include the right to a clean and healthful environment," and the South African constitution says that "every person shall have the right to an environment which is not detrimental to his or her health or well-being."

In short, the idea that environmental integrity should be enjoyed by all has widespread normative appeal. In the allocation of public-sector investments for disaster-vulnerability reduction, such a rights-based approach would place equal weight on mortality and morbidity impacts across the population, regardless of individual wealth and social status. The logic is similar to that used both in voting and in the allocation of basic legal rights: one person, one unit of protection rather than one dollar, one unit of protection.[3]

Both the wealth- and rights-based approaches are also relevant to understanding the legal and regulatory structure that governs private-sector incentives for mitigating risk. In the wealth-based framework, individual households are seen as choosing their risk level based on willingness to pay; they thus bear the burden of obtaining (or not obtaining) insurance against these risks, and any undue or unexpected burdens that arise from firm decisions to pollute or engage in hazardous behavior are to be settled through filing claims against those firms. This creates an incentive structure for firms to locate environmental externalities where they expect that insurance levels will be low, monetary losses will be minimal, and litigation will be less likely. This is a recipe for targeting those with the least power in the social calculus.

In the rights-based framework, any infringement on the right to a safe and clean environment would constitute legal grounds for claims for restitution. Under such a framework, private firms would seek to insure themselves against any resident claims—and the more unsafe the facility, the higher the price of insurance. This weighting would allow the insurance sector to play a more central role in safeguarding against man-made disasters: even if the people whose safety is at risk cannot afford insurance, it would be the responsibility of the owners of facilities that jeopardize public safety to insure against risks to lives and health.

Although our legal system seems to have a bit of each of these elements, with residents and firms battling over liability, the difference in legal and other assets between poor communities and wealthy companies puts more onus on the former than on the latter to take preventive action—by, say, moving away rather than by reducing pollution. In a rights-based framework, more responsibility would lie with the polluter; as a result, the incentive structure would work toward both the reduction of risk overall and a more equitable distribution of risk across populations.

The Environmental Justice Framework

That the acute risks of disaster might be distributed unequally seems unfair to many observers, partly because there is a strong normative sense that catastrophes could befall us all and that the provision of emergency services should therefore also be equally distributed. Yet the pictures of those who evacuated and those who were left behind in the Katrina disaster suggest a sort of auction for rescue that reflects the privileges of wealth more than it does the equal rights of the citizenry.

Such an inequitable distribution of risks on an ongoing basis has been a central concern of the environmental justice perspective. Originally a reaction to the siting of hazards in minority neighborhoods, the environmental justice movement has grown markedly in recent decades. Firmly rooted in the rights-based approach, specific principles of the environmental justice framework include

- *The right of all individuals to be protected from environmental degradation.* This stems from a civil rights framework rooted in the Civil Rights Act of 1964, the

Fair Housing Act of 1968, the Voting Rights Act of 1965, and even the 1948 United Nations Universal Declaration of Human Rights, which recognizes that people everywhere have intrinsic rights to life and health, and to a healthy environment (United Nations 2004).

- *Prevention as the preferred public health strategy.* In the environmental justice framework, affected communities should not have to wait until causation or conclusive proof is established before preventive action is taken. For example, the framework shifts the primary focus of childhood lead issues from treatment (after children have been poisoned) to prevention (elimination of the threat via abating lead in houses).
- *The allocation of the burden of proof toward polluters-dischargers rather than affected communities.* Under a traditional regulatory system, individuals who challenge polluters must prove that they have been harmed, discriminated against, or disproportionately impacted. Few affected communities have the resources to hire lawyers, expert witnesses, and doctors needed to sustain such a challenge—and the environmental justice framework attempts to level the playing field by requiring polluters to prove the absence of harm rather than disprove allegations of harm.
- *The need to redress disproportionate impact through targeted action and resources.* This has become a source of controversy in recent years as the Bush administration has insisted that environmental justice is about protecting "all people." Indeed, it is, but targeting resources where environmental and health problems are greatest and social resilience may be lowest—that is, poorer and more minority communities—is simple common sense (Pastor, Gallegos, and Prichard 2005; Bullard 1994, 237–66).
- *The idea that communities "speak for themselves."* Although traditional environmental policy making is often made by a sort of battle of competing experts, the EJ perspective insists that those who are most affected by the pollution should have a central voice in the regulatory process. Thus, there is a heavy emphasis on community participation, neighborhood autonomy, and democratic decision making.

Environmental justice principles may seem a long way from current practice. Worldwide, the dominant environmental protection paradigm institutionalizes unequal enforcement, places the burden of proof on the victims and not the polluting industry, and creates an industry around risk assessment and risk management that fails to develop pollution prevention as the overarching and dominant strategy (Bullard 2000, 2005). Yet there have been major policy inroads, including the adoption in 1994 of Presidential Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations."

Executive Order 12898 reinforced the Civil Rights Act of 1964, Title VI, which prohibits discriminatory practices in programs receiving federal funds. It called for improved methodologies for assessing and mitigating impacts from multiple and cumulative exposure, and improved collection of data on low-income and minority populations that may be disproportionately at risk. It also, and significantly, encouraged participation of the impacted populations in the various phases of assessing impacts—including scoping, data gathering, alternatives, analysis, mitigation, and monitoring. Most fundamentally, it directed each federal agency to "make achieving environmental justice part of its mission" and specifically identified racial minority and low-income communities as areas of potential concern.

In the years since, environmental justice has come to gain a specific, albeit limited, place in the regulatory world. The U.S. Environmental Protection Agency, for example, defines environmental justice as the "fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations and policies. Fair treatment means that no group of people—including racial, ethnic, or socioeconomic groups—should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies" (U.S. EPA 1998, 1).

This vision clashes with the current state of environmental quality and equality. Some areas are greener than others, some areas have more hazards than others, and the decision of who lives where, particularly given entrenched housing segregation, is not simply driven by choice (Farley, Danziger, and Holzer 2002; Frazier, Margai, and Tettey-Fio 2003). Minorities are likely to bear greater health and environmental risks in their homes, schools, and neighborhoods, as well as in their workplaces (Institute of Medicine 1999). And the connection of race, place, and the environment is deep: in a recent study of all metro areas in the United States, Rachel Morello-Frosch and Bill Jesdale (2006) found a persistent relationship between increasing levels of racial-ethnic segregation and increased estimated cancer risk associated with ambient air toxics across racial lines. Segregation, moreover, solidifies racial disparities in socioeconomic status (SES), and shapes the distribution of resources and wealth at the individual, household, and community levels that can affect access to health services to mitigate the increased environmental risk.

But it is more than just risk at play: the intersection of race and place affects access to jobs, education and public services, culture, shopping, level of personal security, medical services, transportation, and residential amenities such as parks and green space (Bullard, Johnson, and Torres 2000; Dreier, Mollenkoph, and Swanstrom 2001). This has been one of the telling aspects of the environmental justice movement in recent years: the adoption of a broad notion of the environment that includes a critique of the very nature of our contemporary urban form of sprawling suburbs and struggling cities, and how this shapes opportunity.

Disaster Vulnerability and Environmental Justice

The disaster vulnerability literature focuses on acute risks posed by one-time events. The environmental justice literature focuses on chronic risks posed by the day-to-day actions of polluters. As in public health, the chronic-acute distinction is a continuum, not a sharp break: as chronic exposure rises, acute effects become more prevalent. In both cases, the results are ill-health and death.

The social dynamics that underlie the disproportionate environmental hazards faced by low-income communities and minorities also play out in the arena of disaster prevention, mitigation, and recovery. In a sense, environmental justice is about slow-motion disasters—and disasters reveal environmental injustice in a fast-forward mode. Both revolve around the axes of disparities of wealth and power.

Lack of wealth heightens the risks that individuals and communities face for three reasons. First, it translates into a lack of purchasing power to secure private alternatives to public provision of a clean and safe environment for all. Second, it translates into less ability to withstand shocks (such as health bills and property damage) that wealth would cushion. Third, it translates through the "shadow prices" of cost-benefit analysis into public policies that place a lower priority on protecting "less valuable" people and their assets.

The wealth-hazard relationship cuts both ways: hazards also reduce the wealth of individuals and communities. This is most evident when disasters damage or destroy property. But there are also asset losses that occur during post-disaster recovery and reconstruction, when property changes hands from those who have less to those who have more. In the wake of the December 2004 tsunami in coastal Thailand, for example, powerful land grabbers arrived on the scene to take advantage of the weakened circumstances of the local residents (Vatikiotis 2005; Montlake 2005). In

Race, Class, and Katrina

Race-Ethnicity

- Damaged areas were 45.8 percent African American, undamaged areas only 26.4 percent. For the city of New Orleans alone, these figures were 75.0 percent and 46.2 percent, respectively.
- Before Katrina, the city had 475,000 people with about 67 percent African American. Current estimates indicate that soon the population will be only 350,000 with only 35 to 40 percent black.
- Approximately 24,000 legal permanent residents, 72,000 legal temporary residents, and an estimated 20,000 to 35,000 undocumented immigrants may have been affected by Katrina (Woods and Lewis 2005, 8).
- Around the time of Katrina, poor blacks were much less likely to have access to cars than even poor whites, 53 versus 17 percent (Dyson 2006, 145).

Poverty

- Damaged areas had 20.9 percent of households living below the federal poverty line, undamaged areas only 15.3 percent. For the city of New Orleans alone, these figures were 29.2 percent and 24.7 percent, respectively.
- In the city of New Orleans, before Katrina hit, women had much higher poverty rates than men, with 2004 figures of 25.9 percent and 20.0 percent (Gault et al. 2005).
- Damaged areas had 45.7 percent renter-occupied households, undamaged areas only 30.9 percent.

Note: All data not directly cited to another source comes from John Logan (2006).

the aftermath of Hurricane Katrina, there is a similar risk. Asset transfers could turn New Orleans into a little more than a theme park for affluent tourists. In the vicious circle of disaster vulnerability, those with less wealth face greater risks, and when disaster strikes their wealth is further sapped.

But risk is not just about money: as we will see, even middle-class African Americans, Latinos, and Asians face elevated environmental risks. This reflects systematic differences in power and the legacy of racial discrimination. Power also shows up in private decisions by firms choosing where to site hazards and how much to invest in environmental protection: their choices are constrained not only by government regulations, but also by informal governance exercised by mobilized communities, civil society, and the press (see Pargal et al. 1997; Boyce 2004). In both public and private arenas, then, power disparities drive outcome disparities—and the resulting patterns reflect race and ethnicity as well as wealth.[4]

Rights are not cast in stone: they are redefined and reassigned in light of society's values and perceived needs. Clashes between the principle that everyone has an equal right to a clean and safe environment and the reality that access to a clean and safe environment is rationed by wealth and power can help to propel demand for change. By bringing this contrast into sharp relief, an event like Hurricane Katrina can become a catalyst for rethinking both environmental protection and disaster preparedness.

The belief that all individuals should have equal opportunity to exercise power and to influence public policy, regardless of wealth, race, ethnicity, or gender is deeply rooted in public discourse, legislation, and case law in the United States. Although the gap between what laws and legislation say and what is actually done often remains large, the past two centuries have seen great strides toward making this vision a reality in America and across the world. Progress in implementing environmental justice and equal protection from disasters can carry us forward on the historic march towards a more level playing field—one in which we realize more fully shared American values of fairness, opportunity, and democracy.

Environmental Equity: Debate and Evidence

Much as Katrina awakened the country to long-standing problems of differential disaster vulnerability, it was a landmark event back in 1982 that highlighted long-standing patterns of environmental injustice: a decision by the state of North Carolina to place a landfill for hazardous wastes in Warren County, the poorest county in the state and one with a population that was 65 percent African American. Community protests led to the arrest of 500 people and placed the issue of the environment squarely in the tradition of the civil rights movement (Geiser and Waneck 1994).

The Warren County protests launched a wave of research on the location of environmental hazards. The early work seemed to confirm the community wisdom. For example, a U.S. General Accounting Office study, prompted by the controversy in Warren County (in fact, it was requested by a congressman arrested in the protests), found that hazardous waste landfills in the southern states were disproportionately located in black communities (1983). A subsequent study of zip code areas by the Commission for Racial Justice of the United Church of Christ (UCC) established that hazardous waste and toxic disposal facilities across the country were correlated with the proportion of African American residents (1987). And shortly after the early GAO and UCC studies, a National Argonne Laboratory study reported that 57 percent of whites, 65 percent of blacks, and 80 percent of Latinos lived in counties that failed to meet at least one of the EPA's ambient air quality standards (Wernette and Nieves 1992). This large-scale statistical research was backed up by a series of influential case studies, documenting disparities for blacks in the South and Gulf Coast (Bullard 1990a; Wright, Bryant, and Bullard 1994).

By 1990, the combination of research and activism began to provoke changes in environmental thinking and policy. Following a research conference on environmental justice held at the University of Michigan, the U.S. Environmental Protection Agency, under the administration of President George H. W. Bush, created an Environmental Equity Working Group that brought together researchers, activists, and policymakers (see Lester, Allen, and Hill 2001, 30; Bryant and Mohai 1992). The subsequent establishment of an Office of Environmental Equity (subsequently renamed the Office of Environmental Justice), and the 1992 release of the EPA report *Environmental Equity: Reducing Risk for All Communities,* signaled the growing acceptance of the basic precepts of the research demonstrating disparities. "Racial minority and low-income populations," the report concluded, "experience higher than average exposures to selected air pollutants, hazardous waste facilities, contaminated fish and agricultural pesticides in the workplace."[5] Although it noted that such exposure did not always translate into documented health effects, the report expressed concern about disparities and the EPA promised to better document and incorporate the distribution of risk into its decision making. The incoming Clinton administration picked up the momentum generated under President Bush, and in 1994 issued Executive Order No. 12898, mandating environmental justice as part of the federal government's mission.

Yet just as the government was beginning to act, a new set of research studies began to question both the existence of environmental disparities and the rationale for policy attention. Some researchers challenged the large-scale statistical work, suggesting that there were not statistically significant differences by race and ethnicity after controlling for other determinants of the location of facilities (Anderton, Anderson, Rossi et al. 1994; Anderton, Anderson, Oakes, and Fraser 1994).[6] Other researchers disparaged the explanatory power of case studies and suggested that the focus on race stemmed from political concerns rather than concerns about environmental and health policy (Foreman 1998).

Reaction to the perceived pattern of inequality had, in short, bred a counterreaction. Yet in recent years a growing body of evidence, based on rigorous methods and sophisticated statistical techniques, has demonstrated that race is indeed strongly correlated with environmental quality. This quantitative work continues to be complemented by important case studies that illuminate the underlying political and social processes that generate these environmental disparities. Competing explanations for the existence of environmental inequality have surfaced in the course of this research.

Why Environmental Inequity? Land, Markets, and Power

Explanations for the pattern of environmental hazards fall into three categories: rational land-use planning, market dynamics, and the exercise of power. The rational land use explanation suggests that hazards are located in areas based largely on compatibility of use: landfills should be in more rural areas, transfer facilities in urban areas, industrial plants near transport corridors, hazardous waste facilities near industrial plants, and so on. Because detailed land-use measures are few and far between in the literature (for exceptions, see Boer et al. 1997; Morello-Frosch, Pastor, and Sadd 2001; Pastor, Sadd, and Morello-Frosch 2005a), many researchers have used proxies such as population density or the proximity of a manufacturing workforce. The inclusion of such variables in any analysis can help distinguish between biased siting and rational planning.

The market dynamics explanation suggests that placing environmental disamenities in lower income areas has a market logic. First, lower income may be correlated with lower land values: because accurate data on land values is hard to obtain at the census tract level, household income acts as a proxy for land prices. Second, lower-income residents may be willing to trade off health risks for cheaper housing: what looks like an environmental disparity is thus really a reflection of preferences based on market choice. Third, mitigation costs—say, for forgone income from health-related problems—would be less in low-income areas: businesses thus find it cost-efficient to locate pollution sources there.[7]

The power explanation suggests that low-income people and communities of color are systematically disadvantaged in the political decision-making process. This argument can incorporate the other explanations: what seems to be rational land use, after all, may be predetermined by political processes that designate disenfranchised communities as sacrifice zones (see Pulido 2000; Boone and Modarres 1999; Wright 2005). Indeed, land use decisions often build on accumulated disadvantage. In the largely Latino community Kettleman City in California's Central Valley, for example, an effort to place a toxic waste incinerator in a landfill already proximate to the city was viewed as building on existing disamenities but added insult to injury for an already overburdened community (Cole and Foster 2001). Likewise, income is a marker of political power as well as of market strength.

The interplay of land use, income, and power means that certain variables used in statistical analyses—such as zoning and household wealth—carry multiple explanations. To demonstrate convincingly that power is behind siting decisions requires the inclusion of some variables that are directly and irrefutably connected to power differentials.

The most important of these variables is race.[8] Disparate patterns by race, particularly when one has controlled for income and other variables involved in the land-use and market-dynamics explanations, most clearly point to the role of unequal influence and racial discrimination. Racially disparate outcomes are also important in their own right. They can result

Debra's Story

The day before Hurricane Katrina hit, Debra was at her job as a nurse's aide at a New Orleans hospital. Her supervisor encouraged his employees to take shelter during the storm at the hospital with their family members. Debra felt so lucky. She was a single mother of a nine-year-old girl, had few resources, and no way to get out of town. *The hospital would be perfect,* she thought. She packed up her daughter, Cierra, but Debra's sister and her eighty-year-old stepmother refused to leave their New Orleans home. *I'm too old for that,* her stepmother told her, and Debra could not convince them to come.

At first, the hospital seemed like a safe spot for shelter, but soon the water in the streets rose, the power went out, the halls were pitch black, and the hospital was unbearably hot. People were screaming in the streets and the trees were smashing against the large hospital windows. *The people were screaming and the trees were screaming, too,* she recalled later. Water started to rise in the hospital basement, food and drinking water were running out, and people were scared. She explained, *it felt like the world was coming to an end.* At several points, in the darkness, she could not find her daughter. Yet the staff kept working. Debra passed nurses fanning a newborn baby, doctors giving oxygen manually, patients begging for help. *These are things you don't want your child to see,* Debra said sadly.

The hospital staff had to administer drugs and read charts with only the light of a small flashlight. Later, her supervisor informed them that they would have to "close the door" on some patients because there was nothing left that they could do for them. She was shaken, but knew he was right. Eventually, thankfully, Debra and her daughter were airlifted out of the hospital on a helicopter, and then were placed on a bus. *People were screaming, crying, people were throwing up, passing out, dying,* she recounted. Eventually, they arrived at the Cajundome mass shelter in Lafayette, Louisiana. Amidst the thousands of evacuees, they rested on their cots, exhausted, fearful, and sad. It was hard to believe that they had gotten out, but now they had to figure out what to do next. She thought about how they had all been treated: *They didn't care about any of us. . . . Where are our civil rights?*

Then Hurricane Rita hit, and they evacuated again, but then returned to the Cajundome. Like all the other Cajundome guests, they filled out forms, waited for housing, and passed through the metal detectors every time they came in the door. They accepted a few donated clothes and stored them in a box under their cots. During that time they learned that Debra's elderly stepmother and sister had gotten out of their home on a mattress floating on the floodwaters, and eventually ended up in the New Orleans Superdome. *We were so scared,* they told her.

Debra's home was lost, as well as her job as a nurse's aide, because the hospital was destroyed, and she had no savings. Finally, in mid-October, her name was called over the Cajundome intercom. She was to report to the main offices immediately. There, she received the news that one of the new FEMA trailers being set up on a dog racing track parking lot outside of Lafayette would be hers temporarily. She was thrilled by the news. *This is the first time I have truly smiled since the hurricane,* she proclaimed. Debra and Cierra are now living in the trailer and Cierra goes to school, but they are still adjusting and do not feel settled. Debra finds it hard to talk about what happened, and often thinks: *This actually happened. Sometimes you want to wake up and think it's a dream.*

Note: This vignette is taken from a research project on Hurricane Katrina conducted by Professor Alice Fothergill, University of Vermont, and Professor Lori Peek, Colorado State University. The results of this study are unpublished. "Debra" is a pseudonym to protect the identity of the interviewee. As a single mother in New Orleans, Debra is not alone. More than half of New Orleans' families with related children are headed by single females (56 percent of all families with children under eighteen in New Orleans, versus 25.2 percent of such families for the nation as a whole). See Gault et al. (2005, 3).

from processes that are not so much a direct exercise of power as essentially embedded in the nature of our urban form, including housing segregation and real estate steering, informal methods that exclude communities from decision-making processes (including less provision of information regarding health risks), the past placement of hazards (which justifies new hazards as rational land use), and other forms of less direct "institutionalized" or "structural" racism (see Feagin and Feagin 1986; Institute on Race and Poverty 2002). And it is precisely racialized risk that has galvanized a movement for environmental equity rooted in civil rights law and activism. Race and racism therefore are at the heart of the evidentiary debate.

Studies of which came first can also test the relative strength of the land use, market, and power-race explanations. Do environmental disparities reflect biases in the siting of hazards, or are they the result of post-siting decisions by minorities and low-income residents lured, perhaps, by falling property values, to decide to move into neighborhoods marked by higher exposure and risk? Evidence that siting is more important than move-in could square with an explanation focused on power and institutionalized racism; evidence that move-in is more important would support the idea that disparities are simply the result of market dynamics.[9]

In understanding the patterns, both large-scale statistical studies and case studies are critical: the broader studies can illustrate the general pattern and case analysis can help unpack the patterns with blow-by-blow histories that elucidate the motivations of polluters, the resistance of communities, and the incentives facing decision makers. Because much of the more recent research in environmental justice has emphasized large sample quantitative work, we focus here on that; when we turn to disaster vulnerability, we rely more on the case method.

Environmental Inequality: The Evidence

The early GAO and UCC studies, and a 1992 National Argonne Laboratory study all suggested that environmental inequality was rampant, and a series of important case studies provided back-up. Bullard's landmark volume *Dumping in Dixie* (Bullard 1990a) reviewed both siting decisions and community mobilization in southern black communities, and found strong evidence of racial disparity. Sociologist Beverly Wright and others documented the rise of the petrochemical corridor between Baton Rouge and New Orleans and its impact on poor African American "fenceline communities" (Wright et al. 1994; Adeola 1998). Activists in Barrio Logan, a predominantly Latino community in San Diego, noted that one-third of chemical waste in the entire county was generated in their small neighborhood (Kay 1994, 162). Native Americans began to voice concerns about their reservations becoming the dumping grounds for toxic and radioactive waste (Churchill and LaDuke 1986).[10] And minority communities in northern cities such as Boston and New York began to complain of abandoned and polluted "brownfields," poor management of nearby sewage treatment, the rising epidemic of child asthma, and other environmental issues.

In the mid-1990s, however, a series of new studies argued that: one, the scale of previous analyses—usually the zip code—was inappropriate for considering neighborhoods, and that census tracts were to be preferred as neighborhood proxies; and, two, simple correlations between race and hazards did not take into account market and land use dynamics and the use of appropriate multivariate techniques tended to refute conclusions of racial disparities (Anderton, Anderson, Rossi et al. 1994; Anderton, Anderson, Oakes, and Fraser 1994).[11]

The most important of the refutations, the studies by Anderton and his colleagues, have now found themselves challenged on different methodological grounds. The first is the authors' decision to restrict their national analysis to metropolitan areas that had at least one commercial hazardous waste facility. A subsequent study by Vicki Been (1995) used the same basic variables but avoided this selection bias and found evidence of racial and income disparities. A second issue involves the authors' decision to highlight findings only for the census tracts hosting transfer storage and disposal facilities. As J. Michael Oakes, a member of the Anderton team, noted in his 1997 doctoral dissertation, considering the more densely populated neighborhoods surrounding these tracts, an approach that has become standard in the field, yields significant evidence of racial disparity (see also Mohai and Saha 2006).[12] A third issue is that the use of multivariate techniques does not give researchers free rein to include as many covariates as possible; the likely result of that approach is collinearity, which will eliminate statistical significance (see the critique in Boer et al. 1997).[13]

Indeed, more recent research has tended to reinforce the basic conclusions of the early studies. A national analysis by three researchers who were initially skeptical of environmental inequality claims found evidence of disparities by both race and class, showing that these were sensitive to the geographic scale used (Lester, Allen, and Hill 2001). And though some researchers have argued that the existence of environmental inequality depends on which region is being examined, a recent national study on toxic air emissions from large industrial facilities that statistically controlled for regional variations, found sharp racial and ethnic disparities in pollution burdens, even after taking income and other variables into account (Ash and Fetter 2004). The authors note that not only are African Americans concentrated in the most polluted metropolitan areas, but also that within any given area they tend to live in the most polluted neighborhoods. Latinos are concentrated in metropolitan areas with lower pollution burdens, but within these areas they too tend to live on "the wrong side" of the environmental tracks.

A recent meta-analysis by Evan Rinquist (2005) examined forty-nine empirical studies (including the studies of Anderton and his colleagues) and used newly developed regression techniques to assess common inequity patterns in the various research efforts.[14] The analysis suggests that evidence of racial disparity in environmental hazard burdens exists regardless of "the type of risk examined, the level of aggregation employed, or the type of control variables used in the analysis" (233). The author concluded that though "some scholars have protested that race-based inequities are limited in scope, produced by misspecified models, or are artifacts of aggregation bias . . . protests claiming that these factors can explain away such inequities are empirically unsustainable" (241).

Rinquist suggests, however, that the racial disparities, though statistically significant, are small, making use of Jacob Cohen's (1988) standard for estimating impacts across different studies. But that conclusion may be problematic for two reasons. First, as Rinquist notes, the effects are actually large in those studies that use distance-based methods—that is, that take into account the location of a facility and include census tracts by proximity rather than by whether the facility is in the tract itself. In a forthcoming paper that echoes the Oakes discussion of adjoining tracts. Paul Mohai and Robin Saha (2006) show that the distance-based approach is analytically superior because hazards are often on the borders of tracts (perhaps because they are on transit corridors); indeed, the authors use data from a previous national study to demonstrate the a tract-oriented approach would miss evidence of racial and income disparity, whereas a distance-based approach confirms the racial disparity hypothesis in both simple comparisons and multivariate analysis.

Second, the Rinquist conclusion of a small race effect neglects cumulative impacts. Studies have now found disparities in proximity to a range of potential hazards, including treatment, storage, transfer and disposal facilities, the industrial facilities reporting to the EPA's Toxics Release Inventory (TRI), Superfund sites, and estimates of cancer risk from stationary and mobile source pollution. Assuming that these burdens are additive—and detailed analysis of various hot spots in major urban areas suggests exactly such a clustering—then small differences in each of these dimensions could add up to a large difference in environmental quality. To paraphrase the late Senator Everett Dirksen: "A little overexposure here, a little overexposure there, and pretty soon you're talking about real disparity."

Turning to the effects of income, Rinquist notes that the findings are mixed. This is not surprising. In very low-income areas with little economic activity, there are few nearby sources of pollution from industry, commerce, or transport. On the other hand, at very high levels of income, residents have the political power to resist unwanted land uses. Thus we might expect a nonlinear relationship in which pollution burdens peak at income levels somewhere in the middle range (Been and Gupta 1997; Boer et al. 1997; Sadd et al. 1999; Morello-Frosch, Pastor, and Sadd 2001). And this complex mix of income effects—particularly in light of the consistent effects of race—is more a challenge for the market dynamics argument than it is for the power-based set of explanations.

Research on the temporal dimension—which came first, the minority communities or the hazards?—has been the subject of a more limited range of quantitative research, primarily because of the methodological challenges of such time-series analysis.[15] The results have been mixed. In keeping with the work of Douglas Anderton and various colleagues (Anderton, Anderson, Rossi et al. 1994; Anderton, Anderson, Oakes, and Fraser 1994), John Oakes, Douglas Anderton, and Andy Anderson (1996) found little evidence of either contemporary disparity or historical patterns. Using an improved database, Vicki Been and Francis Gupta (1997) found no evidence for the move-in view but did find some that Latino communities were the subject of disproportionate siting.[16] Sabina Shaikh and John Loomis (1999) found in a study of Denver that minority populations rose faster in areas without hazards, countering the market dynamics view. James Mitchell, Deborah Thomas, and Susan Cutter (1999) find evidence of minority move-in for South Carolina. A study of the Los Angeles area by Manuel Pastor, James Sadd, and John Hipp (2001) found that siting was significantly disproportionate, and that the movement of minorities into affected neighborhoods was no faster than in the rest of the region.[17]

Although the evidence is more muddled in this temporal arena, it does suggest little support for the move-in hypothesis and some limited support for the disproportionate siting hypothesis. In a recent article, Saha and Mohai (2005) help to resolve the muddle by noting that siting processes may change over time. They suggest that disparate siting was on the rise after the 1970s, when a combination of environmental legislation, NIMBY ("Not In My Backyard") attitudes, and the Resource Conservation and Recovery Act of 1976 made it more "politically rational" to try to site environmental hazards in neighborhoods with less influence. They find empirical evidence of this in Michigan. This shift in the temporal dynamic may also help explain why environmental justice concerns emerged so vigorously in the 1980s and 1990s.

In cases where minorities have seemingly moved to places of higher risk, case studies reveal that the story is often more complex. For example, two almost entirely black New Orleans subdivisions, Press Park and Gordon Plaza, were built on the Agriculture Street Landfill, a site used as a municipal dump for more than fifty years, and one that included debris from Hurricane Betsy in 1965 (Lyttle 2004; Wright 2005). Both subdivisions emerged from a federally subsidized program in the 1970s to encourage lower income families to purchase their first home, with the development undertaken in cooperation with the Housing Authority of New Orleans.

In 1983, the Orleans Parish School Board purchased another portion of the Agriculture Street Landfill site for a school. The board contracted engineering firms to survey the site and found evidence of heavy metals and organics. In May 1986, EPA performed a site inspection and—despite the lead, zinc, mercury, cadmium, and arsenic found—determined that the site was not problematic enough to be placed on the National Priorities List for toxic-waste clean-up. The Moton Elementary School opened on the site with 421 students in 1989. In December 1990, EPA published a revised hazard scoring system in response to the Superfund Amendment and Reauthorization Act of 1986. Upon the request of community leaders, an expanded site inspection was conducted in September 1993. The soil was found to contain 149 toxins, forty-four of them carcinogenic, and in December 1994 the community was placed on the National Priorities List.

The Agriculture Street Landfill community, home to a low- to middle-income population that is around 97 percent African American, pushed for a buy-out of their property and relocation of residents. Instead, EPA ordered a clean-up that began in 1998 and was completed in 2001—one that residents contend was more expensive than a community preferred option of a buy-out (Lyttle 2004).

This case suggests that even when move-in has occurred, it can hide a history of public policies based on misleading or inaccurate information. Ironically, the environmental damage wrought by Katrina may force the cleanup and relocation of the Agriculture Street Landfill community, the goal many residents had been seeking since finding out about the toxins under their homes.

In sum, research, methodologically bolstered in response to the useful challenges by critics, seems to confirm the ubiquity of environmental inequalities revealed in the first watershed studies (GAO 1983; United Church of Christ 1987). It is said that the first step of a program to eliminate addiction is to admit you have a problem. In a society seemingly hooked on putting hazards in the backyards of those already burdened by poverty and racial discrimination, owning up to the reality would make a good starting place for policy making.

Does Environmental Inequality Matter? Risk and Policy

Inequalities in health that are unexplained by income levels or insurance coverage (see Smedley, Stith, and Nelson 2003) have led some to wonder about the role of environmental disparities. The disparity concern is especially sharp with regard to children's environmental health, particularly in view of a growing body of scientific evidence indicating that children are more susceptible than adults to the adverse effects of environmental pollution because of fundamental differences in their physiology, metabolism, exposure, and absorption patterns (see Bearer 1995; Guzelian, Henry, and Olin 1992; Landrigan and Garg 2002).[18] One dramatic environmental issue is childhood lead poisoning, a preventable disease that continues to pose the number one environmental health threat to black children in the United States, especially those living in inner cities with concentration of older housing with lead paint (see Kraft and Scheberle 1995). Black children are five times more likely than white children to have lead poisoning. Although the pattern partly reflects lower incomes and older housing, nearly 30 percent of all low-income black children are lead poisoned versus fewer than 10 percent of their white counterparts. And the effects are quite real: recent studies supported by the National Institute for Environmental Health Sciences suggest that a young person's lead burden is linked to lower IQ, lower high school graduation rates, and increased delinquency (Shannon et al. 2005; Needleman 2004).

Although some causal chains from hazard to health, such as that for lead, are relatively well established, linking environmental pollution to adverse health effects is an ongoing challenge, particularly when populations are chronically exposed to complex, chemical mixtures (Institute of Medicine 1999). Epidemiological studies and risk assessment help elucidate whether documented disparities have potential health implications, and help to prioritize which hazards should be minimized and at what costs.

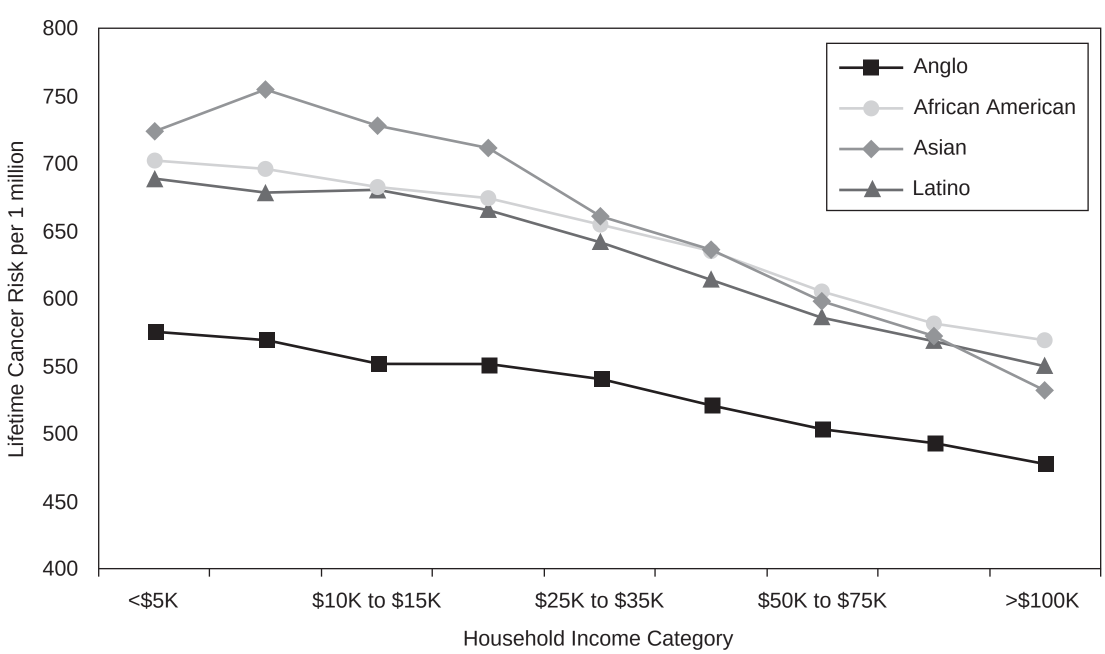
Risk assessment and prioritization are important. Finding, for example, that the vast majority of hazardous air pollutants emerge from mobile rather than stationary sources could lead one to focus on cleaner vehicles versus cleaner plants. But a focus on risk assessment should be nuanced. First, some risks are imposed and others are chosen. It may be that an effective antismoking campaign could yield more anticancer bang for the buck than an effort to curtail emissions of certain chemicals at a manufacturing facility. But the risks taken by smokers are voluntary, and those taken by residents nearby the facility are often not.

Second, even if a particular source contributes more to total risk, it does not necessarily follow that focusing on its reduction meets fairness criteria. For example, in California's South Coast Air Basin, a market-based plan to decrease traffic emissions through the purchase and disposal of older, higher emitting vehicles was proposed to offset emissions by large petrochemical facilities involved in unloading tankers in the Port of Los Angeles. Backers of this mobile-to-stationary emissions trading plan argued that it would have a bigger impact on decreasing air pollution region wide, but communities living near the port successfully fought the plan by arguing that it could create a toxic hot spot in an area already impacted by polluting sources (Chinn 1999).

Despite the limitations of risk assessment as a regulatory and policy tool, this methodology has been useful when applied in a comparative framework in environmental justice studies. For example, recent work has compared estimates of lifetime cancer risk associated with air toxics exposures. Figure 1 shows how this estimated risk varies by race and income in Southern California (Morello-Frosch et al. 2001). Particularly notable is that though the risk declines as income rises, it is consistently higher at all income levels for African Americans, Latinos, and Asians.[19]

Other risks that concern environmental justice communities include respiratory hazards and vulner-

FIGURE 1 Distribution of Estimated Risk from Ambient Hazardous Air Pollutant Exposures, Southern California



Source: Chart based on risk assessment of air toxics data from mobile and stationary sources as explained in Morello-Frosch et al. 2001.

ability to asthma attacks. Asthma prevalence and mortality are three times higher among minorities than among whites (National Heart, Lung, and Blood Institute Working Group 1995; Persky et al. 1998). African American and Latino children are three to five times more likely to die from asthma than white children (Frumkin, Frank, and Jackson 2004; see also Metzer, Delgado, and Herrell 1995). Asthma disparities between whites and minorities persist even after controlling for income (Litonjua et al. 1999), and there is some evidence that such disparities are correlated with differing air toxics levels (Pastor, Sadd, and Morello-Frosch 2005b).

Health outcome patterns result not only from the cumulative impacts of environmental stressors but also from what is termed social vulnerability. Living in hazardous, deprived, and segregated neighborhoods that lack resources and have weakened social networks leads to chronic stress, which ultimately degrades health and well-being (Geronimus 2000; Schultz et al. 2002) and heightens biological vulnerability to the adverse health effects of toxic exposures (Gee and Payne-Sturges 2004; Morello-Frosch and Lopez 2005; O'Neill et al. 2003). The impacts of these intersecting individual-level and community-level processes are manifested through specific health outcomes, such as asthma, cancer, infant mortality, diabetes, and other diseases that are both socially and environmentally mediated.

Of course, risk is a fact of modern life. But what the environmental justice framework raises is the moral question posed when such risk is systematically distributed along characteristics such as race.

How have policymakers responded to this growing body of evidence and community concern? In the 1990s, various federal agencies developed their own environmental justice initiatives, and some states, such as California, worked to integrate environmental justice concerns in regulatory enforcement and research activities (Bonorris 2004). These steps were a response to political pressure to change a record of disparities in regulatory programs. For example, a 1992 *National Law Journal* study uncovered glaring inequities in the way the EPA enforces its laws, noting that white communities got faster action and better results, with stiffer penalties for polluters, than did black and minority communities, even accounting for income (Lavelle and Coyle 1992).

Unfortunately, progress at the EPA has faltered under the President George W. Bush administration. A March 2004 EPA Office of Inspector General report suggests that after a decade, the EPA "has not developed a clear vision or a comprehensive strategic plan, and has not established values, goals, expectations, and performance measurements" for integrating environmental justice into its day-to-day operations (2004, 1). A July 2005 U.S. General Accountability Office report criticized the EPA for its handling of environmental justice issues when drafting regulations on the implementation of clean air legislation.

The same month, the EPA responded by proposing that it eliminate race and income as explicit targets for consideration in its Environmental Justice Strategic Plan. This remarkable proposal was met by a firestorm of criticism, as was the EPA's subsequent proposal to scale back reporting requirements for industrial facilities in the Toxics Release Inventory program (see Morello-Frosch, Gallegos, and Pastor 2006). This proposal, if carried out, would have a particular impact on environmental justice research and activism: the TRI has been a key data set used in assessing environmental inequality in several of the studies reviewed above. Indeed, in December 2005, the Associated Press released results from its study *More Blacks Live with Pollution,* which was based on emission information from the TRI reports that the administration hopes to weaken. Results showed that blacks are 79 percent more likely than whites to live in neighborhoods where industrial pollution is suspected of posing the greatest health danger (Pace 2005).

Reducing the availability of incriminating information will do nothing to ameliorate the disparities. The real challenge lies in the government response—or lack of response—to these health and environmental issues. And the issues of ongoing disparities and lack of action seems to have characterized governmental efforts at emergency preparedness, response, and recovery.

It Is Not Just Hazards: Parks, Transit, and Preparedness

The environmental justice framework emerged in response to hazards, risks, and disasters. Since its inception, however, the environmental justice movement has advocated a broad definition of the environment as the place "where we live, work, and play"—and thus considered not only the allocation of costs but also the distribution of benefits.

For example, environmental justice advocacy has emphasized the distribution of parks and open space. Older urban areas, home to disproportionately lower income and minority populations, often have less access to park resources than do suburbs (Harnick 2000). The inequality is all the more striking given that the living conditions facing many in the inner city—multifamily housing in dense conditions—means that private space is scarce and thus public parks are all the more critical for public health (de Vries, Verheij, and Groenewegen 2003). A careful study of the Los Angeles area found that neighborhoods that were more than 75 percent white enjoyed thirty-two acres of park per thousand residents, whereas those that were more than 75 percent Latino enjoyed less than one acre per thousand residents, and those that were more than 75 percent black had about two acres per thousand residents (Wolch, Wilson, and Fehrenbach 2005, 17).

Environmental justice researchers and activists have also focused on the costs and benefits of transportation. Decisions about building new roads, the density of truck and automotive traffic, and the degree of pollution control for transport activities have significant consequences for air pollution (Forkenbrock and Sheeley 2004). But "transportation justice" has taken on a larger, positive meaning that includes access to affordable and quality transport that can facilitate a community's linkage with jobs, retail shopping, parks, and other opportunities. This benefit side of the equation has been important to environmental justice advocates, and has led to debates and conflicts over the degree of funding devoted to the mass transit options frequently used by low-income and minority residents.[20]

This issue was critical in New Orleans when Hurricane Katrina struck. Many people were stranded in the city even after the call for evacuation. But issues of transit inequality were evident before the storm: public transit use by blacks was four times that of whites (19.2 to 5.1 percent), and carpooling, another indicator of lack of independent transportation, was twice as high (19.2 to 10.1 percent). Reliance on public transit must be taken into account in disaster planning and evacuation procedures. Otherwise, the disparity in transportation access will, as in New Orleans, translate into many who get "left behind" in a time of crisis.

Environmental and transportation justice, in short, are at the heart of emergency preparedness and emergency response. The former provides a guidepost to who is most likely to be vulnerable to the disaster itself, and the latter provides information about who will need the most help when disaster strikes. It is to the intersection of disaster vulnerability with race, income, and other social characteristics that we now turn.

The Social Ecology of Disasters

Hurricane Katrina is not the first time in U.S. history that blacks, the poor, and other marginalized groups have suffered more in a disaster. It may be, however, the first time most Americans realized the degree of inequity in social and economic impacts of disasters. This inequity, however, is a fact long noted and studied by disaster scholars—including sociologists, anthropologists, economists, and geographers—who recognize that race, ethnicity, resources, income, gender, ability status, and age can shape disaster readiness and consequences.

The disaster literature often starts with a sharp distinction between natural and man-made events. The former include hydro-meteorological disasters (such as hurricanes, floods, and droughts) and geophysical disasters (such as earthquakes, volcanic eruptions, and tsunamis). Traditionally, the latter are industrial accidents and wars. Rather than a simple dichotomy, however, disasters often lie on a continuum between the natural and man-made poles.

This intermediate terrain is the common ground for many disasters for two reasons. The first is physical interaction: when a hurricane damages industrial facilities, for example, leading to oil spills and toxic chemical releases, the disaster has both natural and man-made elements. The second reason is the social fabric through which disaster vulnerability is filtered: to borrow a phrase from George Orwell, when disaster strikes, some people are more equal than others.

Experts on disasters recognize that unequal risks are structured by social differences in wealth and power that arise before, during, and after the actual cataclysmic events. When the Union Carbide plant in Bhopal released a cloud of poisonous methyl isocynate gas in 1984, killing 7,000 to 10,000 people and injuring many thousands more, the victims were disproportionately poor and low-caste communities living in squatter settlements near the facility.[21] During the accident, plant officials waited two deadly hours before sounding the siren to alert surrounding communities to evacuate. After the disaster, compensation to the victims reflected their paucity of wealth and power: in cases of death, the typical compensation was about \$2,500; for injuries, the average was less than \$600.[22]

Source: © Shawn Thew, EPA, Corbis.
Note: A cleanup worker cleans up crude oil spilled from a local refinery in the wake of Hurricane Katrina. The toxic spill was inundating an estimated 1,500 to 2,000 homes.

Similar patterns were revealed by Hurricane Katrina. Ninety-eight percent of the residents of the Lower Ninth Ward, the lowest-lying area of New Orleans that was most vulnerable to flooding, were African Americans (versus 67 percent in the city as a whole and 37 percent in the entire metropolitan area).[23] As the hurricane drew near, many of the poor were unable to flee because they lacked private transportation. And, in the aftermath of the storm, a second disaster that involves disparities in recovery and reconstruction processes has started to unfold.

The flip side of excess vulnerability for some is favoritism for others. Before, during, and after natural disasters, the rich and powerful occupy privileged positions by virtue of residential location, quality of construction, means of escape, and preferential access to insurance and to postdisaster grants and loans (Platt 1999). These disparities are not only inequitable but also inefficient. For the affluent, the assurance of generous post-disaster government aid creates a moral hazard: being well-insured against a risk, they have little incentive to avoid that risk. This encourages rebuilding in risky but attractive locations such as beach fronts.[24] At the same time, it diverts scarce government resources away from disaster-vulnerability reduction measures that could yield greater benefits to society.

The point here is that however natural the disaster's origins may be, much is often unnatural in the distribution of its costs (and possibly benefits) across the affected population. And, given that the ongoing risks of environmental negatives seem to be inequitably distributed by race, income, and privilege, it is little surprise that one group of disaster studies scholars has found that these dimensions of privilege and power also impact emergency preparedness, response, and recovery.

Preparing for the Worst

Research examining issues before a disaster often finds telling differences in risk perception and attitudes about a hazard, preparedness activities, and warning

What About the Elderly?

She called her uncle for the last time before the storm on Sunday morning. Relatives she had entrusted to take care of him had decided to ride out the storm, and by the time she discovered this change in plans, "contra flow" made it impossible to drive back into the city to get him.

It was nine days before she would hear from him again. In an anguished voice, he reported feeling the entire house shake, then feeling initial jubilation when he realized that the house had sustained minor roof damage and, of course, the loss of electricity. But with a gas stove that was working and pre-cooked food in the freezer, he felt secure. His confidence proved to be short-lived, when the water rapidly rose in the basement and approached the upstairs in a fast-paced circular motion. He decided to go to his bedroom where the bed sat somewhat high off the floor, but before he could reach his room the water rose above his ankles. As he got to his bed, the water receded. For the next several nights with no running water or electricity, he could hear the furniture downstairs floating and bumping together against the walls and stairs in the house. The only other sounds he heard were from helicopters overhead and his neighbors with one-story homes sitting on roofs and trying to summon them. He would look outside of his window and could see only water and roof tops. It felt like he was lost in the middle of the ocean.

Just as the last of his food was running out, he heard a voice on a bullhorn calling out "is there anyone here?" He made his way to the front picture window in the living room and began beating on it to garner attention. At last, he was seen and picked up by the National Guard. He was taken by boat to a dry location where he was then airlifted by helicopter to the Louis Armstrong International Airport. At that point he had no idea where they were taking him. Several hours later he landed in Lubbock, Texas, at Reese Air Force Base. It was three days before he was able to make contact with family members, who immediately brought him to Marietta, Georgia, where his family was temporarily taking refuge. The family was relieved: the agony of not knowing, coupled with the suffering of persons aired on television every day, had made the waiting even more torturous.

Although what happened to this seventy-eight-year-old retired New Orleans public school teacher in the storm was frightening, the aftermath has been of equal concern. This elderly evacuee lived on a meager retirement package from the New Orleans public school system, for which he had worked for more than thirty years. He lived with his sister, a widow, who owned her house, which had a downstairs apartment she rented to her brother for half the cost of utilities and phone bills. The flood insurance policy was far less than what is needed to repair the house or to rebuild and he has been thrust into extreme poverty. The cost of housing alone is likely to be more than his monthly check. His health insurance premium has increased from $200 a month to $600, and he is not eligible for Medicare because the school system was privately insured. He has yet to receive anything from FEMA except the first $2,000 given to most evacuees who applied.

For many elderly, home ownership is the only thing that stands between them and poverty. Another set of relatives are age seventy-two and seventy-five. Both retired and living on fixed incomes, their house was destroyed by Katrina. They were underinsured for flooding, and the homeowner's policy that they had paid faithfully for the last forty years gave them a check for only $3,000. They applied for an SBA loan, which was approved for $170,000. They are both very confused. How will they ever be able to pay it back? Borrowing that amount of money this late in life was simply not an option for them. Yet they have worked hard all their lives and given much back to their communities and to their country. What will America do for them now?

Note: This story was provided by Beverly Wright, director of the Deep South Center for Environmental Justice and a Katrina evacuee from New Orleans East.

communication and response. For example, studies have found that minorities and the poor are more concerned about disaster threats, including the risks of earthquakes, floods, hurricanes, or tornadoes (Blanchard-Boehm 1997; Flynn, Slovic, and Mertz 1994; Palm and Carroll 1998). Heightened risk perception comes from both previous experiences with vulnerability and disasters—such as Mexican Americans who lived through or heard about the 1985 Mexico City earthquake—and from a general lack of control and power these groups have in their daily lives. This heightened perception of risk, however, does not mean these groups are more prepared for a disaster situation.

The lack of power that leads to increased anxiety about the threat is also associated with an inability to translate the perception of risk into preventative action—because that requires resources that are often unavailable to the poor and minorities, especially women and children. Research on disaster preparedness behavior—such as devising disaster plans, buying insurance, gathering emergency supplies, training response teams, and educating residents about a potential disaster—finds many barriers for marginalized groups in the United States.

Wealth helps explain a portion of the preparedness differential: income levels affect the rate of adoption of some of the more costly mitigation measures, such as purchasing insurance, strengthening of homes, and purchasing fire extinguishers (Palm and Carroll 1998; Vaughan 1995; Fothergill 2004; Bolin and Bolton 1986; Blanchard-Boehm 1997). But it goes beyond income. After the 1987 Whittier-Narrows earthquake in California preparedness information was disseminated only in English despite the language needs of likely victims (Tierney 1993). Similarly, before Hurricane Hugo in 1989 in Georgia and the Carolinas, racial and ethnic minority communities were less likely to have had disaster educational opportunities to help them prepare for the storm (Faupel, Kelley, and Petee 1992).

Research has also examined issues of diversity in how disaster warnings—such as flood sirens or emergency broadcasts—are disseminated and how groups respond to those warnings of an immediate danger. Overall, groups of people with lower socioeconomic status are especially likely not to receive, understand, or believe disaster warnings (Panel on the Public Policy Implications of Earthquake Prediction 1975). Minority households are more likely than white households to report that relatives were an important information source with regard to emergencies and to rely on local television for updates (Morrow 1997; Perry and Nelson 1991). Research has also found that Hispanics are more likely than whites, blacks, and Asians to use social networks for disaster information, and both blacks and Mexican Americans preferred neighborhood meetings as a communication channel regarding hazards more than whites (Blanchard-Boehm 1997; Perry and Mushkatel 1986; Phillips and Ephraim 1992). Efforts to ensure that all groups receive accurate, timely warnings require that disaster planning organizations plan for different preferences for warning dissemination—using culturally appropriate materials through television, neighborhood meetings, radio, or informal networks of family and friends.

As we saw in the Hurricane Katrina disaster, contextually understanding the evacuation behavior of residents (especially the most vulnerable) following disaster warnings is critical. Some research indicates that race, ethnicity, and socioeconomic status have no effect (Perry and Lindell 1991, Bourque, Russell, and Goltz 1993), whereas other studies have found that the poor and minorities are less likely to evacuate or undertake protective action short of evacuation (Perry and Mushkatel 1986; Lindell, Perry, and Greene 1980; Gladwin and Peacock 1997; Morrow and Enarson 1996).

This pattern of evacuation delay, even after warnings, may also reflect differences in wealth. Research suggests that the average level of net worth (a straightforward measure of wealth) for blacks is around 20 percent of the average net worth for whites (Gittleman and Wolff 2000). However, the weight of home ownership in that bundle of assets—which can include businesses, stocks, and other financial wealth—is much higher for African Americans: home equity accounts for nearly 63 percent of black wealth but only about 43 percent for white (Oliver and Shapiro 1995, 106).[25] Home equity is also a disproportionately important component of Latino net worth. Thus the urge to stay behind and protect one's assets, especially if underinsured, may be understandable, albeit dangerous.

Nevertheless, evacuation delay is not primarily a matter of choice. Hurricane Andrew in 1992 provided an eerie foreshadowing of Katrina's evacuation crisis. Before Andrew hit, blacks and those with low incomes in the evacuation zone were less likely to evacuate than other groups, most likely due to the lack of transportation and few affordable refuge options (Gladwin and Peacock 1997). There were also reports of public housing residents having to walk or hitchhike out of evacuation zones (Morrow 1997), and of poor women unable to leave because they did not have enough money for supplies or transportation (Morrow and Enarson 1996).[26] Although the apparent abandonment by public authorities of New Orleans residents during Hurricane Katrina was perhaps the most egregious and visible to date, it was not the first instance of American residents being left with too few evacuation options as a disaster approached.

When Disaster Strikes

What are the patterns of mortality, morbidity, and injury when disaster finally strikes? In general, studies find that more marginalized groups, often the poor, women, and minorities, are hit hardest in U.S. disasters, a pattern also seen in disasters worldwide (Wisner et al. 2004). Katrina is actually part of a long-run historic record of inequality in disaster vulnerability.

In 1822, for example, hundreds of slaves died in a hurricane in South Carolina because there was no high ground and no shelter (Mulcahy 2005). The 1927 Mississippi Flood took the lives of hundreds of blacks who were rounded up and put on levees without food, water, or shelter. White authorities did not allow them to evacuate because they feared they would lose their inexpensive labor force (Barry 1997). In 1928, a major hurricane hit South Florida and more than 2,500 people, mostly black migrant workers, drowned in what is considered one of the worst disasters in U.S. history (Gross 1995; Van Orden 2002; U.S. Weather Service 2006). In Hurricane Audrey, which hit Louisiana in 1957, the death rate was thirty-eight per thousand for whites versus 322 per thousand for blacks (Bates et al. 1963). Research conducted in the 1970s concluded that disaster-connected deaths were disproportionately high among ethnic minorities (Trainer and Hutton 1972), and research on loss from natural hazards in the United States from 1970 to 1980 further confirmed that lower income households experience higher rates of injuries in disasters such as floods, earthquakes, and fires than more affluent households (Rossi et al. 1983).

The pattern of differential impacts is often due to the quality of housing afforded those lower on the socioeconomic scale. The low quality construction of low-cost housing puts residents of such housing at greater risk (Aptekar 1990; Bolin 1986; Bolin and Bolton 1986; Greene 1992; Phillips 1993). For example, in the United States many ethnic group members live in older buildings with unreinforced masonry, which are dangerous in an earthquake (Bolton, Liebow, and Olson 1993). Mobile homes, also low-income housing, are the highest risk in a tornado (Bolin and Bolton 1986; U.S. Department of Commerce 1995). The poor and minorities also encounter more problems with homelessness after a disaster, as was evident in 1989 after the Loma Prieta earthquake and Hurricane Hugo (Phillips 1998; Federal Emergency Management Agency 1990). And even though beachfront property exposes all residents, regardless of SES, to the risks of hurricanes, victims with the lowest incomes have the greatest proportionate losses to their housing (Bolin and Bolton 1986; Bolin and Stanford 1991).

A lack of economic, cultural, and social capital increases the vulnerability of poor women in a disaster, including violence from spouses and partners. The most vulnerable evacuees—minorities, girls and women, elderly, and the poor—can become victims of violence, such as beatings, rapes, assault, forced labor, and forced prostitution (Barry 1997; Bergin 2006; Fisher 2005; Enarson and Fordham 2001; Fothergill 1999; Morrow 1997; Morrow and Enarson 1996). There are also issues of violence toward vulnerable, minority groups after a disaster. In New York after the 9/11 terrorist attacks, a study of Muslim students found that many of them had been confronted about the terrorist attacks, including young women having their headscarves yanked off by strangers, and many felt it was not safe to leave their homes (Peek 2003).

Research also shows that psychological impacts are experienced in different ways by different groups, depending on factors such as race, ethnicity, gender, and income. There are, of course, many different forms of stress stemming from a disaster: the trauma of the actual disaster itself, the grief and anguish over injuries and loss of life, and the challenges that emerge immediately afterward, including the strains of relocation and temporary life in tent camps or shelters. Studies show that minorities and lower income groups tend to suffer more psychological impacts along these dimensions than higher-income and white victims, and may also have less access to mental health services (Aptekar 1990; Bolin 1993; Bolin and Bolton 1986; Goltz, Russell, and Bourque 1992; Garrison 1985; Shoaf 1998; Bolin and Klenow 1988; Fothergill 2004; Perilla, Norris, and Lavizzo 2002; Yelvington 1997).

Part of the reason for higher stress is that the poor, minorities, and single mothers may already feel a lack of control over their lives, and the dislocation and increased uncertainty about the future add to underlying and persistent stress. Psychological reactions are also affected profoundly by financial concerns, increased indebtedness, and the challenges of navigating bureaucracies. Emotional distress has been found to be greater when victims find that they will not be compensated for their financial losses. Elderly blacks, especially, have slower psychosocial recovery than elderly whites, partly due to economic constraints (Bolin and Klenow 1988). This financial stress can be felt immediately. Many middle- and upper-middle-class professionals can continue to receive paychecks during a disaster, whereas those who are paid hourly, such as service workers, do not.

The research record does point to important ways in which the poor and minorities deal with or mitigate the psychological impacts of disasters and their aftermath. In one study in rural Mississippi, black children who survived a tornado fared better than white children in a different disaster because the black children had more support beyond the immediate family and more household and farm responsibilities, which helped stabilize the children and made them feel more important to the family (Perry and Perry 1959). Some research has found that family was especially important for black victims (Bolin and Klenow 1988), backing up the notion that family ties are important for emotional recovery. This is one reason why the extended family dispersion after Hurricane Katrina has been of such concern to disaster scholars and community activists alike.

The poor and minorities may also suffer disproportionately in terms of immediate disaster services. In the famous 1928 Florida hurricane, African Americans were subjected to racial segregation and inequity in aid services, and were given less time for bodies to be identified and for the burial of the dead. They were also forced to recover and handle the dead through enforced servitude in recovery crews (Van Orden 2002). In the 1989 Loma Prieta earthquake in northern California, the Red Cross declined an invitation from community-based organizations to do outreach in low-income and non–English speaking communities (Subervi-Velez et al. 1992). Overall, the poor are one of the groups most likely to "fall through the cracks" during emergency relief operations (Colorado State University 1985).

For example, after Hurricane Hugo hit Georgia and the Carolinas in 1989, service agencies found that providing assistance to the rural poor was complicated because of high illiteracy rates, physical isolation in rural communities, fear and distrust of government officials, and lack of electronic media for weeks following the storm. Moreover, due to the total lack of pre-storm interface with the rural poor, they were "invisible" until the hurricane hit, living in unmarked homes, on unmapped roads, or hidden behind large estates (Rubin and Popkin 1990). Indeed, in an eerie parallel with the lesson Katrina delivered America about poor people in its midst, emergency response workers commented that until the hurricane, they were unaware of the extent of the poverty in their own neighborhoods (Miller and Simile 1992).

Differences have also been found in post-disaster sheltering efforts. The tent cities erected after Hurricane Andrew had a population roughly 50 to 60 percent Latino and 30 percent black, well above their share in the affected zone (Yelvington 1997). In the United States more generally, those lower on the socioeconomic scale are more likely to use mass shelters (Bolin and Bolton 1986; Bolin and Stanford 1990; Fothergill 2004; Mileti, Sorensen, and O'Brien 1992; Yelvington 1997).

Language is often also an issue during the emergency response phase. Local, state, and federal emergency response agencies have either too few or no bilingual personnel for bilingual populations (Phillips and Ephraim 1992; Subervi-Velez et al. 1992; Yelvington 1997). After the 1987 Whittier Narrows earthquake, officials put Not Fit for Occupancy signs on buildings with English-speaking tenants, whereas the Spanish translation for buildings with Spanish-speaking residents read Entry Illegal (Cooper and Laughy 1994, 7). After the 1989 Loma Prieta quake, some house warning tags, placed on homes to warn residents of the building's status, were printed in English only (Phillips and Ephraim 1992). Complaints were also numerous in the Katrina response about inadequate language capacities to deal with affected Latino residents, a rapidly growing population in the South (Muñiz 2006).

Existing inequities are often played out in the interactions between relief workers and victims. For example, after the 1979 Hurricane Frederick in Alabama, black communities received less food, ice, shelter, and assistance than white communities, and white neighborhoods had their power restored first (Beady and Bolin 1986). After the Loma Prieta earthquake, shelters in well-off neighborhoods had more volunteers than homeless clients and received visits from the mayor, whereas a low-income emergency shelter reported that the mayor did not visit and that white volunteers had made racist remarks (Dhesi 1991).

Media coverage also plays a role in which communities are favored or disfavored in the process of response and subsequent recovery, partly because disaster officials themselves sometimes rely on media coverage for setting priorities. In the Loma Prieta earthquake, the English-language news focused on the damage in San Francisco and, to a lesser degree, on Santa Cruz (which was nearly 80 percent white when the quake struck), often skipping over the effects in the devastated town of Watsonville (which was nearly 65 percent Latino). Some analysts argue that the increased media attention contributed to the more rapid recovery in the wealthier and whiter communities and continued stagnation in Watsonville (Subervi-Velez et al. 1992; Rodrigue and Rovai 1995).

Did the media do a better job in covering the disparate effects of the Katrina crisis? Reporters got on the scene quickly, often before government officials; indeed, one striking moment of the crisis occurred on the evening of September 1, three days after Katrina struck, when FEMA head Michael Brown indicated that he had just learned about evacuees at the New Orleans convention center and was asked by ABC Nightline anchor Ted Koppel: "Don't you guys watch television?" Media also kept significant attention on those who had been displaced and were at risk—and probably helped expedite the assistance that eventually arrived.

At the same time the mass media seemed to exaggerate incidents of looting and violence in ways that cast many of Katrina's victims as victimizers. Although lawlessness was afoot in post-Katrina New Orleans, the reporting—erroneous in part because of the chaos and incomplete information—seemed to only confirm the worst suspicions about the urban poor. Still, to the media's credit, many reporters were horrified by the lack of governmental response, labeled it an affront to basic American values of decency and community, and highlighted important issues of race, class, and poverty in their longer-term analysis of the crisis.

The overall record suggests that the media were right to pick up on this race and class dimension of the Katrina story. The pattern of difference and neglect that was so dramatic in the immediate aftermath of Hurricane Katrina was not an exception to the historical rule, but the most recent in a long line of inequitable disaster impacts.

Relief and Recovery

The inequities before and during a disaster are often played out further in the period after a disaster. Many minorities and the poor have had greater difficulties recovering from disasters due to less insurance, lower incomes, fewer savings, more unemployment, less access to communication channels and information, and the intensification of existing poverty (Bolin and Bolton 1986; Bolin and Stanford 1998; Cooper and Laughy 1994; Hewitt 1997; Peacock et al. 1997; Tierney 1988). After Hurricane Andrew, for example, blacks and non–Cuban Hispanics were more likely than whites to receive inadequate settlement amounts, and black neighborhoods were less likely to have insurance with major companies, a fact that may have been connected to redlining (Peacock and Girard 1997).[27]

Studies have also addressed racial, class, and ethnic differences in who receives disaster recovery assistance. Bolin and Bolton (1986) concluded that the blacks, who had lower income than whites in their study, needed multiple aid sources to deal with large losses because they did not receive enough support from fewer sources. Blacks were also less likely than whites to receive Small Business Administration (SBA) loans, more likely to use interfaith disaster services, and tended to recover economically more slowly. Following the 1997 Grand Forks flood in North Dakota, flood relief was geared away from migrant workers, hurting primarily Hispanic single mothers (Enarson and Fordham 2001).

Upper middle-class victims in several disasters have been more likely to receive assistance than minorities and the poor because they knew how to navigate the relief system, fill out the forms, and work within the government bureaucracy (Aptekar 1990; Fothergill 2004; Rovai 1994). In addition, poorer victims had more trouble making trips to the disaster assistance centers following Hurricane Andrew because of transportation, child care, and work difficulties (Dash et al. 1997). Furthermore, the traditional nuclear family model used by some relief programs left poor, minority women at a disadvantage (Morrow and Enarson 1996).

Housing continues to be a significant issue for low-income and minority disaster victims in the recovery period. Past research has found that housing assistance favors middle-class victims, particularly homeowners. Of course, helping homeowners is important and may be especially critical for middle-class black and Latino families. Such families have much lower homeownership rates but, as noted earlier, tend to have more of their net worth tied up in home equity than their white counterparts do. Still, including renters prominently in the relief mix is part of a more racially equitable approach.

Renters are affected in several ways. Higher-income evacuees often secure the surplus housing available in a community, leaving none for lower-income victims (Quarantelli 1994). In many disasters, rebuilding services are geared toward homeowners and legal tenants, and not toward multifamily and affordable housing units which are occupied by low-income tenants. Some landlords also take active advantage of the situation. The Whittier-Narrows earthquake, for example, occurred on the first of the month, the day rent was due. Many landlords evicted low-income renters for late rent and some even lied about building conditions to get rid of their low-income tenants (Bolton, Liebow, and Olson 1993).

There are alternatives. In the aftermath of the Loma Prieta earthquake of 1989, political pressure was put on FEMA to provide more housing for low-income victims. In mid-November 1989, FEMA agreed to provide more than 140 mobile homes in Watsonville and Pajaro, two areas with a lack of affordable housing. FEMA had initially resisted offering mobile homes, with one FEMA spokesperson referring to them as "instant slums" (Bolin and Stanford 1993, B46). But a formal petition brought against FEMA for violating regulations and statutes for low-income earthquake victims forced the change (U.S. House of Representatives 1990). And a bold plan put together by the U.S. Department of Housing and Urban Development after the 1994 Northridge quake (see profile that follows) managed to help many low-income renters quickly get back on their feet.

Legal residency is another critical issue in disaster recovery. Following disasters, many undocumented immigrants, unsure about the Immigration and Naturalization Service (INS) policy, avoid recovery assistance for fear of deportation (Subervi-Velez et al. 1992; Bolin 1993; Cooper and Laughy 1994; Yelvington 1997). Muñiz (2006) offers anecdotal evidence that this was an issue in Katrina as well. She also shows how the occasional assumption that Latino residents were undocumented rather than legal residents sometimes led FEMA to fail to offer appropriate information about housing assistance to eligible individuals.[28]

In addition, the nontraditional family structures of immigrant households can be a challenge for disaster officials. Following Hurricane Andrew, FEMA was not prepared for some of south Florida's family structures, particularly Haitian families, who often had several families in one household—FEMA's temporary assistance was set up for nuclear families with one head of household (Morrow 1997).

Culture can also influence resident attempts to access service. Many Latinos have experienced or had been told, through personal networks, of earthquakes in their countries of origin, such as the 1985 Mexico City earthquake and its deadly aftershocks; they thus feared the temporary shelters set up after quakes (Bolton, Liebow, and Olson 1993; Phillips 1993). In Miami, immigrants from countries with a history of political repression, such as El Salvador and Guatemala, avoided official assistance (Enarson and Morrow 1997). In California, some residents of Central American origin refused to use the National Guard camps, because the tents and fences reminded them of death camps in their native countries (Phillips 1993).

Indeed, the presence of disadvantaged persons, already living in marginal housing, presents disaster service providers with demands that are often unanticipated within the provisions of routine shelter and housing programs (Bolin and Stanford 1990). In the context of the limited resources that might be available after a disaster, this issue is a simple reflection of the ongoing crises of poverty, inequality and discrimination in American society—and disasters often provide a window on a world of hurt being ignored on a daily basis by the media, policy makers, and the general public.

Reconstruction and Long-Term Effects

The long-term reconstruction after a disaster can simply continue the pattern of inequity and stress that has played out throughout the disaster itself. As with the stage of short-term recovery, the search for safe, affordable housing after a disaster is one of the most critical, and unsolved issues for lower income families and minorities in the United States. In virtually all of America's major urban areas, there is already an acute housing crisis for lower income households before a disaster hits—and the disaster exacerbates existing problems.

Numerous studies have found that problems of homelessness and low-income housing shortages become even more serious in the years after a disaster (Bolin and Stanford 1990, 1991; Comerio, Landis, and Rofe 1994; Greene 1992; Phillips 1993, 1998; Wright 1989). For example, a year after the Loma Prieta earthquake, 90 percent of the affected multifamily units were still out of service; four years later, 50 percent of the affected multifamily units remained unlivable (Comerio, Landis, and Rofe 1994). Several other studies have found that poor women have the most difficult time rebuilding homes, finding new places to live, and getting out of substandard temporary housing (Enarson and Fordham 2001; Morrow and Enarson 1996).

Members of racial and ethnic minorities and the poor are also less likely to qualify for and receive various types of aid for reconstruction, including SBA

Where Is New Orleans East? Race and Invisibility

The telephone began ringing very early in the morning of November 19, 2005, for a former New Orleans resident who had, like most of her family and friends, lost her home and possessions to Katrina. They were all told that it was the storm surge that had destroyed the levees that flooded their homes and 80 percent of the city. But two and a half months after hurricane winds had buffeted the city, it was a policy surge that seemed about to complete what Katrina had begun.

The phone was ringing because today was the day that the Bring New Orleans Back Commission would unveil a report it had commissioned from the Urban Land Institute, a nonprofit organization that includes real estate professionals, academics, and others with expertise in land issues. The word on the street was that the plans did not look good for eastern New Orleans. New Orleans East, like the Lower Ninth Ward, lies below the industrial canal and is also predominantly African American. The similarities, though significant, completely dissipate for education and income. Where the Lower Ninth Ward has been portrayed as black and poor, New Orleans East has hardly been portrayed at all.

New Orleans East was a community where most of the city's black professionals, school teachers and administrators, famous musicians (from hip-hop to jazz), businessmen, and politicians lived. It was an area primarily of homeowners with flood insurance. It represented nearly 40 percent of the city's tax base, but the Urban Land Institute plan included a map showing most of New Orleans East being relegated to parks and green space or subject to a building moratorium until neighborhoods proved viability.

In the aftermath of Katrina, New Orleans East evacuees and their friends have learned that all of their education and money did not shield them from natural disasters, the neglect of the levee system and coastal wetlands erosion, and the ways in which public policy decisions reinforce the legacy of race. Their community was literally wiped off the map with no regard for the social, economic, and financial impact this decision would have on those affected. Worried residents are still waiting to see what will emerge with regard to levee protection, SBA loans, insurance settlements, and land buyouts. Will race, once again, be a factor that colors the decision-making process?

Note: This story was provided by Beverly Wright, director of the Deep South Center for Environmental Justice and a Katrina evacuee from New Orleans East.

loans, and to have trouble with the housing process. For instance, after a Texas tornado, whites were much more likely to qualify for and receive such loans than blacks (Bolin 1986; Bolin and Bolton 1986), and after the Northridge earthquake, ethnic minority households had limited access to FEMA loans and SBA grants (Bolin and Stanford 1998). In the Loma Prieta reconstruction, victims were ineligible for disaster aid if they had had illegal housing before the disaster. After the 1995 flooding in New Orleans, even though low-income elderly women were overrepresented in the population applying to FEMA for low-interest loans, they were three times less likely than other elderly households to receive them (Childers 1999).

A few studies show that some of the poorest victims may temporarily do better after a disaster. This was the sentiment expressed by some, including former First Lady Barbara Bush, who after visiting Katrina evacuees in the Houston Astrodome, said: "so many of the people in the arena here, you know, were underprivileged anyway, so this is working very well for them."[29] But most of the empirical evidence shows that most victims—especially minority and low-income victims—are worse off in the years that follow the disaster. For example, residents of very low-income housing, such as single room occupancies (SROs), do not easily qualify for assistance programs. Many disasters have pushed the marginally homeless population into the category of permanently homeless.[30] In general, disasters may also push many lower income and working class families into debt and financial insecurity, dashing hopes to buy houses, attend college, and so forth.

The Loma Prieta quake in California also shows that physical recovery can vary in different areas. This likely differentiation in long-term recovery is a source of great controversy now in New Orleans, with some plans suggesting that the black areas of the city will be the last to be brought back in a sort of phased recovery. Yet, as in contemporary New Orleans, the research suggests that many disaster victims often do not want to relocate, and remain in, or try to return to, badly damaged communities. Post-earthquake studies found that many Hispanics were connected to their neighborhoods and did not want to move away (Bolin 1993). After Hurricane Andrew, blacks were less likely than whites to relocate, and data show that blacks remained in damaged areas (Girard and Peacock 1997). Reasons for this persistent of attachment include economic barriers, residential segregation, and a sense of place. Often overlooked in the reconstruction effort are the ways in which communities find meaning in where they live and where their families have lived for generations, and why the right of return has such special salience.

Indeed, the reconstruction of neighborhoods has an importance that goes beyond simply respecting sentiment. Although African Americans and Latinos have often been steered through housing practices to segregated areas, such areas can also constitute ethnic enclaves where minority entrepreneurs can find clienteles and build up local-serving businesses. One emerging worry in New Orleans is exactly what will happen to the black middle class if the communities they have served are dispersed across the United States and their neighborhoods are not rebuilt for return. The social capital of a community and the financial capital of its entrepreneurs are often intertwined. Rebuilding must take this into account before designating certain areas as unfit for reconstruction.

Learning from History?

The historical record suggests a pattern of differential impacts: groups that lack access to resources, power, and information often find themselves further disenfranchised before, during, and after a disaster. Despite some efforts at reform, the question that results is straightforward: with so much evidence, why was so little done to address disparities before Hurricane Katrina struck the Gulf Coast?

In our view, one reason may be that unlike the environmental justice field, the disaster field has not been immersed in the difficult but fruitful interplay of rigorous scholarship with an emerging social movement. Disaster scholars have tried to affect policy—indeed, the field has been criticized for being too applied—but unlike the work of the EJ scholars, it has generally not informed, and been informed by, activists (Fothergill, Maestas, and Darlington 1999). This is partly due to the nature of disasters—one sees episodic organizing against particular abuses by, say, FEMA rather than the sort of sustained efforts around changing EPA policy typical of the EJ field. But this is a gap that should be addressed. Real policy change is usually driven by social pressures and not simply the good science and good research we associate with academic scholarship.

Communities sometimes become politicized in their reactions to the social disruption and inequities that arise in the wake of a disaster—and disasters can open broader political dialogues on social inequalities (Bolin and Stanford 1991) or create an enhanced sense of ethnic identity (Davis 1986). After the mistreatment of blacks during the 1927 Mississippi Flood, blacks shifted from the Republican to the Democratic Party, and many left the South for the northern states (Barry 1997). After Hurricane Andrew, Mexican farm workers, Haitian immigrants, and African American church women organized and mobilized their neighborhoods (Enarson and Morrow 1997) and several African Americans were elected to public office (Peacock et al. 1997). After the Loma Prieta earthquake, coalitions of community activists, federal agencies, and private organizations pushed to build low-income housing as part of the planned reconstruction in Santa Cruz County—and these efforts not only helped to improve the living conditions of Latinos, but also helped fuel a broader movement to increase Latino political voice in the Monterey Bay region (Bolin 1993).

Katrina certainly seems to have put a spotlight on the chasms of race, poverty, and environmental injustice in the United States. Whether the window stays open for policy change with regard to disaster readiness, response, and recovery remains to be seen. In our view, part of keeping that window open involves understanding the continuum between chronic and acute risk, and building increased ties between environmental justice researchers and disaster studies scholars, and between environmental justice activists and those working in the affected communities of the Gulf Coast.

Until Hurricane Katrina, there was a gap between the work of environmental justice and the sociology of disasters, even though both areas are concerned with inequality and environmental hazards and risks. Environmental sociology books, for example, rarely discuss disaster research, and disaster studies rarely draw on environmental justice literature. Yet the goals and principles of the environmental justice field are the same as those of the disaster field: to use systematic and thorough research to uncover inequality in exposure to hazards and risks, and to support organizing and policy change to reduce risk and suffering. New research bridges are being formed. Bolin (2006) argues, for example, that environmental justice's historical equity studies might be a particularly useful tool for disaster sociologists to use to understand pre-disaster vulnerabilities and post-disaster processes.

In general, a move toward more vulnerability analyses and more use of the EJ framework could help disaster research be more historically and geographically informed. It could help the field—and policymakers—move away from viewing disasters as acute events, concentrated in time and space, and separate from routine, or nondisaster, social processes. Perhaps the disaster field could also use some of the concepts and themes of the EJ movement, such as taking a broad view of the environment, including housing, air quality, transportation, and the like, using a rights-based approach to environment, applying the idea that everyone has a right to the environmental quality and protection from risks, and advocating for democratization in decision making about the environment and disaster readiness.

Homeland Security and Unequal Risks

Since the tragic events of September 11, 2001, national officials have been preoccupied with the important task of fighting terrorism and preventing terrorist incidents. However, for homeland security programs—and related emergency preparedness programs for that matter—to be effective, they must have the cooperation and trust of all Americans (Working Group on "Governance Dilemmas" in Bioterrorism Response, 2004).

Yet the history of racial disparity affects popular views of the effectiveness and fairness of a government response to an emergency: for example, a 2004 RAND Corporation study in Los Angeles County found that 77 percent of white respondents perceived that the public health system would respond fairly in a bioterrorist event (Eisenman et al. 2004), while 63 percent of African Americans, 68 percent of Asian–Pacific Islanders, and 73 percent of Latinos felt that the public health system would respond fairly in a terrorist crisis. The study concluded: "To strengthen bioterrorism preparedness, public health officials must continue to improve perceived fairness among African Americans and Asian/Pacific Islander communities."[31]

The emergency response in the aftermath of Katrina has done little to build trust in government. This is particularly so in the Louisiana petrochemical corridor so heavily populated by poor residents and blacks. Although to date no such attack has been made on a U.S. chemical facility, more than 3,000 accidents involving more than 10,000 pounds of hazardous materials have occurred since 1987, with smaller incidents occurring daily (Hinds 2001). It is little wonder that the Justice Department has determined that threat of a terrorist targeting such plants is "both real and credible" and could be more serious than attacks on nuclear power plants, which at least undergo regular security assessments by the Nuclear Regulatory Commission (Gremaldi and Gugliotta 2002, A1).

The magnitude of a terrorist attack on U.S. chemical facilities could easily exceed the loss of life suffered on September 11, 2001. The surgeon general of the U.S. Army identified chemical plants as second only to bioterrorism in terrorist threats to the United States, and a 2002 Brookings Institution report ranked chemical facilities third in the number of fatalities that could occur from a terrorist attack (O'Hanlon et al. 2002). Of the nation's 15,000 chemical facilities, the U.S. Government Accountability Office reports that 123 are close enough to potentially endanger more than 1 million people if a terrorist attack occurred (2004).

Railroad cars carrying chemicals are also of concern. Millions of Americans are at risk from toxic "time bombs" that travel on railroad cars through populated areas. In October 2004, government safety officials warned that more than half of the nation's 60,000 pressurized rail tank cars did not meet industry standards, and they raised questions about the safety of the rest of the fleet as well. In January 2005, two Norfolk Southern Railway Company trains crashed into each other, releasing deadly chlorine gas in Graniteville, South Carolina, killing nine people, injuring 240, and forcing the evacuation of nearly 5,500 residents (Daily 2005). Some residents in the all-black New Hope Graniteville community complained that the Aiken County government emergency responders left the black community behind for nearly thirteen hours as they evacuated whites (Brundrett 2005; Bogdanich and Drew 2005).

Post-Katrina events have done little to stir new confidence among those fenceline communities that have been subject to pollution releases from nearby chemical facilities, or living near the potentially dangerous transit corridors discussed. In January 2006, for example, a storage tank at the Exxon Mobil Refinery in Baytown, Texas, spilled a 150,000-barrel storage tank that contained benzene, a known carcinogen. Although Exxon Mobil officials insisted the release was not harmful, a day after the incident and hours after residents bombarded the company with complaints, Exxon Mobil sent a team of thirty workers wearing jumpsuits and plastic gloves. The following day, the company distributed a letter, signed by the manager describing and apologizing for the incident, to the residents and the Baytown Housing Authority.

The current Texas law calls for reporting such spills within twenty-four hours to the Texas Commission on Environmental Quality (TCEQ); Exxon Mobil took twelve hours to report, and waited a full day and a half before informing TCEQ officials that the incident went off the plant's grounds and affected the nearby community. Harris County's Pollution Control and Environmental Health Division officials learned of the off-site release from media accounts on Wednesday, more than two days after the incident. Local residents, state, and county environmental officials have questioned the delayed notification—but the penalties for late reporting and creating a nuisance are set between $2,500 and $10,000, at a level that is hardly a deterrent for Exxon Mobil, the largest energy company in the world, and seems to grossly undervalue the lives of fenceline communities.

Although such communities may be especially vulnerable, releases of toxic chemicals can kill and injure people relatively far from the accident scenes. Protecting those with the least resources is critical to protecting all of us. Addressing the issues of disparity that seem to plague both chronic risk, as indicated by the statistical studies cited, and the acute risks of accidents due to terrorism, accidents, and other factors would surely build the sort of widespread trust that will be needed in a real national emergency.

Katrina, Environmental Justice, and New Policy

Long before Katrina struck, residents and activists had struggled against the disparate social, economic, and health impacts of the rapid proliferation of chemical facilities and sprawling industrial and residential development on poor African American residents in the Gulf Coast (Bullard 1990a; Roberts and Toffolon-Weiss 2001; Allen 2003; Lerner 2005; Urbina and Wald 2005). The evolution of this corridor, which included massive buyouts by large corporations of large swaths of small towns to build large petrochemical complexes (Markowitz and Rosner 2002), has been driven by the availability of oil, natural gas, and sulfur but has also resulted from two other important factors. One is a state government that proactively pursued the jobs and tax revenue promised by the petrochemical industry. The other is a legacy of racism that has left poor African American residents hostage to hazardous working conditions, reduced labor rights, and worsened environmental quality.

Although Hurricane Katrina has laid bare for the entire nation the consequences of this discriminatory system and its social, political, and ecological dimensions, it also raises opportunities for civil rights, environmental, labor, and environmental justice organizations to advocate for a process of relief, recovery, and rebuilding that can begin to dismantle systemic socioeconomic and environmental inequalities that have plagued the region. Environmental justice organizing will be central to ensuring that the diverse voices of African American and poor communities are central to the long recovery and rebuilding process that lies ahead.

Preventing a "Second Disaster" After Katrina

The amount of debris left behind by Katrina—an estimated 22 million tons—is staggering (Griggs 2005, 12A). More than half, 12 million tons, is in Orleans Parish. In addition to wood debris, EPA and LDEQ officials estimate that from 140,000 to 160,000 homes in Louisiana may need to be demolished and disposed (EPA and Louisiana Department of Environmental Quality 2005). These homes include over one million pieces of "white goods"—such as refrigerators, stoves, and freezers—that require disposal. An additional 350,000 automobiles must be drained of oil and gasoline and then recycled; 60,000 boats must be staged and maybe destroyed; and 300,000 underground fuel tanks and 42,000 tons of hazardous waste must be collected and properly disposed (Varney and Moller 2005).

Currently, officials are debating about how to dispose of the debris. The EPA's Science Advisory Board (SAB) expressed deep concerns over the LDEQ debris management plan that calls for burning hurricane debris in open pits, using so-called "air-curtain incinerators" (EPA Science Advisory Board 2005, *Inside EPA*). The SAB recommended that the EPA consider actions other than open burning, such as temporary landfilling at parish collection points, significant processing, recycling and reuse at collection points, and long term land filling, outside the area if needed. The Solid Waste Association of North America (SWANA), in its September 21, 2005, report, *Hurricane Katrina Disaster Debris Management: Lessons Learned from State and Local Governments,* also noted that the use of open pit incineration in Florida after Hurricane Andrew in 1992 generated many complaints from the public, and county commissioners responded by shutting down all debris open pit burning operations whether they used the air curtain process or not.

The disposal process, whether through burning or landfills, can have serious equity dimensions. After the 1994 Northridge earthquake, for example, the removal of concrete rubble from collapsed freeways stirred controversy when one entrepreneur in Huntington Park, a city that was over 90 percent Latino and far from the epicenter of the quake, sought to store and recycle the concrete. Already host to numerous hazards, including elevated levels of air toxics due to heavy industrial uses and truck traffic, the community found itself living next to a pile of concrete that was sixty feet high and soon nicknamed La Montaña (the mountain). With concrete dust draping cars and houses, and asthma attacks on the rise, community members organized, and pressured the city council to take action.

The city council eventually declared the site a public nuisance and, in 1998, the business owner was ordered by a judge to remove the rubble. The owner declared bankruptcy, leaving the future of La Montaña in doubt; three years later, another judge ordered the owner of the land on which the business sat to clear up the debris. But those orders were also ignored. It was not till 2004 that the California Integrated Waste Management Board took responsibility and authorized a clean-up. In the words of Linda Moulton-Patterson, board chairwoman, "if there has ever been a poster child for environmental justice, this is it" (Renaud 2004, B3). And if this is any harbinger of how timely and equitable debris removal will be, there are reasons to be worried about the aftermath of Katrina.

In the Gulf Coast, there are other critical environmental and public health threats beyond the issue of the cleanup and disposal. Katrina toppled offshore oil platforms and refineries, causing six major oil spills releasing 7.4 million gallons of oil (Cone and Powers 2005). It also hit sixty underground storage tanks, five Superfund sites, and numerous hazardous well facilities. In addition, more than a thousand drinking-water systems were disabled—E. coli in the floodwaters far exceeded the EPA's safe levels (Cone 2005, A18).

New Orleans area residents also face complex health threats from contaminated soil and sediments left by Katrina floodwaters (CDC–EPA 2005). This includes threats from contaminated drinking water supplies, polluted floodwaters, broken sewage treatment systems, oil and chemical exposures, toxic sediments and sludge. EPA tests in some New Orleans neighborhoods found elevated lead and arsenic concentrations (CNN 2005). Tests from independent sampling conducted by the Louisiana Environmental Action Network (LEAN) in several New Orleans neighborhoods showed high levels of polynuclear aromatic hydrocarbons (PAHs), many of which are known or suspected carcinogens (Dunn 2005).

How, when, and at what level of standards contaminated neighborhoods get cleaned up is a major environmental justice concern. More than 110,000 of New Orleans 180,000 houses were flooded, and half sat for days or weeks in more than six feet of water (Nossiter 2005). As many as 30,000 to 50,000 homes citywide may have to be demolished, and many others can be saved only with extensive repairs (Loftis 2005). Instead of emphasizing uniform cleanup standards, equal protection, and environmental justice for low-income and minority communities, some public officials have sent mixed signals for rebuilding low-lying black neighborhoods such as the Lower Ninth Ward (Sontag 2005). This issue has heightened the anxiety among residents who want to return home and caused division within the Bring Back New Orleans Commission created by the mayor (Rivlin 2005).

Talk of not rebuilding black New Orleans neighborhoods after a hurricane is not new. In 1965, Hurricane Betsy hit the mostly black and poor New Orleans Lower Ninth Ward especially hard, and accelerated the decline of the neighborhood and the out-migration of many of its longtime residents (Dyson 2006, 11). Given this history, many residents today do not trust the government to protect their interests and prioritize their neighborhoods for clean up and reconstruction (Remnick 2005). They are worried about some sort of "second disaster."

Promoting an Eco-Social Approach to Recovery

In our view, understanding and proactively addressing the socioeconomic, political, and public health impacts of Hurricane Katrina requires an eco-social approach that merges the focused reconstruction process with broad attention to issues of economic and environmental justice. The joining of social and environmental concerns is critical. Although there has been substantial research documenting the ecological problems plaguing coastal communities in the Gulf

Source: © Ted Soqui, Corbis.
Note: Paul Guerra standing inside his brother's flooded home. He is trying to save their valuables and other documents. Most were destroyed by the murky flood waters and toxic black molds. The house is in the Lake View area of New Orleans.

region on one hand, and a large body of work assessing the socioeconomic and public health problems on the other, there have been few attempts to purposefully integrate these two fields in a way that makes explicit the connections between public health, the environment, and social inequality in the region (for notable exceptions, see Bullard 1990a; Colten 2005).

An eco-social approach would ensure that regulatory activities, as well as disaster management, recovery, and planning initiatives effectively integrate the goals of social equity and economic justice with comprehensive environmental sustainability objectives. Over the last decade, environmental justice advocacy has transcended reactive strategies that emphasize hazardous facility siting and has moved toward proactive approaches aimed at transforming the underlying structural causes of environmental inequality, economic inequities, and health disparities. In the realm of environmental health, EJ activists have also pushed scientists and regulatory authorities to move beyond facility-by-facility or chemical-by-chemical risk assessment and regulation toward more holistic strategies that address a multitude of pollutant exposures and incorporate concepts of social inequality, economic disparities, and residential segregation into assessments of community susceptibility to environmental hazards (Morello-Frosch et al. 2001).

Such cumulative impact assessments are critical. They would better account for the real exposures borne by diverse populations generally exposed to a variety of pollutants where they live, work, and play—such as the air they breathe and the food and water they consume. Although data gaps pose challenges for estimating the cumulative health risks associated with multiple pollutants and emission sources, some researchers and regulatory agencies have begun thinking about how to integrate existing information to address community concerns (National Environmental Justice Advisory Council 2004). In a place like Louisiana, where environmental insult seems to have

Counting Our Blessings, Counting Our Losses

For many American families, a home is both a part of a dream of belonging and the family's greatest source of wealth. Consider a Katrina evacuee, happy to survive the hurricane and now contemplating the financial storm ahead.

She owns her home, the last payment having been made in August, the same month Katrina hit the city. Before Katrina, a similar house in her block sold for $219,000. The only proposal that our evacuee has seen for compensating her if she is not allowed to rebuild is in a bill proposed by a Louisiana congressman, Richard Baker. The bill proposes funds such that property owners be given 60 percent of the equity in their homes less any money they receive from the insurance company. Based on this proposal, our evacuee would receive $131,000, 60 percent of the assumed $219,000 equity. Her insurance policies, however, paid $28,000 more—$159,000. Thus she would receive nothing from the government and it would be able to take over her land and prevent her from rebuilding. Her net loss from the federal bail-out is $60,000, not to speak of the loss of control.

The story gets worse. After the death of her mother in April 2005, our evacuee, along with one sister, inherited the family house. She remembers her father saying with pride, "his house is for you, children. Always remember, it's easier to get ahead if you don't start from scratch. This is your scratch." Her parents worked to purchase their home—in fact, they acquired two houses and three lots in Mississippi. Yet the home that her parents struggled so hard to acquire for future or generational wealth is scheduled for demolition. Her parents had more than adequate homeowner's insurance, but had only $39,000 in flood insurance, a sum woefully inadequate to replace the family home. Like most elderly persons or couples in the New Orleans area whose homes were paid off, the flood insurance policy had not been revisited since Hurricane Betsy—forty years ago. The homeowner policy adjusters are fighting clients to ensure that they receive as little as possible from a policy that has been in effect for nearly fifty years.

It is easy to count the actual dollar loss for the family. But the social capital that spans nearly a hundred years, based on the vision and foresight of the parents and grandparents of our evacuee, cannot be measured. What this will mean for the wealth, health, and security of this family and the many families just like them is the untold story. Is this the way to treat those who bought into the American dream, worked hard all of their lives, raised and educated their children, and placed God and country at the center of their lives?

Note: This story was provided by Beverly Wright, director of the Deep South Center for Environmental Justice and a Katrina evacuee from New Orleans East.

been piled on economic and social injury, a cumulative impacts approach certainly seems warranted.

Nevertheless, scientists and policymakers are still catching up to community wisdom on this issue. For example, Alternatives for Community and Environment (ACE) has taken a holistic approach to addressing spiraling asthma rates in the Roxbury-Dorchester areas of Boston. This entails advocacy across several fronts including housing quality, transportation justice, disparities in municipal investment in neighborhood infrastructure, access to preventive health care, pollution sources and sanitation, and health education (Agyeman 2005; Morello-Frosch et al. 2006). This form of broad-based advocacy is influenced by a hard lesson from environmental justice activism. Even though local, hazard-by-hazard organizing is a powerful strategy, it drains community resources and locks organizing efforts into a reactive rather than a proactive mode (Agyeman 2005).

In the context of promoting socially equitable disaster planning and recovery in the wake of Hurricane Katrina, such a holistic strategy implies consideration of two major issues: the confluence of social vulnerability and cumulative impact. As the government response to Hurricane Katrina so tragically revealed, attention to social vulnerability is not systematically integrated into disaster planning and management. This is partly because vulnerability is deeply rooted in the legacy of racial and class-based discrimination, which requires systemic political and economic changes to overturn. But the challenges of change do not obviate the realities: the combination of socioeconomic stressors faced by disenfranchised communities coupled with the elevated environmental hazard exposures documented above has been described as a form of double jeopardy (Institute of Medicine 1999).

In New Orleans, this double jeopardy was revealed by a legacy of race and class discrimination that had literally corralled and trapped African Americans and the poor into ecologically and economically vulnerable spaces from which many were unable to escape. Indeed, although residents were urged to evacuate the city before, in one post-Katrina study, 55 percent of the respondents who did not evacuate said that one of the main reasons they did not was that they did not have a car or other way to leave (Washington Post, Kaiser Family Foundation, Harvard School of Public Health Project 2005). This left people stranded in a rapidly flooding city, often on rooftops and in deplorable, life-threatening conditions in makeshift shelters with little food, water, or basic services. In the same survey, 68 percent of the respondents felt that the federal government would have responded more quickly to rescue people trapped by floodwaters if more of them had been wealthier and white rather than poorer and black.

But even as Katrina graphically revealed deep structural divisions across racial and class lines, the storm also washed away the illusion that the wealthy can fully insulate themselves from the invisible health risks and long-term consequences of environmental inequalities and social injustice. As sociologists Drake and Cayton noted more than fifty years ago: "The color line is not static; it bends and buckles and sometimes breaks" (1945, 101). And when the levees shielding the poorest and blackest community in New Orleans broke, the water left nearly 80 percent of the city in a toxic soup. All New Orleans neighborhoods must now contend with the reality of a new riskscape that has spilled across traditional racial, class, socioeconomic, and political lines. Indeed, after conducting preliminary soil and air sampling and analyzing state and federal regulatory data, some environmental groups have concluded that without extensive cleanup and remediation of toxic sediment, nearly 75 percent of the city will be unfit for families with children (Barringer 2005).

Better Safe Than Sorry?

Community participation is critical to develop long-term regional development initiatives that are economically viable and protect public health. This necessitates moving regulation, land use planning, economic development, and environmental policy "upstream" to promote "just sustainability"—that is, an emphasis social justice and economic equity as well as the need to live within ecosystem limits and preserve resources for future generations (Agyeman 2005, 79). One path toward achieving this goal is to integrate the precautionary principle more systematically into environmental policy making, regulation, and future infrastructure investments in the Gulf region.

The meaning of the precautionary principle has been interpreted broadly by many stakeholders, which has made the framework controversial (Sustein 2003; Dorman 2005). Yet, the essence of the precautionary principle promotes planning, alternatives assessment, and anticipatory action, with the aim of minimizing environmental health and ecological calamities. The precautionary principle also seeks to mobilize environmental and public health policymaking that otherwise can be paralyzed when implementation depends too much on technocratic or scientific certainty.

In the case of environmental health, the principle would require that regulators be more proactive if scientific evidence strongly suggests, but does not yet fully prove, that a facility, chemical exposure, or production process may be jeopardizing public health, particularly among communities already disparately impacted by toxics. It acknowledges that in the never-ending quest for better data and unequivocal proof of cause and effect, environmental regulators can lose sight of a basic public health principle—namely, the importance of exposure reduction and disease prevention (Morello-Frosch, Pastor, and Sadd 2002).

Equally important, the precautionary principle shifts the burden of hazard assessment, monitoring, and data generation activities onto those who propose to undertake potentially harmful activities or chemical production (Kriebel and Tickner 2001; Kriebel et al. 2001). For example, a precautionary approach requires that the health and safety effects of new chemicals be fully examined before they are approved for widespread commercial use and released into the environment. This contrasts with our current model of environmental regulation, which presumes that chemicals and production processes are safe unless definitive data and research prove otherwise. This reactive approach to regulating industrial production inevitably creates economic and social costs (such as decreased property values and increased incidence of environmentally mediated diseases, such as cancer and childhood asthma), and does not avoid the effects of cumulative exposures locally to multiple emissions sources through various exposure pathways.[32]

Opponents often argue that the precautionary principle can result in overregulation that decreases economic efficiency and threatens jobs. Yet the precautionary principle is not really that radical. In the United States, for example, precautionary regulatory approaches are evident in current regulatory practices for marketing new drugs and pharmaceutical products: extensive testing and clinical trials are required to assess the effectiveness and safety of new products before they can be marketed to consumers and health providers. Moreover, the precautionary principle appears in several international environmental accords and treaties and enjoys widespread public support in other economically thriving industrialized countries in Europe, including codification in an innovative regulatory program just passed by the European Union Parliament (Raffensperger and Tickner 1999; Calver 2000; Sustein 2003; Dorman 2005).[33]

Several states have taken the lead on both environmental justice and the precautionary principle (SERC 2003). In California, for example, the synthesis between the two is evident in the state's recently adopted environmental justice guidelines (California Environmental Protection Agency 2004). California has already taken major steps toward integrating precaution into its regulatory process by phasing out the use of a category of polybrominated diphenyl ethers, a widely used fire retardant chemical, that has problematic, albeit poorly understood, human health effects, and which has been shown to be accumulating at an rapid rate in the breast milk of San Francisco Bay area women.

States are also developing precautionary strategies to improve disaster planning and to protect vulnerable communities and workers from environmental health calamities. New Jersey recently became the first state to require developing and implementing chemical plant security measures to protect facilities from either a natural disaster or a terrorist attack. Such proactive regulatory strategies could be a model for other states, such as Louisiana, that are vulnerable to regular natural disasters and that have major industrial facilities adjacent to densely populated fenceline communities or in low-lying areas prone to flooding.

Of course, new regulatory regimes and policy initiatives, particularly when they are locally or state-based, can lead to "hazard-shifting" from one group to another. Such risk reallocation, for example, from residential communities to workers occurred in Chicago when the city, due to a moratorium on building new landfills and strict rules on incineration, sought new ways to recycle and dispose of municipal waste. As a result, the city's corporate contractor, Waste Management Incorporated, was allowed to institute a recycling system that required workers to sort and separate waste, which exponentially increased the workplace hazards and injuries that the predominantly African American workforce in the recycling industry faces (Pellow 2000, 2002).

In the wake of Hurricane Katrina, we are witnessing risk shifting phenomena in the attempt to quickly dispose of hazardous debris from neighborhoods across New Orleans and consequent lax enforcement of safety standards for workers engaged in demolition, hauling, and reopening hazardous landfill sites (Russell 2005). Moreover, EPA has suspended air pollution regulations, ostensibly to ramp up refinery production and address the national shortfall in energy supply due to storm damage of large production facilities in the Gulf region.

The precautionary principle seeks to bridge community health and worker safety concerns to promote opportunities for introducing and promoting less toxic alternatives in production. The hope, after all, is not to simply reallocate environmental hazard burdens from one population to another, but rather to promote an integrated regulatory approach in which industry, government, and society are compelled to adopt viable strategies for pollution prevention and toxics use reduction that benefit everyone.

One highly effective approach involves using information-based (or "right-to-know") strategies at the state and federal levels. For example, the Massachusetts' Toxics Use Reduction Act (TURA) of 1989 requires that firms develop both an inventory of chemicals flowing in and out of each production process at a facility, and a toxics use reduction plan. Although firms are not required to implement these plans, the process itself helps the organizations identify more efficient production methods that prevent pollution and decrease production costs. TURA has resulted in significant toxics use reduction. After adjusting for production increases, 2003 data indicates that reporting firms decreased their toxic chemical use by 40 percent from the 1990 base year and generated 70 percent less waste per unit of product (TURI 2005).

At a national level, the Toxics Release Inventory, which was created by Congress in 1986 in the wake of the Bhopal disaster, requires large firms that emit a threshold volume of chemicals to report annually to EPA their own estimates of pollutant releases into the air, ground, and waterways. Despite some of its limitations in terms of regulatory oversight and the number of chemicals covered, the TRI is still one of the more successful regulatory tools promulgated by EPA in over a decade. OMB Watch recently reported that since 1988, disposals or releases of the original 299 reportable chemicals have dropped by close to 60 percent (OMB Watch 2005).

Indeed, the database and its accessibility to the public are the keys to its success. With annual reporting, TRI data has been leveraged to educate and mobilize the public about those facilities with persistently high emissions of some of the most toxic pollutants. Industry has used the database to assess and improve its own performance as evidenced by some impressive emissions reductions over the years. The Bush administration has sought to reduce reporting requirements by both lowering the threshold of use that triggers a report and by having the reports required every other year rather than the current annual timetable. The rationale has to do with reducing cost but the proposal also works against the community-level and market-driven empowerment that the administration purports to support.

Social Infrastructure and Community Voice

Community empowerment is central to the precepts of environmental justice, and many EJ advocates have particularly emphasized including the voice of those who may be traditionally shut out of the regulatory and policy-making process due to challenges such as language or citizenship barriers. Although this emphasis is driven by a sense of justice, government also functions most effectively when it works in partnership with community groups that can provide local knowledge, mobilize resources, recruit volunteers, and highlight urgent issues that easily fall below the technocratic and regulatory radar screen.

Agencies charged with overseeing the recovery and rebuilding of New Orleans claim to have developed systems to ensure that decision making includes some form of community participation (such as access to information, public meetings, and hearings). Historically, however, these processes tend to be procedural and do not necessarily ensure equitable outcomes in regulatory, zoning, land use planning, economic development, and facility siting decisions. Moreover, if state and federal agencies are to truly enhance effective public participation in the recovery process, they need to consider basic tenets of EJ organizing.

First, an overemphasis on technocratic and scientific expertise for decision making can lead to a process that inappropriately frames fundamentally political and moral questions (that is, "transcientific" issues) in scientific terms (Weinberg 1972). This ultimately excludes the public from important policy debates and diminishes its capacity to participate in the production of scientific knowledge itself. Second, diverse communities have important insights and localized knowledge about ways in which environmental hazards may be affecting their health and well-being (Morello-Frosch et al. 2006). Third, although economic, technocratic, and scientific analysis will be critical to informed decision making about how, where, and whether to rebuild, this expertise should not be the sole driver of how agencies set priorities, allocate resources, and address community health concerns.

Keeping these precepts in mind is part of systematically ensuring that communities are central to shaping disaster planning, recovery, and rebuilding efforts. After all, the future resilience of New Orleans will depend just as much on repairing social infrastructure as on repairing physical infrastructure. Ensuring effective community participation in post-Katrina decision making will thus necessitate extensive preparatory work, including building capacity, and providing economic and social support. This will enable residents to return, find jobs, restart businesses, and repair the social fabric of their neighborhoods, including schools, places of worship, health care facilities, and other institutions.

In understanding the contours of community participation, history matters. Katrina was evenhanded in its winds but the disparate impact on blacks and the poor has its roots in previous inequities in the infrastructure related to storm protection and the systemic racial segregation of neighborhoods into high ground versus low-lying areas. This form of discrimination, coupled with disparities in public investments in drainage and pumping systems, consistently worked to the advantage of white, wealthier communities (Colten 2005). History both structured the disaster and affects community attitudes and suspicions about the rebuilding process.

The Bring New Orleans Back Commission, formed by city government, recently released a planning report to address the reconstruction process. One of its most controversial provisions is a proposed four-month moratorium on new building permits in areas heavily flooded by Katrina (2006). The plan and other current discussions suggest that certain communities will never be resettled, and the potential equity implications for future recovery efforts are problematic. A recent analysis, for example, indicates that if the rebuilt New Orleans were limited to the population previously living in zones relatively undamaged by Katrina it would be a city of fewer than 120,000 people—losing about 60 percent of its white but more than 80 percent of its black population (Logan 2006).

Community organizations are concerned. They and the residents they represent should be welcomed as valuable partners and be empowered to play a central role in rebuilding and ensuring the future sustainability of their neighborhoods. Capacity-building is critical and significant independent support is needed to allow organizations to pursue goals that may run counter to government and business interests. Such support would give communities the assistance and training necessary for them to understand and critique complex environmental impact statements, scientific data, and other technical documents and thus be able to engage effectively in policy advocacy.

Given the wide dispersion of New Orleans residents, civic engagement poses unique and significant challenges. Outreach efforts will require innovative communications and technology infrastructure that in turn provides returning and displaced residents with the means to receive and share information related to community rebuilding, support services,

Source: © David Bacon.
Note: A community protest at Romic Environmental Technologies, a firm that processes toxic waste in California's Silicon Valley. The company's main operation is located in East Palo Alto, a city with an overwhelmingly minority population—59 percent Latino, 23 percent black, and 9 percent Asican Pacific Islander. Residents concerned about company expansion plans joined labor advocates in protest after a Filipino immigrant worker named Rodrigo Cruz was asked to clean a railroad car containing toxic sludge after another worker refused because his breathing equipment indicated dangerous concentrations of carbon monoxide. Cruz complied, but his breathing apparatus had a defective line, and he wound up suffering permanent brain damage.

job opportunities, and housing. Moreover, legislation that ensures a living wage and provides affordable housing, quality schools, and opportunities to recoup economic losses and restart affected small businesses will be central to giving middle- and lower-income residents a real opportunity to return and collectively rebuild their communities in New Orleans.

Rebuilding the Louisiana, Mississippi, and Alabama Gulf Coast region will test the nation's ability and commitment to address lingering social inequality and institutional barriers that created and maintained current racial divides. In the rebuilding process for the Gulf, certain principles are, we think, key for both environmental and economic justice:

- *Enforce existing environmental and health standards.* Cleanup standards should not be weakened or compromised in low-income and minority neighborhoods. Allowing waivers of environmental standards could compound the harms already caused by Katrina and undermine health protection of the most vulnerable members of our society.
- *Ensure equal funding, equal cleanup standards, and equal protection of public health and environmental response in minority and low-income communities.* EPA, FEMA, and the Army Corps of Engineers need to enforce Executive Order 12898 regarding environmental justice in the cleanup and rebuilding in the hurricane-affected Gulf Coast region. They should report to Congress on their compliance with this provision monthly for the next twenty-four months to ensure that minority and low-income communities do not receive disparate treatment.
- *Conduct independent environmental testing and monitoring.* Because of the loss of trust in government, independent testing and monitoring of the water, soil, sediment, and air in the affected areas is needed using the best testing technology and methods available. This testing must provide an assessment of current contamination levels, as well as continuous monitoring.
- *Build healthy, clean, and safe schools for children.* It is imperative that schools and the land on which they sit are safe, clean, and free from health-threatening contamination. Existing schools and school grounds should be tested and remediated to the most protective existing cleanup guidelines set by the EPA. Repairs and rehabilitation of schools should use new green standards for school construction, with an emphasis on healthy indoor air, nontoxic materials for construction, maximum design for energy efficiency, and natural light for improved learning.
- *Update emergency transportation and mass evacuation plans.* Funding for local transportation providers is needed to furnish ongoing emergency transportation preparedness for all public transportation personnel, as well as specific training on public transportation provisions of the Americans with Disabilities Act. An emergency transportation fund is also needed to support hurricane evacuees in their return home and to support transportation needs in cities where evacuees are currently living.
- *Balance green building and social justice.* Rebuilding efforts in the Gulf Coast region should adopt smart growth and green building principles to ensure that past environmental inequities are repaired along with the physical infrastructure. However, greenness and justice need to go together. Green building in New Orleans and the Gulf Coast could involve exorbitant fees for architects, materials, and construction—and greening that fails to address issues of affordability, access, and equity may open the floodgates for permanent displacement of low income and minority home owners and business owners.
- *Recognize the right to self-determination and voice.* Katrina survivors have a right to self-determination, and displaced persons should be allowed to return to their homes and neighborhoods to exercise their democratic rights guaranteed under our constitution. Hurricane evacuees, who are scattered across the United States, should continue to have full voting rights in their home states and be allowed to participate in decision making that affects their lives and their communities. Such a democratic impulse is at the heart of the environmental justice paradigm.
- *Stress equitable development.* In the real world, costs and benefits associated with development are not randomly distributed. Equitable development strategies should be implemented that safeguard the interests of long-term residents in communities undergoing change.[34] Given the history of race relations in New Orleans and the Louisiana, Mississippi, and Alabama Gulf Coast region, equitable development models could address many longstanding inequities and actually offer a new start on the region's promise and, perhaps, the promise of America.

Finally, we would suggest that the principles of economic and environmental fairness that drive our rebuilding prescriptions also be incorporated into the funding decisions needed to finance the reconstruction of the Gulf Coast. If this was a national emergency—and the media and public concern signaled that it was—then we need a national response and federal funding. Such funding should not be generated, as the Bush administration has proposed, by cutting spending on other populations suffering from economic deprivation and environmental duress. At the very least, we should remember the physician's adage: "First, do no harm." Cutting food stamps and health care for one group of poor people to fund relief for another group of poor people does not fit well with that admonition.

Disasters Beyond Katrina

Although Katrina rightly cast attention on the shortfalls in existing environmental and emergency policies, positive policy inroads have been made in recent years. Some disaster agencies, for example, have made a concerted effort to incorporate better policies for a diverse population. First, groups have worked to disseminate information in more languages to better serve non–English-speaking populations. Since the early 1990s, both warnings before and recovery information after disasters have been released in as many languages as practical in most situations in an effort to reach increasingly diverse populations. For example, the Association of Bay Area Governments (ABAG) and the United States Geological Survey (USGS), after a Bay-area earthquake, produced a large newspaper insert about the risk in a dozen languages (Mileti and Darlington 1997). FEMA has also worked to publish material in several languages and has produced materials in Spanish on their website.

Change has often been driven by community pressure and innovation. Richmond, California, for example, is home to a large Laotian community consisting primarily of low income refugees who entered the United States after the 1970s. Richmond has more than 350 petrochemical industrial facilities, including the Chevron-Texaco oil refinery, the largest refinery in the western United States. Regulatory agencies in the county had set up an early warning system to inform community members of toxic emissions from industrial accidents, but this system had a significant shortcoming: Despite the multilingual needs of the Richmond community, the warning system functioned only in English. Organizing by Asian Pacific Environmental Network's Laotian Organizing Project (LOP) led to a multilingual warning system for toxic releases.

In general, the past decade has seen an increased sensitivity by many disaster response agencies. Following criticism in the Loma Prieta earthquake, the American Red Cross, America's leading nongovernmental disaster relief group, has become more aware of, and committed to, diversity. Still, progress is slow. A recent Red Cross Survey found that only 5 percent of its volunteers are black, 2 percent Latino, and 2 percent Asian—and its board of governors is overwhelmingly white (Muñiz 2006, 10–11). The California Governor's Office of Emergency Services (OES) also attempted to educate, prepare, and assist those in this highly diverse state. The California Department of Social Services also contracted with a consulting firm headed by a former FEMA official to lead workshops for their disaster workers and school administrators on issues of race, ethnicity, religion, culture, and issues around decision making in disasters. One of the focuses of these workshops is to get officials to think issues of language, and to use traditional and nontraditional approaches to communicating disaster risk to diverse populations.

Some institutional innovations have also been noteworthy. After Hurricane Hugo, for example, FEMA hired a civil rights organization to work with affected communities that had low levels of trust in government. Perhaps most remarkable was the successful housing plan that the U.S. Department of Housing and Urban Development (HUD) put together following the 1994 Northridge earthquake. HUD decided to provide special Section 8 housing vouchers to help the poorest victims of the quake find housing anywhere in California and quickly begin their recovery. It sold the plan to Congress and received millions in funds within a few days after the quake, and then got the state, landlords, and the region's leaders to work together to quickly distribute vouchers. This allowed many low-income renters, often forgotten in the rush to redress homeowner needs, to make their own choices about their next home, and expedited the process of getting some stability back in their lives (Katz and Muro 2005). This bold, unprecedented government plan was unfortunately not repeated after Hurricane Katrina in 2005.

Support from the National Science Foundation, which funds many disaster research projects, and from FEMA, which runs its Higher Education Project, to study and teach issues of differential vulnerability has also increased. The National Science Foundation has provided funding for many projects in an effort to understand issues of inequity and reduce vulnerability. In some cases, these efforts are participatory action projects that bring researchers and racial minorities and poor communities together to work on hazard issues. These are exactly the sort of interactions that we think will move the field.

FEMA's efforts also include a recently developed course on differential vulnerability called "A Social Vulnerability Approach to Disasters," which is posted on its website for teachers to use in their college classrooms. In the course students learn about the feminization of poverty, political marginalization, and how racism results in hazards vulnerability. Because this is a new project, it remains to be seen how widely it will be used and whether the information will reach those who need it—one wishes that FEMA officials themselves had taken the course before Katrina devastated the Gulf Coast.

There is also evidence that local governments and communities can use a disaster situation to improve housing conditions or other aspects of the community. For example, after Hurricane Andrew some local projects were initiated to improve poor neighborhoods, and some replaced or restored public housing units were better than those there before the storm. After the Loma Prieta earthquake, the city of Watsonville established a variety of redevelopment projects and adopted an ordinance requiring that 25 percent of housing built after the disaster be affordable for farm workers and low-income families.

Still, much needs to change in the arena of disaster policy. First, attention should be given to the interactions of relief workers and victims of different classes, races, and ethnicities. There is some indication that emergency personnel who arrive in a disaster setting to offer assistance may be culturally insensitive. Cultural awareness and sensitivity—to religious, linguistic, class, ethnic, and racial differences—are imperative for disaster agencies and relief organizations. National agencies such as FEMA and the Red Cross and other groups that respond to disaster on a large scale need to continue to be educated on the diversity of various communities and plan accordingly.

Housing, as noted earlier, is a significant issue in understanding the vulnerability of the poor and minorities in disasters. Research has shown that older, low-cost housing that is brought up to safety standards often becomes unaffordable, thus creating a situation whereby low-income families cannot find housing that is both safe from natural disasters and affordable. Such circumstances are partly due to the fact that the private housing market hinders the reconstruction of low- and moderate-income rental unit rebuilding—with this in turn due partly to redlining by insurance companies, partly to exclusionary zoning, and partly to the usual challenges of rising housing prices in an unregulated market. Policies should be initiated that address these issues, including pressure on insurance companies, strategies for inclusionary housing, and flexible rent controls in overheated markets.[35]

Another policy thrust should encourage community participation in both preparing for and recovering from disasters. Individuals, households, and communities may be vulnerable in many ways to various risks, but also have capacities and strengths. Large-scale organizations and agencies working on disasters need to understand the specific diversity issues of each area, plan for changing demographics of the area, and ensure that members of all communities are involved in the process. These institutions should also continue efforts to disseminate disaster information in the needed languages for communities and move the voices of the most disenfranchised and vulnerable to the forefront by bringing women's, civil rights, interfaith, and environmental justice organizations to the disaster planning table.

Marginalized groups need to be a part of the rebuilding process from the beginning, especially if they have been historically excluded and marginalized in community affairs. Emergency management should identify and locate high-risk sectors on community vulnerability maps, integrate this information into GIS systems, and then involve those community members in planning and response (Morrow 1999). More inclusive participation could also be furthered by recruiting more members of the lower and working classes and minorities for disaster professions and in the research community.

The media also need to coordinate with emergency managers, public officials, and disaster relief workers to better understand disaster events. This coordination will likely lead to more accurate reporting and to inclusion of all affected groups, not just the affluent. Future research on the issues of inequality in disasters should also be developed in conjunction with practitioners working in communities and follow up with practitioners to see how research findings are, or are not, being implemented in the field.

Finally, much discussion after Hurricane Katrina has revolved around what went wrong and who was to blame.[36] We and many other Americans are pleased at the recent congressional report in February 2006 that focused on problems in the government's immediate response to the Katrina disaster. This report, however, did not meet the nonpartisan "gold standard" of the 9/11 Commission—whose recommendations as a result were widely accepted—nor did it make sufficient use of outside researchers on long-term issues of disaster preparedness and recovery.

We advocate an independent, objective, scientific commission to investigate the governmental response to Hurricane Katrina and to recommend future policy and practice. In our view, a commission should include experienced researchers and practitioners who represent a wide range of views and backgrounds, and should have a broad charge. Katrina was a catastrophic event in its own right but it is also an example of the environmental vulnerabilities that affect many communities on an everyday basis. From the brownfields of Detroit to the refineries of Los Angeles, from the nuclear waste dumps on Indian Land to the pesticides threatening the health of Latino farm workers, the country boasts a sad history of inequality in exposures and government indifference. Understanding this broader pattern and suggesting how both ongoing environmental policy and disaster readiness could minimize differential risks would be a major contribution to the public debate.

Conclusion: Justice and the Commons

Certain moments in human history somehow clarify all that has gone wrong and all that needs to change. In Selma, Alabama, in 1965, state and local police attacked civil rights demonstrators with tear gas and clubs, only to fuel a nonviolent resistance that led to the all-important Voting Rights Act. In South Africa in the early 1960s, Nelson Mandela was arrested and jailed, but his solid and dignified resistance from his prison cell helped bring about a dramatic political transition and an end to racial apartheid. In East Germany in the 1980s, activists and common citizens, who felt the sting of restrictions on their travel and other freedoms, demonstrated against a repressive government, toppling both their Communist Party leaders and the Berlin Wall.

Was Katrina such a historical moment? Surely the crisis and its disparities have cast American issues of both poverty and inequality in stark colors. Although some conservative critics have sought to dispel any "lessons from Katrina," the sort of environmental disparities brought to light by the storm defy an American value system that insists that everyone has the right to a decent environment. The differential effects of Katrina were neither natural nor accidental. In the Gulf Coast, the crisis built on an existing pattern wherein minorities and the poor lived in more precarious low lands and the ongoing risk from the infamous Cancer Alley was already distributed in ways symptomatic of environmental injustice. The problem is not limited to the South and its legacy of Jim Crow. Research suggests that environmental disparities by race are rampant in much of the United States, that rational land use choices and market mechanisms do not explain the pattern of difference, and that there are often important consequences for the health of diverse communities.

Research and experience also suggest that there are important racial and class differences in the experience before, during, and after many cataclysmic events. These disparities include differential readiness, gaps in the attention of relief and emergency agencies, and sharp inequalities in the process of rebuilding and reconstruction. In a sense, this is no surprise—the existing distribution of chronic risk sets the parameters for disaster and recovery—but it is disturbing nonetheless for a society that generally believes that both disaster and relief should be equal opportunity affairs.

Worries about the inequality of power, wealth, and environmental risk may seem the province of justice, but evidence is growing that the distribution of environmental health and safety can affect the level of environmental quality for society as a whole. When inequalities of wealth and power are great, after all, those at the top of the scale have (or think they have) greater opportunities to avoid reliance on public goods. Why worry about toxic pollution if you can live far from the scene of the crime? Why worry about public transportation if you have your own car? Why worry about disaster vulnerability if you can count on generous subsidies from the government to recoup your losses?

Yet emerging statistical evidence now suggests that wide disparities in environmental conditions may jeopardize overall environmental quality. In a cross-sectional analysis of the fifty U.S. states, James Boyce et al. (1999) find that those with a more unequal distribution of power—as measured by data on voter participation, educational attainment, Medicaid access, and tax fairness—tend to have weaker environmental policies, greater environmental stress, and worse public health outcomes. A recent Morello-Frosch and Jesdale analysis (2006) indicates a persistent relationship between increasing levels of racial-ethnic segregation and increased overall magnitude of environmental degradation, such as air pollution, and health risks, such as individual estimated lifetime cancer risk (see also Lopez 2002).

Parallels may exist in the acute moments of disaster. When acute events are more likely to affect the least powerful, it is possible that the social guards will be let down. One wonders how well the levees would have been maintained had it been thought that whiter and wealthier neighborhoods would have suffered as much as they eventually did. One is curious whether chemical plant security would be an even higher priority were the distribution of the fenceline population not so predominantly minority and poor.

Yet by allowing the weak link in the social chain—the poorest communities in the low-lying areas of the city—to be exposed, all of New Orleans was put at risk. By failing to value fenceline lives and communities, the risks rise for neighborhoods far from the first releases from a chemical incident. When the political economy of environmental protection allows hazards to be placed in someone else's backyard, they often will, and there may well be more of them.

Establishing environmental justice as a serious policy concern is therefore not simply the right thing to do—it may be the best thing for protecting the "commons." We mean this in more ways than simple disaster prevention or hazard mitigation. The environmental justice framework elevates important concerns about fairness and voice in the decision-making process. It suggests that everyone has the right to a decent environment and that such a basic human right should not simply be usurped by the vagaries of the market or the privileges of power. It returns us, in short, to basic American values of equity, democracy, and opportunity.

Will we learn from Hurricane Katrina? To do so, we need to remember the shock and concern so many felt in the days of the emergency and apply this to both new preparations for disaster and new strategies for environmental protection. More research is needed but so is political and civic leadership. Katrina has opened a window on a dark side of America—the economic and environmental vulnerability of poor and minority communities. We can close that window or we can use the new view to chart a better, healthier, and more equitable future for all Americans.

Notes

1. A Knight-Ridder analysis focusing on deaths from Katrina suggested that there were very few differences by race or income (see Simerman et al. 2005). However, a reanalysis of the data shows that such a simple comparison was misleading. The most likely to die were the elderly who were often stranded in nursing homes and hospitals. But whites were much more likely to be among the old—the median age for whites in New Orleans in 2000 was 41.6 years while it was 29.4 for blacks. Once one accounts for the age distribution of whites and blacks in the affected areas, there was disparity by race for both those younger and older than 65 (Sharkey 2006). Moreover, death is only one, albeit the most extreme, form of victimhood: loss of property and community, and the suffering and grief that came with being stranded in the city, seems to have distributed quite unequally by race and income (see Logan 2006).
2. Economists have long known how to incorporate such distributional weights into cost-benefit analysis (see, for example, Little and Mirrlees 1974, 234–42; Ray 1984, 22–31; for further discussion, Boyce 2000).
3. Extending this approach to intergenerational allocation implies that future lives and health should not be heavily discounted (as is done when a discount rate is used in conventional cost-benefit analysis), but rather valued on a par with present lives and health.
4. The purchasing-power advantages of high-wealth individuals and communities are compounded when they wield disproportionate political power; conversely, the disadvantages of low-wealth people are compounded when they belong to politically disenfranchised racial and ethnic groups (Boyce 1994).
5. Taken from the executive summary, http://www.epa.gov/history/topics/justice/01.htm.
6. Some environmental justice activists argued that the Anderton et al. studies were biased, at least in their presentation of the results, because they were funded by a grant from the largest waste management firm in the United States. However, the techniques Anderton and his colleagues used did represent methodological advances at the time, though there have since been methodological criticisms, discussed later.
7. For discussion, see Anderton, Anderson, Rossi et al. 1994; Been 1993, 1995.
8. Other power-related variables have been explored in the literature, including home ownership (which is also an indicator of wealth but also highly associated with community engagement and political influence), voting turnout, and recency of immigration.
9. Note, however, that the move-in explanation is essentially based on income, not race. Although little explored in the literature, a racial move-in pattern could be the result of housing discrimination, an explanation that would shift the locus of attention to that arena but would not obviate either the role of power or the legacy of racism.
10. See Noriko Ishiyama (2003) for a discussion of the role of tribal sovereignty, particularly the right of a tribe to choose to host facilities that might be unwelcomed elsewhere in exchange for payment.
11. There was also a subsequent argument that the significance of previous multivariate results may have been overstated because of inappropriate controls for spatial relationships (see Bowen et al. 1995; Bowen 2001).

12. John Oakes (1997) specifically shows charts in which percent minority and various income variables rise sharply as tracts within one mile of a TSDF tract are considered. In a polytonomous logistic regression, he uses a two mile standard and finds that all the socioeconomic variables indicate disparity and are significant at the .01 level. These findings are also subtly suggested by the tests for area aggregation using a 2.5 mile buffer in Anderton, Anderson, Rossi, et al. (1994, 238–39) but are used only to dismiss previous zip code analyses.
13. Another issue is the challenge of correctly locating hazardous sites that are incorrectly listed. For efforts to correct location information, see Vicki Been (1995) and Boer et al. (1997); Sadd et al. (1999) discuss GIS techniques to improve reliability in existing large databases.
14. Earlier reviews of the literature include Paul Mohai and Bunyan Bryant (1992), Andrew Szasz and Michael Meuser (1997), and William Bowen (2001).
15. The challenges are several. First, because census tracts change shape over time, demographic information of previous years should be "reshaped" to fit new tract polygons. Second, information on facilities is sometimes incomplete for decades prior to the emergence of strict environmental standards. Third, because siting and move-in can occur simultaneously, sophisticated statistical techniques are required.
16. A longitudinal study by Yandle and Burton (1996) claimed to find no evidence of disproportionate siting, but methodological critiques of this work were quite sharp by authors associated with both sides of the environmental justice debate (Anderton 1996; Mohai 1996).
17. As indicated in an earlier note, another methodological issue involves spatial autocorrelation (Bowen 2001). This refers to the tendency of variables to be influenced by their neighbors—or in common parlance, the tendency of land uses, ethnic groups, and income classes to cluster together such that, for example, a neighborhood's income level is influenced by its proximity to similar neighborhoods. Such clustering is likely in the spatial data typical of environmental justice studies, and it means that the error terms in statistical analyses do not satisfy the independence conditions—and thus significance levels can be overstated. This is a thorny issue, but a few recent studies have suggested that though this problem may be important in theory, its impacts on significance levels, particularly for race, are relatively slight (Pastor et al. 2004, 2005a).
18. Studies have linked air pollution exposures to preterm birth, low birth weight, and birth defects (Bobak 2000, Ritz et al. 2002, Ritz et al. 2000, Ritz and Fei 1999), and a recent study by Kenneth Chay and Michael Greenstone (2003) finds that air pollution has a significant impact on infant mortality. Pastor, Sadd, and Morello-Frosch (2005b) have suggested that differential levels of hazardous air pollutants may also impact asthma rates and the academic performance of young schoolchildren.
19. Although the clinical significance of these differences are not known, these results do have public health significance, especially given that these air toxics exposures are fairly ubiquitous and affect a significantly large number of people (Morello-Frosch, Pastor, and Sadd 2001).
20. For example, whereas the 2000 census reported that only 2.9 percent of non-Latino whites in the United States took public transit to work, the comparable figures for Latinos and blacks were 8.9 and 12.2 percent respectively. Data here and for the figures for New Orleans are taken from tables PCT65B and PCT65I of Summary File 3, U.S. Census, 2000, through runs using American FactFinder (http://factfinder.census.gov).
21. Amnesty International (2004) reports that in addition to those who died in the immediate aftermath of the Bhopal disaster, at least 15,000 more people died subsequently, and roughly 100,000 people suffer from chronic and debilitating illnesses as a result of the accident.
22. Death compensation from Desai (1997), who also reports that large numbers of false claims were filed; injury compensation from Amnesty International (2004, 63).
23. Data on the city and metro area percent African American taken from table P8 of the U.S. Bureau of the Census Summary File 1, 2000, and includes only non-Hispanic blacks; the numbers are virtually identical for all black residents.
24. Platt reports that 40 percent of all payouts from the government's National Flood Insurance Program have been for "200,000 structures that have experienced repetitive losses: two or more claims while insured" (1999, 280).
25. Using a more recent database and slightly different methods and samples than Melvin Oliver and Thomas Shapiro (1995), Maury Gittleman and Edward Wolff (2000) suggest that 50 percent of black wealth and 30 percent of white wealth is due to one's primary home.
26. The pattern is not limited by race. In a study of the 1997 Red River Valley Flood in largely white area of North Dakota, homeless, unemployed, and low-income women were less able than more affluent women to evacuate to alternative shelters (Morrow and Enarson 1999).
27. In the Coalinga, California, 1983 earthquake, whites faced more damage to their workplaces than Latinos because whites worked downtown and Latinos in agriculture (Bolin and Bolton 1986). Hispanics, however, were unlikely to have household insurance, and they were more likely to have moved more frequently after the disaster than whites. After the Northridge earthquake, many Latinos faced political and cultural marginalization, and limited housing and employment opportunities, which impacted their ability to successfully recover in the long term (Bolin and Stanford 1998).
28. Muñiz also suggests that FEMA should be more forthcoming in educating immigrants that households may be eligible for assistance even if some members are undocumented as long as there are eligible family members, including U.S. citizen children (2006, 4).
29. See http://news.minnesota.publicradio.org/features/2005/09/06_ap_katrina/.
30. FEMA's temporary housing assistance program is designed for those who had stable housing before the disaster, and therefore SRO residents, who do not live continuously in their rooms, do not qualify.
31. See also the 2005 RAND analysis of racial differences in the perceptions of postal workers and U.S. Senate staffers in Washington after they were exposed to a letter contaminated with anthrax in 2001 (Blanchard et al. 2005; see also Hughes 2002).

32. A precautionary regulatory strategy would also address the significant problem of "toxic ignorance" that currently plagues our environmental regulation system. There are more than 80,000 chemicals currently registered for commercial use in the United States, and about 3,000 of these are high production volume chemicals. For more than 80 percent, we lack adequate toxicological data needed to assess their potentially adverse human health effects (Thorton 2000).
33. The EU's REACH (registration, evaluation, and authorization of chemicals) program would require commercial firms to register chemicals currently produced or imported in large quantities with a central EU database. A designated EU agency would be responsible for assessing this information on a case-by-case basis and use of chemicals that exhibit certain hazardous characteristics (such as persistent bio-accumulative toxins [PBTs] and endocrine disrupting chemicals) would be banned unless specifically authorized by regulatory agencies.
34. For one set of widely endorsed principles for equitable development in the rebuilding process for the Gulf Coast drafted by PolicyLink, a national intermediary that works in low-income and minority communities, see http://www.policylink.org/EquitableRenewal.html.
35. As the gap between the wealthy and the poor increases in the United States, there will be more low-income residents in risky housing situations, particularly mobile homes. This situation could be remedied by enforcing and subsidizing programs to improve the strength of mobile homes in high winds, and by requiring mobile home park owners to provide tornado shelters in areas where this is an issue.
36. One criticism focused on President Bush's decision to place FEMA within the Department of Homeland Security. It may make sense to separate the agencies, restore funding and power back to FEMA, and once again support the FEMA Mitigation Directorate. This could be accompanied by an attempt to encourage the disaster professionals who have left FEMA in the last few years, partly because of frustrations with the diversion of resources, to return and help the agency become more effective in carrying out its mission. We would leave such specifics, however, to the sort of investigation and recommendation committee we suggest.

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Article

Playing It Safe: Assessing Cumulative Impact and Social Vulnerability through an Environmental Justice Screening Method in the South Coast Air Basin, California

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Abstract: Regulatory agencies, including the U.S. Environmental Protection Agency (US EPA) and state authorities like the California Air Resources Board (CARB), have sought to address the concerns of environmental justice (EJ) advocates who argue that chemical-by-chemical and source-specific assessments of potential health risks of environmental hazards do not reflect the multiple environmental and social stressors faced by vulnerable communities. We propose an Environmental Justice Screening Method (EJSM) as a relatively simple, flexible and transparent way to examine the relative rank of cumulative impacts and social vulnerability within metropolitan regions and determine environmental justice areas based on more than simply the demographics of income and race. We specifically organize 23 indicator metrics into three categories: (1) hazard proximity and land use; (2) air pollution exposure and estimated health risk; and (3) social and health vulnerability. For hazard proximity, the EJSM uses GIS analysis to create a base map by intersecting land use data with census block polygons, and calculates hazard proximity measures based on locations within various buffer distances. These proximity metrics are then summarized to the census tract level where they are combined with tract centroid-based estimates of pollution exposure and health risk and socio-economic status (SES) measures. The result is a cumulative impacts (CI) score for ranking neighborhoods within regions that can inform diverse stakeholders seeking to identify local areas that might need targeted regulatory strategies to address environmental justice concerns.

Keywords: environmental justice; environmental health; geographic information systems; social vulnerability; cumulative impacts

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1. Introduction

Air pollution has long been recognized as a high priority for both environmental health and justice by researchers, government regulators, and community residents [1-4] In California in particular, there is consistent evidence indicating patterns of both disproportionate exposure to air pollution and associated health risks among minority and lower-income communities [5-9]. These same communities also face challenges associated with low social and economic status, including psychosocial stressors, which make it more difficult to cope with exposures and may be connected with the persistence of environmental health disparities [10-12].

Environmental justice (EJ) advocates have argued that scientists and regulatory agencies should better account for the cumulative impacts (CI) of environmental and social stressors in their decision-making and regulatory enforcement activities [13,14]. These advocates and others have suggested that traditional chemical-by-chemical and source-specific assessments of potential health risks of environmental hazards do not reflect the multiple environmental and social stressors faced by vulnerable communities, which can act additively or synergistically to harm health [15-17]. Regulatory agencies are beginning to respond to the National Research Council's call for the development "cumulative risk frameworks" within their scientific programs and enforcement activities [18]. In California, the Office of Environmental Health Hazard Assessment maintains a Cumulative Impacts and Precautionary Approaches Work Group which has advised the Agency in its efforts to develop guidelines for consideration of cumulative impacts within the different programs of the California Environmental Protection Agency [19].

This approach represents an advance from earlier definitions of environmental justice concerns which emphasized the racial/ethnic make-up or income levels of the communities in question (such as President Clinton's Executive Order #12898 which directed federal agencies to focus on "minority communities and low-income communities"). Still, the work to develop more sophisticated tools for assessing cumulative impacts and environmental disparities is in its infancy. For example, Su and colleagues developed an index to characterize inequities by race/ethnicity and SES in the cumulative impacts of environmental hazards at the regional level, which allows for comparisons at large geographic scales [20]. However, this approach is not conducive to ranking and assessing distributional patterns of CI at more local, neighborhood-level scales within regions, which has been a primary concern for EJ advocates and some regional air quality agencies. These within-region CI assessments are important because industrial clusters, as well as land-use planning decisions, are often rooted within metropolitan regions; thus regulatory interventions to mitigate the cumulative impact of environmental and social stressors often require regionally-specific strategies [21,22].

The U.S. EPA has also been developing a GIS-based cumulative impacts screening tool, known as the Environmental Justice Strategic Enforcement Assessment Tool (EJSEAT) [23] to identify areas with disproportionately high and adverse environmental health burdens nationwide. EJSEAT defines a set of 18 cumulative impacts indicator metrics organized into four categories (demographic, environmental, compliance, and health impact), scales these values within each state (rather than, say, the metropolitan region or the air basin) and then applies to each census tract a composite score. However, EJSEAT is considered to be a "draft tool in development, currently under review and intended for internal EPA use only" and it has certain limitations due to the requirement for national consistency. These limitations include the fact that much of the non-Census data used to develop indicators is limited to that generated by EPA itself and sources of EJ concern, such as land use activity, are not captured. Additionally, county level health impacts information is imputed to census tracts, thus, ignoring much of the important variation by neighborhood. Compliance data, which consists of inspections, violations, formal actions and facility density, is problematic; for example, more inspections could indicate better regulatory oversight or worse behavior on the part of facilities. Moreover, violations and actions are not ranked by severity, leading one assessment to suggest that "the application of compliance statistics are so uncertain in meaning that their use as an indicator is highly questionable" [24].

We present an Environmental Justice Screening Method (EJSM) that facilitates examination of patterns of cumulative impacts from environmental and social stressors across neighborhoods within regions. We demonstrate an application of the EJSM to the six county area covered by the Southern California Association of Governments (SCAG), a region that is home to nearly half (48.8%) of California's population. We specifically sought to create an EJSM that relied on publicly available data in order to facilitate its application to different contexts, as well as the addition of new data layers and the updating of information as needed.

The analytical work to develop the EJSM was solicited and funded by the California Air Resources Board (CARB). Therefore, the method was developed with considerable input from Agency scientists as well as an external scientific peer review committee that provided ongoing advice on methods and metrics selection. We also solicited feedback from environmental health and environmental justice advocates regarding appropriate metrics and we previewed preliminary results for their feedback. This strategy of soliciting peer review from agency personnel, scientific colleagues and community stakeholders was aimed at ensuring that the final EJSM was methodologically sound and transparent to diverse audiences in the regulatory, policy and advocacy arenas. As discussed below, the multiple audiences also required certain trade-offs; in particular, we made several choices to insure that the method would be more easily understood by community stakeholders as that would encourage their acceptance of the EJSM as a reasonable approach for regulatory guidance.

2. Experimental Section

2.1. Methods

The EJSM allows a mapping of cumulative impacts using a set of 23 health, environmental and social vulnerability measures organized along three categories: (1) hazard proximity and land use; (2) estimated air pollution exposure and health risk; (3) social and health vulnerability. Individual indicators and data sources are summarized in Table 1.

Table 1. Summary of cumulative impact and vulnerability indicators used in the EJ Screening Method.

Sensitive land use indicators.

INDICATOR	GIS SPATIAL UNIT	SOURCE/DATE
Childcare facilities	Land use polygons	Southern California Association of Governments (SCAG), 2005
	Buffered points	Dunn and Bradstreet by SIC code, 2006
Healthcare facilities	Land use polygons	SCAG 2005; California Spatial Information Library
Schools	Land use polygons	SCAG 2005
	Buffered points	CA Dept of Education 2005
Urban Playgrounds	Land use polygons	SCAG 2005

Environmental hazards and social vulnerability indicators.

INDICATOR	GIS SPATIAL UNIT	SOURCE/DATE
Hazardous Facilities and Land Uses		
Air Quality Hazards		
Facilities in California Community Health Air Pollution Information System (CHAPIS)	Point locations	CA Air Resources Board (CARB) 2001
Chrome-platers	Point locations	CARB 2001
Hazardous Waste sites	Point Locations	CA Dept. Toxic Substances Control 2004
Hazardous Land Uses		
Railroad facilities	Land use polygons	SCAG 2005
	Line Features	National Transportation Atlas Database (NTAD)
Ports	Land use polygons	SCAG 2005
Airports	Land use polygons	SCAG 2005
	Line Features	NTAD 2001
Refineries	Land use polygons	SCAG 2005
Intermodal Distribution	Land use polygons	SCAG 2005
	Line Features	NTAD 2001

Table 1. *Cont.*

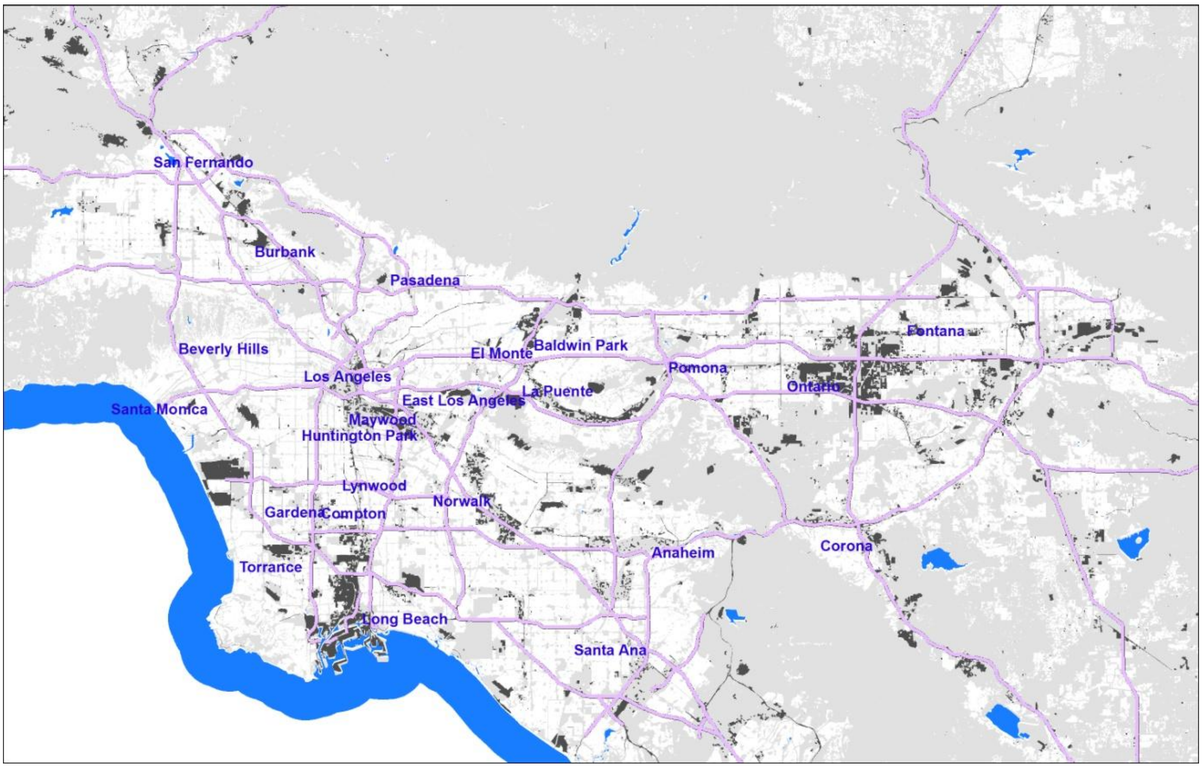
INDICATOR	SOURCE/DATE
Health Risk and Exposure all at census tract level	
Risk Screening Environmental Indicators (RSEI) toxic concentration hazard score	USEPA 2005
National Air Toxics Assessment respiratory hazard for air toxics from mobile and stationary emissions	USEPA 1999
Estimated cancer risks from modeled ambient air toxics concentrations from mobile and stationary emissions	CARB 2001
$PM_{2.5}$ estimated concentration interpolated from CARB's monitoring data	CARB 2004–06
Ozone estimated concentration interpolated from CARB's monitoring data	CARB 2004–06
Social and Health Vulnerability all at census tract level	
% people of color (total pop–non-Hispanic white)	US Census 2000
% below twice the national poverty level	US Census 2000
Home Ownership–% living in rented households	US Census 2000
Housing Value–median house value	US Census 2000
Educational attainment–% >age 24 with <high school	US Census 2000
Age of residents–% <age 5	US Census 2000
Age of residents–% >age 60	US Census 2000
Linguistic isolation–% residents under age 4 in households where no one over age 15 speaks English well	US Census 2000
Voter turnout–% votes cast in general election	UC Berkeley Statewide Database 2000
Birth outcomes–% preterm and small for gestational age	CA Dept Public Health Natality Files 1996–2003

The EJSM involves a four-step process: (a) an initial GIS spatial assessment to create a detailed regional base map for estimating hazard proximity; (b) the use of GIS techniques to appropriatly summarize the resulting hazard proximity indicators for each of the region's census tracts; (c) the coupling of the resulting tract level scores with tract level data on air pollution exposure and/or health risk as well as data on social and health vulnerability, (d) a cumulative ranking based on all the tract-level indicators that is then presented visually.

The regional base map is constructed by integrating specified residential and sensitive land use classes (see below) as classified by the California Air Resources Board [25]. This focuses CI screening on areas with land uses where people reside or locations hosting schools, hospitals, day care centers, parks and other sensitive receptor locations. Areas that are, for example, strictly industrial or commercial or undeveloped open space are not included in the regional base map (see Figure 1).

To geographically link the regional base map with the tract-level metrics of social/health vulnerability and air pollutant exposure/health risk, the residential and sensitive land use polygons were intersected using a GIS procedure with census block polygons from the 2000 Census, to create a base map composed of neighborhood-sized cumulative impact (CI) polygons, each with a known land use class and attribute key to attach census information. The base map for the Southern California area we developed consists of over 320,000 CI polygons, with the median area of these polygons being 0.017 square kilometers. There are slightly less than 145,000 populated census blocks in the same area, suggesting that our base units are generally portions of blocks.

Figure 1. Map of a portion of the study area showing CI Polygons in white, and areas not scored (including open space, vacant land, industrial land use, *etc.*) in gray.



2.2. Data and Scoring

The regional base map and the buffer-based hazard proximity scoring were derived using GIS. We also used Statistical Analysis Software (SAS) 9.2 and Statistical Package for the Social Sciences (SPSS) 17.0 for distributional calculations and tract-level scoring to facilitate documentation and error-checking.

The first step in our analysis involved attaching to each of the CI polygons on our regional base map a set of hazard proximity indicators and then summarizing these to create scores at the tract level. We then attached the other metric categories (air pollution exposure and health risk; and social and health vulnerability) and calculated a total CI score. Examining each metric category separately and then combining them into a total score facilitates screening for relative cumulative impacts of environmental and social stressors between neighborhoods in a structured manner that can inform regulatory decision-making in diverse regulatory and community contexts [26].

2.2.1. Hazard Proximity and Land Use Indicators

This category captures the location of stationary emission sources and sensitive land uses based on the California Air Resources Board (CARB) Air Quality and Land Use Handbook which recommends buffer distances to separate residential and other sensitive land uses from potential hazards in order to protect susceptible populations.[25] Susceptible populations are considered to be young children, pregnant women, the elderly, and those with existing respiratory disease, who are especially vulnerable to the adverse health effects of air pollution [27]. The non-residential sensitive land uses indicated by CARB include schools, childcare centers, urban playgrounds and parks, and health care facilities, and senior residential facilities.

Residential and sensitive land use features were mapped using several data sources, including regional land use spatial data from the Southern California Association of Governments (SCAG) [28], state regulatory agency databases, and geocoded locations from address lists. The residential uses were straightforward as housing is clearly delineated in the SCAG 2005 land use data layer. That layer also had several of the non-residential sensitive uses. However, not all sensitive land uses are available as polygon features in this data layer, due to limitations either of the spatial resolution or other issues. For example, some commercial and other facilities contain childcare centers or health care facilities that are not mapped separately. In addition, because of a recent boom in school construction in California, some schools post-date the vintage of the SCAG land use layer.

To address this shortcoming, point locations for these additional sensitive land use features were identified from other data sources, and address geocoding was used to create point feature spatial layers. School location points, for example, were automated using the address list provided by the California Department of Education (2005); public and private schools were included. Childcare centers were automated from the addresses provided from a search of Standard Industrial Code (SIC) 8350 and 8351 using the D&B (formerly Dunn and Bradstreet) Business Information Service; senior housing facilities were similarly automated (SIC 8361). Point locations of healthcare facilities were obtained from the California Spatial Information Library (http://www.atlas.ca.gov/download.html). To avoid duplication with polygon features, any point feature that intersected an equivalent polygon feature was dropped—for example, a point location for a school that is located within a SCAG land use school polygon was deleted.

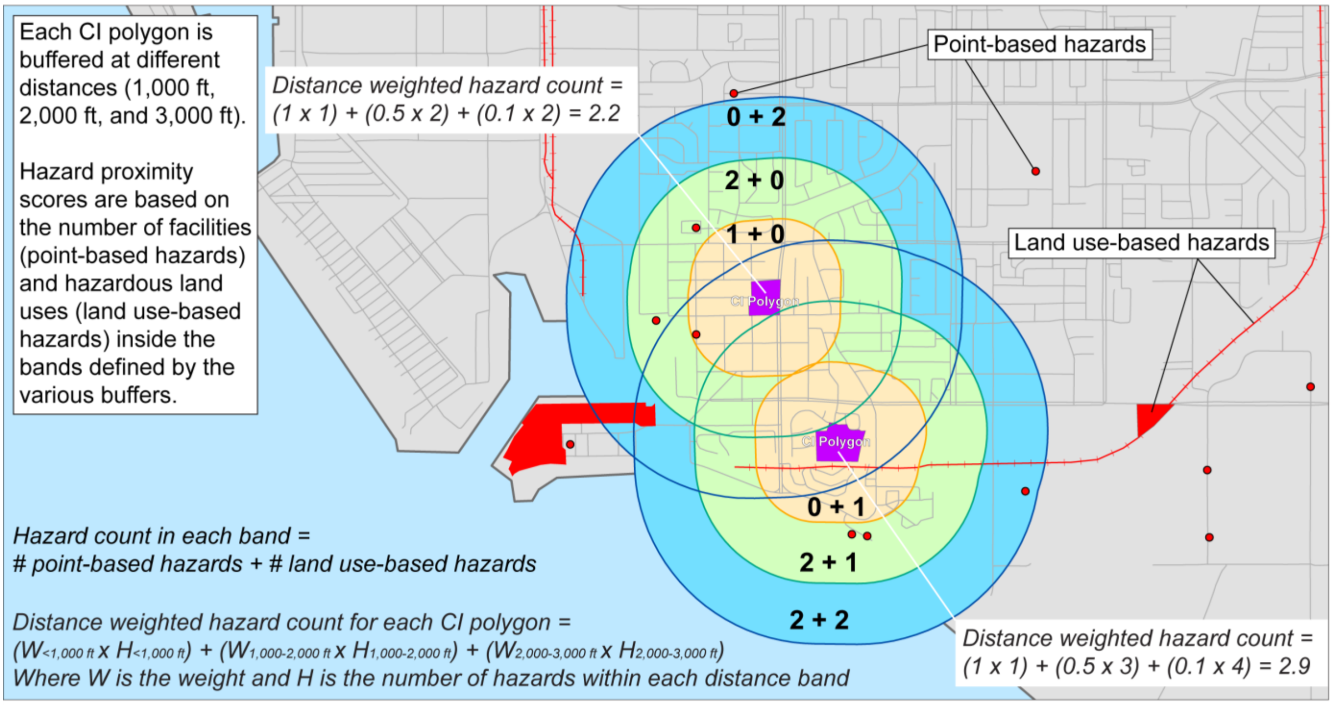
Finally, because representing these features as dimensionless points would result in misclassification of proximity metrics, we assigned a minimum area to each point feature by creating circular buffers. The size of these buffers was selected based upon the area of the smallest equivalent land use in the SCAG Land Use data layer, with the rationale being that the smallest SCAG polygons represent the limit of the spatial resolution of the SCAG data, and smaller features were simply not mapped.

We then added to the map point source locations prioritized by CARB as significant sources of air pollution and also prioritized in community scoping sessions as locations of concern. Point feature locations include: (a) facilities from the Community Health Air Pollution Information System (CHAPIS)—a subset of the California emissions inventory with criteria and air toxics emissions of primary concern for health impacts [29]; (b) chrome-plating facilities identified from the California air toxics emissions inventory [30]; and (c) selected hazardous waste facilities from the California Department of Toxic Substances Control (DTSC) [31]. Stationary emission sources prioritized by CARB (CARB 2005) include rail facilities, airports, intermodal distribution facilities, refineries and ports where diesel emissions are concentrated; these are added as polygon and/or line features from the land use layer.

Each CI polygon—consisting of either a residential or sensitive land use—was scored as follows. We first constructed buffers at 1,000 feet, 2,000 feet, and 3,000 feet (*ca*. 305, 610 and 915 m, respectively) from the boundary of each polygon. The 1,000 foot distance was chosen because it is the standard that CARB generally applies in its community health risk assessments and is specified in its land use manual [25]; we also included hazards within two other bands (1,000–2,000 feet and 2,000–3,000 feet) because there is some degree of locational inaccuracy in the GIS data making strict buffering problematic, and some features (e.g., geocoded stationary hazards) may be spatially represented as point features just outside a buffer but, in reality, are polygons that stretch across buffers.

The number and type of sources within each of these buffer distances was determined for every CI polygon; a similar procedure is done for all hazards represented as area features (e.g., airports, refineries, railroad tracks). We then utilized a distance-weighted scoring procedure where the influence of the hazards on the sum attached to the CI polygon diminishes with distance (Figure 2) as those places with proximity to numerous air quality hazards are assumed to be more highly impacted. We applied this tiered buffering approach rather than a continuous distance-weighting method to ensure that the hazard and land use scoring was transparent to community stakeholders. Using this method, the summed point totals for each CI Polygon in the Southern California area we examined ranges from 0 to 9.8.

Figure 2. Method for assessing hazard proximity for CI polygons.



We then added to the distance- weighted hazard proximity counts a binary dummy variable indicating whether the CI Polygon was residential land (0) or a non-residential sensitive land use. A tract-level hazard proximity score is then calculated based on the hazard proximity and sensitive land use measure by attaching to each CI polygon a population weight derived from assigning population using the underlying intersection of census block data and polygon land area; we then used that value to weight the scores to a census tract average score for hazard proximity/sensitive land use. The downside of this strategy is that it can underweight the hazard proximity measure if a block that is attached to a particular polygon has either no residents or a low population (for example if part of the block is a school). An alternative approach involves area weighting; however, this approach can overweight larger CI polygons which may have few residents. As the results were generally similar and our focus was on community impacts, we conducted population-weighting.

Finally, a quintile ranking from 1 (low) to 5 (high) was applied to derive a tract-level score which integrates the presence of both sensitive and hazardous land uses. More complex ranking strategies were available, including the utilization of Jenks' natural breaks for these figures or the determination of a mean and standard deviation, with four breaks determined as being more than one standard deviation above (or below) the mean or between one standard deviation and the mean. However, quintile ranking yielded results similar to the more complex approaches and were more transparent to community stakeholders; this was also the case for the other variables discussed below.

2.2.2. Health Risk and Exposure Indicators

This category includes five metrics of air pollution concentration estimates or health risk estimates associated with modeled air toxics exposures, all calculated at the census tract level. They include toxicity weighted hazard scores for air pollutant emissions from the 2005 Toxic Release Inventory facilities included in the U.S. EPA's Risk Screening Environmental Indicators, estimated at the census tract level using a Gaussian-plume fate-and-transport model (RSEI-Geographic Microdata database) [32,33]; the CARB cumulative estimated lifetime cancer risk associated with ambient air toxics exposures from mobile and stationary sources for 2001 [34,35]; tract-level estimates of cumulative respiratory hazard derived from the 1999 National Air Toxics Assessment (NATA) [36]; tract-level ambient concentration estimates interpolated from the CARB statewide criteria air pollutant monitoring network for $PM_{2.5}$ and ozone concentration estimates and averaged for 2004–2006 [34].

Intermediate scores for each health risk and exposure metric were calculated based on quintile distribution rankings (with scores ranging from 1–5) for all tracts in the study area. As these health risk and exposure metrics are at the tract level, each CI polygon receives the metric score for its host census tract and the ranking is done at the tract level. For example, a CI polygon located in a tract that ranks in the least impacted 20% for each of the five exposure and health risk metrics ($PM_{2.5}$ concentration, ozone concentration, estimated cumulative cancer risk for air toxics, estimated respiratory hazard for air toxics, and toxicity-weighted pollutant emissions from RSEI) would receive a total health risk and exposure score of 5 (5 metric scores of 1), whereas a tract that ranked in the highest quintile for all five metrics would have a total exposure and health risk score of 25 (5 metric scores of 5). These total intermediate scores are then re-ranked into quintiles by tract to derive the final score for this air pollution exposure/health risk category, which ranges from 1 to 5.

2.2.3. Social and Health Vulnerability Indicators

This category of indicators includes tract level metrics identified by the social epidemiology and environmental justice research literature as important factors for adverse health outcomes and statistically significant determinants of patterns of disparate impact. Variables from the 2000 U.S.

Census [37] include measures of race/ethnicity (% residents of color), poverty (% residents living below twice national poverty level), wealth (% home ownership using % living in rented households), educational attainment (% population over age 24 with less than high school education), age (% under 5 years old and % over 60 years old), and linguistic isolation (% residents above the age of 4 in households where no one over age 15 speaks English well). Non-census metrics include % voter turnout (% votes cast among all registered voters in the 2000 general election) [38] as a proxy for degree of engagement in local decision-making (which has been linked to community health status [39]), and adverse birth outcomes (% preterm or small for gestational age infants 1996–03) both of which are sensitive health endpoints that reflect underlying community health status (California Automated Vital Statistics System, 2006, unpublished data).

Intermediate social and health vulnerability indicator scores were calculated using the same quintile distribution and normalization technique employed for the health risk and exposure indicators, above, with scores ranging from 1 to 5. To ensure that social and health vulnerability scores were not distorted by missing data or based upon anomalously small populations, tracts with fewer than 50 people and those with fewer than six indicator values were not scored (n = 34 out of 3,381 tracts or about 1% of census tracts). Some of these tracts had already been eliminated in the hazard proximity scoring phase owing to having no residential land. To insure comparability between tracts with all metrics and those tracts missing 1 to 4 metrics, we summarized the ranks in the individual metrics but then calculated a score based on dividing that sum by the number of non-missing metrics.

3. Results and Discussion

Mapping the intermediate EJSM scores for the three indicator categories at the census tract level reveals some interesting geographic patterns. The maps shown below cover only the South Coast Air Quality Management District (SCAQMD) portion of the Southern California region studied, as most of the variation in scores is represented in this area. Areas with high hazard proximity and sensitive land use scores (Figure 3) tend to correspond with the more densely populated areas, and either tend to cluster around major industrial centers or follow major transportation corridors. High scores are typical in areas with populations characterized by high minority, low income populations, and adjacent to sectors of concentrated industrial activity (shown in dark gray), such as the Ports of Los Angeles/Long Beach, the Los Angeles International Airport, and the industrial core of Los Angeles running from the ports to downtown L.A.

The geographic distribution of the Health Risk and Exposure scores (Figure 4) is less complex, but with a clear concentric pattern with little fine-scale variation with broad areas with a single score. Areas with the highest scores surround heavily industrialized areas, including central and East Los Angeles, the Alameda corridor connecting downtown to the ports along the 710 transportation (truck, rail, freeway) corridor, and the industrial centers in Baldwin Park and east of Ontario International Airport. Coastal and foothill neighborhoods are characterized by low scores, and the apparent effects of the freeway system on the overall pattern are minor. This pattern is similar to the results of the MATES III (Multiple Air Toxics Exposure Study) project which evaluated and mapped health risks associated with air toxics and diesel particulates using the SCAQMD emissions inventory and monitoring programs [40] even though the MATES analysis is done at a much coarser level of spatial resolution, and includes mapping across all land use types. This suggests that this metric category of the EJSM is consistent with other screening approaches; the innovation here is combining this with other dimensions as well as the adoption of a more transparent and community-engaged approach to developing the EJSM.

Figure 3. Hazard proximity and sensitive land use quintile scores at the tract level (mapped on CI polygons)—South Coast Air Quality Management District (SCAQMD), California.

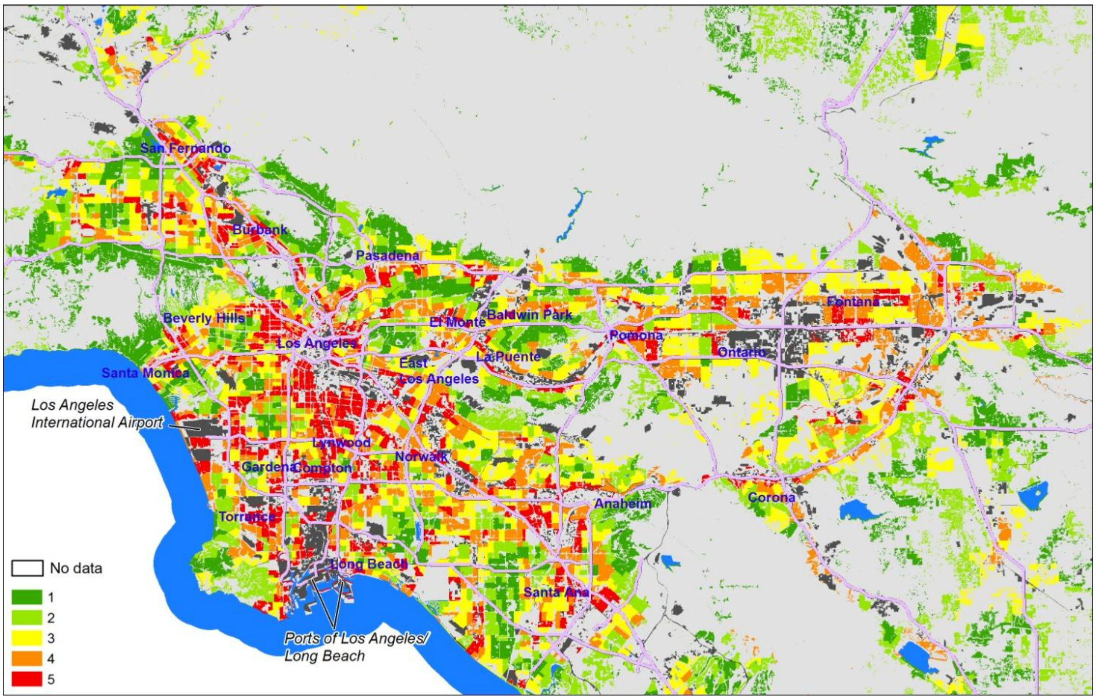
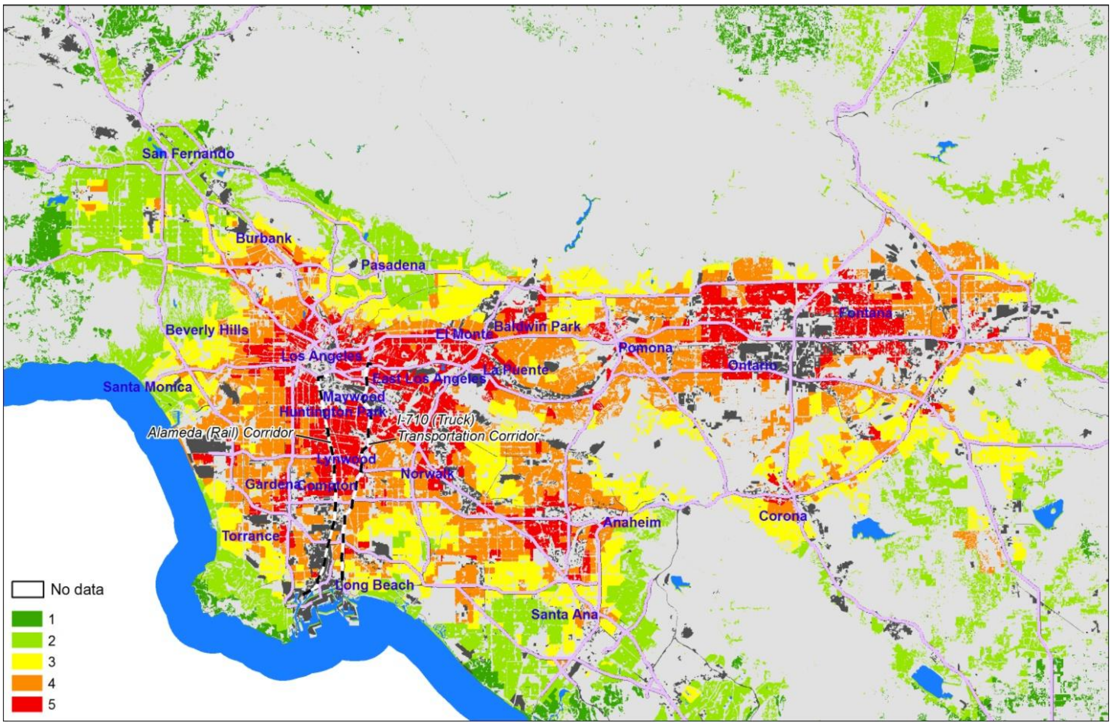
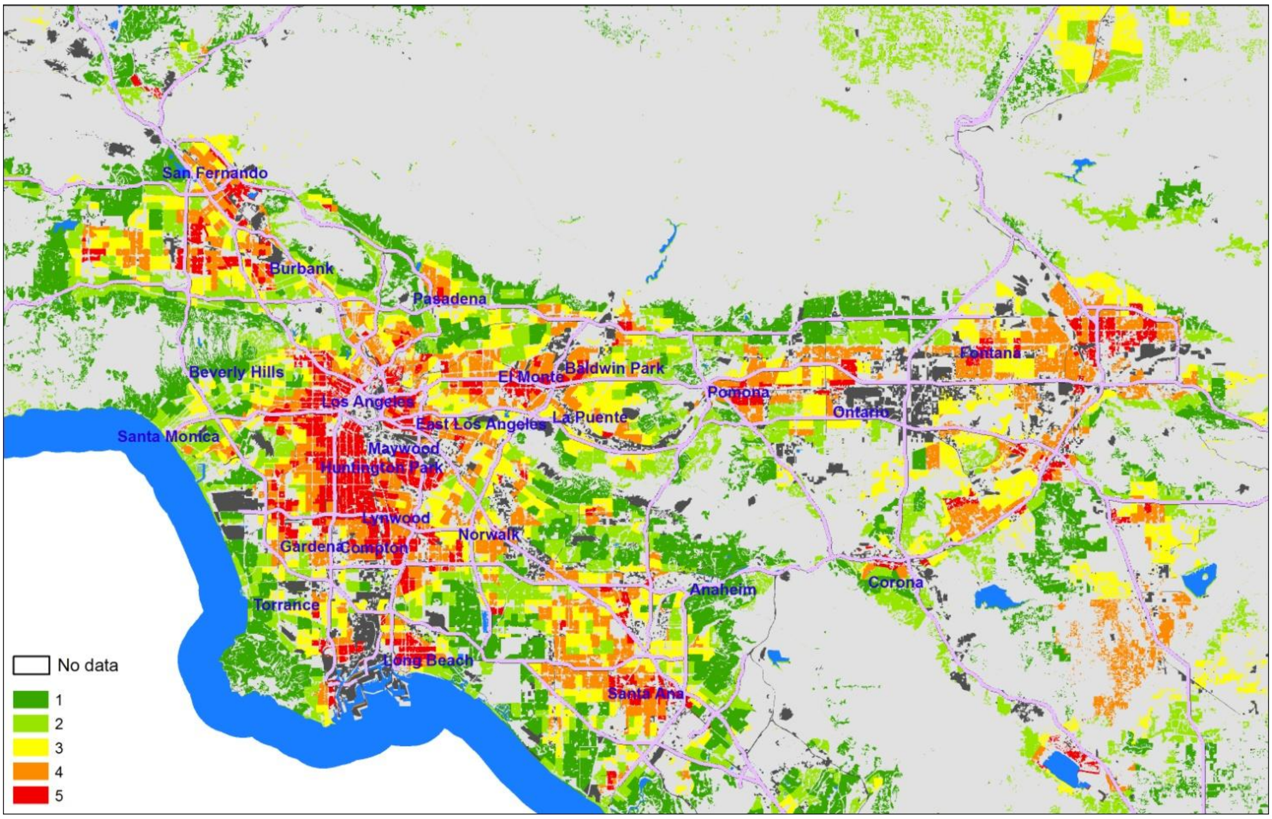


Figure 4. Air pollution exposure and health risk quintile scores at the tract level (mapped on CI polygons)—SCAQMD.



Social and Health Vulnerability scores (Figure 5) reflect the well documented pattern of residential segregation in metropolitan Los Angeles by SES variables of race and class. Many of the same neighborhoods bearing the burden of high exposure to air pollution and its attendant health risks are also those where the most vulnerable populations are also concentrated.]

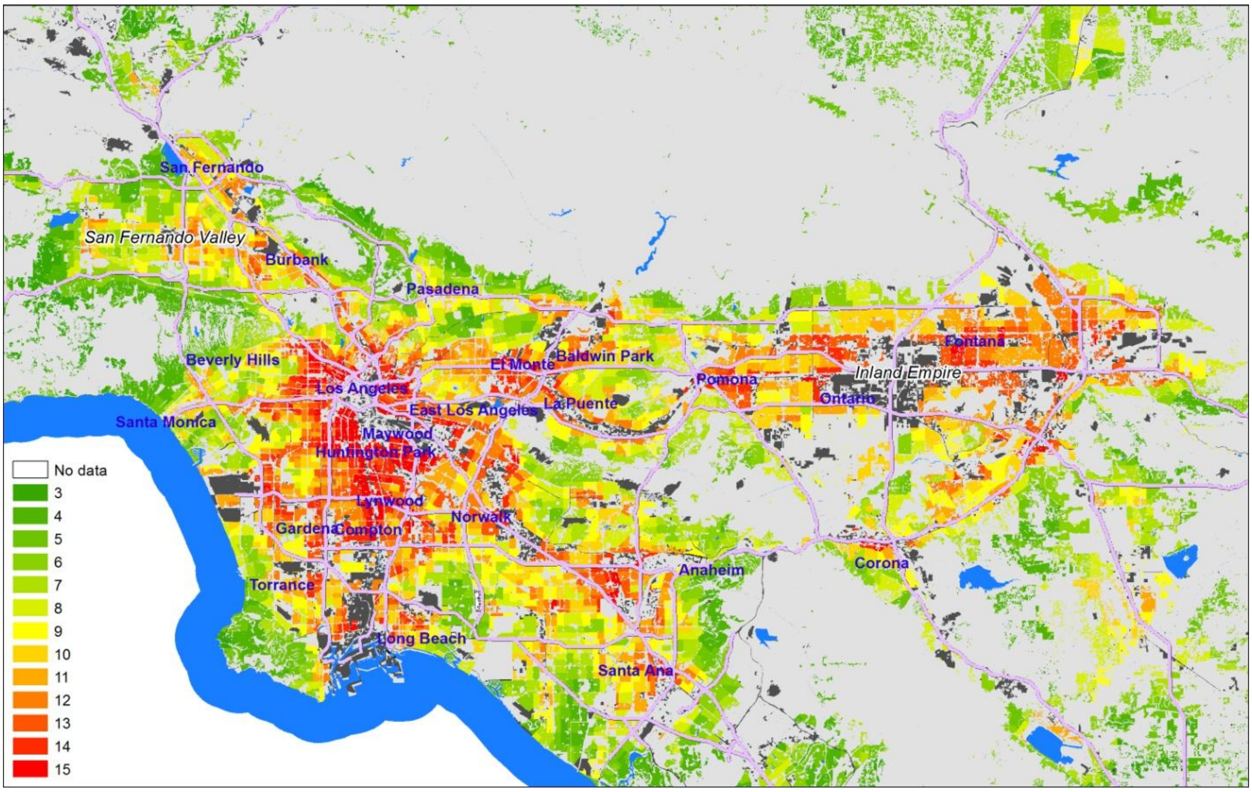
Figure 5. Social and health vulnerability quintile scores at the tract level (mapped on CI polygons)—SCAQMD.



The three intermediate category scores are summed into a Total Cumulative Impacts (CI) Score that ranges from 3–15 (Figure 6). For visual representation, these scores are attached in the GIS system to each CI polygon (since that focuses attention on the residential and sensitive land use areas) but they are based on tract-level scores. It is worth noting that the regional distribution of Total CI Scores is near normal.

Certain areas, like communities near the ports and airports as well as the heavily impacted Pacoima neighborhood in the San Fernando Valley have the highest CI scores (shown in red). Community activism around environmental justice has occurred in these areas and they are often receiving targeted attention from regulators and policy makers. What is perhaps more useful is that the CI map also points to communities that do not have a record of organizing and have not brought themselves to the attention of regulators or decision-makers, such as East Los Angeles (which is intersected with freeways and populated with smaller hazard), Pomona east of Los Angeles, and parts of the Inland Valley (Riverside and San Bernardino Counties). From the view of regulators, the map helps direct attention to places where specific attention may be needed to address environmental health concerns not usually considered; from the point of view of community stakeholders, the map highlights locations where residents may need to be educated and engaged to address environmental hazards.

Figure 6. Total cumulative impact quintile scores at the tract level (mapped on CI polygons)—SCAQMD.



A number of science-policy choices must be made during the development of any screening method and the EJSM is no exception. For example, we chose to include hazard proximity (and sensitive land use designation) as well as air quality and health risk measures. While it can be argued that the health risk measures are most important and that including a category for hazard proximity is duplicative, we believe that CI screening should include metrics that are also meaningful for land-use and planning contexts to better account for the larger impact of place on community health. Indeed, studies indicate that communities living near industrial and hazardous waste sites experience an increased risk of psychosocial stress and mental health impacts in addition to other health outcomes [41,42]. Therefore, in order to be accessible to a variety of community, agency and other regulatory stakeholders, we chose not to limit the EJSM to quantitative risk estimates of potential health impacts.

We also did not to attach explicit weights to any of the three metric categories or to any of the specific metrics within each category (e.g., rankings for the cumulative estimated lifetime cancer risk associated with ambient air toxics and ranking for the tract-level ambient $PM_{2.5}$ concentration estimates both have the same weight within our category of air pollution-related estimated health risk). Our decision was based on the fact that there is a paucity of scientific evidence that provides specific guidance for a particular weighting scheme and it was also guided by community stakeholder feedback expressing worries about arbitrary weights. We note, however, that the EJSM has been developed with enough flexibility to allow for weighting of metrics if a specific decision-making context warrants such an approach. Weights could be assigned directly to metric scores, or the range of scores for specific metric categories could differ based on determinations of the strength of the data available.

This latter approach is one that is currently being considered by California's Office of Environmental Health Hazard Assessment [43].

Similarly, our use of quintiles as the basis to score metrics and to derive a single CI score was driven at least partly by our desire to have our method be more transparent and accessible to diverse audiences. As noted earlier, alternative approaches could use means and standard deviations to capture outlier CI tracts; however, since the health risk metrics are not normally distributed, this requires taking the mean and standard deviations of a logged measure. Since the relative ranking of tracts is not changed significantly by this more complicated procedure compared to quintile-based scoring, we chose the approach that is more accessible and more easily understood by the public. This is particularly important in policy areas like environmental justice where a pattern of distrust between agencies and community stakeholders might argue that simple and straightforward is best, at least in the initial phases of developing screening approaches.

We also note that the hazard proximity and land use dimension could be evaluated using different distance buffers than the ones we applied. We made use of CARB-specified land use buffers [25] but expanded the distance with multiple buffers and distance-weighting to account for potential locational inaccuracies of point and area emission sources. We also chose to summarize hazard proximity/land use scores to the tract level to harmonize the data from this category with the tract-level data from the air pollution exposure/health risk and social/health vulnerability categories. An alternative approach would have been to attach to each hazard proximity/land use polygon the tract-level exposure/health risk and social vulnerability scores. However, as we have suggested, this approach misrepresents the geographic accuracy of the health risk/exposure and social/health vulnerability metrics, all of which are calculated at the tract level. The tract level approach likely has the effect of lowering scores for those CI Polygons that are within the high range of the distribution because of the averaging at the tract level, possibly under-representing cumulative impacts for some neighborhoods.

4. Conclusions

The EJSM was developed as an approach for assessing patterns of cumulative impacts from environmental and social stressors across neighborhoods within regions, using Southern California as a case study. Relying on secondary data sources, the EJSM integrates and scores multiple metrics of environmental and social stressors to rank census tracts in a way that is rigorous yet transparent to diverse stakeholders, particularly regulators, policymakers and communities.

In part because we consider hazard proximity and land use to be an essential component of cumulative impact screening, we constructed the EJSM by intersecting a land use spatial layer with census block geography. This creates the distinct advantage of targeting CI screening in areas where people live or where there are sensitive receptors. However, this approach also poses one disadvantage, in that it relies on reasonably precise and well-classified land use data. This information is not uniformly available in all regions of California or elsewhere in the country.

Our future work will examine whether land use data with lower spatial resolution or different types of classification, such as automated classification of aerial photo and satellite imagery or land parcel data, might be utilized and how that would affect the accuracy of screening results. As the quality and availability of land use data continues to improve, we believe that this challenge is not likely to be a serious long-term liability for cumulative impacts screening methods such as the EJSM.

Of course, any screening method that assesses and compares cumulative impacts across diverse locations must be followed with further validation efforts to assess the accuracy of the data as well as the predictive value of the approach. Such validation work will require ground-truthing efforts to verify the locational accuracy in data sets and more refined air monitoring to assess whether and how interpolated exposure estimates are under- or over-predicting measured values in certain locations. Although discussion of this work is beyond the purview of this paper, we have begun to conduct such ground-truthing work in the Los Angeles area [44]. Finally, although the EJSM is flexible enough to allow for comparisons across different study areas (e.g., within regions or across the state) we have emphasized a regional application because generally land use planning, industrial and transportation development, and environmental regulation are regionally rooted and require regionally specific interventions to reduce hazard exposures or to address social and health vulnerability factors.

Despite these limitations, screening methods such as the EJSM can help regulators and policy makers more efficiently target their efforts to remediate cumulative impacts, environmental inequities, and focus regulatory action at the neighborhood level. Currently, the burden of proof is placed on communities to demonstrate the cumulative impacts of environmental and social stressors and push for action. CI screening such as the EJSM provides environmental policy and programs with a more proactive approach that removes this burden from vulnerable communities so that those without an active environmental justice movement or capacity for civic engagement can also receive regulatory attention and protection.

Moreover, the EJSM can advance regulatory decision-making and the implementation of environmental policies. In California, for example, recent climate change legislation, known as the Global Warming Solutions Act [45] mandates statewide goals to reduce greenhouse gas emissions and also requires consideration of how the law's implementation will impact "communities that are already adversely affected by air pollution." Moreover, the law requires that measures to reduce greenhouse gas emissions must be designed to "direct public and private investment toward the most disadvantaged communities in California and provide an opportunity for small businesses, schools, affordable housing associations, and other community institutions to participate in and benefit from statewide efforts to reduce greenhouse gas emissions." As a result of this legislative mandate, CARB is developing its own EJ Screening approach, partly based on the EJSM, in order to comply with the law [46].

One key element of CI screening is the importance of soliciting stakeholder feedback on method development, metric choices and scoring approaches as these evolve. In addition to having extensive peer review by regulatory scientists and academic researchers, the EJSM was previewed multiple times by community stakeholders, including in early scoping sessions to solicit input on potential metrics. We also conducted some local "ground-truthing" exercises to test or verify the locational accuracy of secondary datasets [44,47].

Other regulatory agencies are currently grappling with the development of CI screening tools to inform decision-making in their regulatory programs. As noted earlier, US EPA has been developing an Environmental Justice Strategic Enforcement Screening Tool (EJSEAT) to identify communities experiencing disproportionate environmental and public health burdens for the purposes of enhancing enforcement and compliance activities [48]. Similarly, California's Office of Environmental Health Hazard Assessment is also developing guidelines for cumulative impacts analysis to inform regulatory programs and enforcement activities within Cal-EPA [43]. The field of CI screening is likely to expand as land use and other data sources improve, and these efforts, if implemented, could be very helpful to identifying vulnerable communities and improving environmental health.

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Historical Context and Hazardous Waste Facility Siting: Understanding Temporal Patterns in Michigan

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This article tests the proposition that, beginning in the 1970s, historic growth of public environmental concern and opposition to waste facilities, as well as changes in the policy environment increasingly encouraged hazardous waste facilities siting to follow the path of least (political) resistance and resulted in environmental inequities. Our longitudinal analysis of sitings in the State of Michigan from 1950 to 1990 reveals a distinct temporal pattern supporting our hypotheses. Whereas significant racial, socioeconomic, and housing disparities at the time of siting were not in evidence for facilities sited prior to 1970, patterns of disparate siting were found for facilities sited after 1970. Thus, we call for environmental justice studies employing longitudinal methods to understand the processes and factors contributing to environmental inequalities with greater consideration to changes in historical context.

Environmental justice research largely has been devoted to examining social inequalities in the geographic distribution of environmental hazards such as waste facilities and other pollution sources (Brown 1995; Bullard 1983, 1990; Mohai and Bryant 1992; Ringquist 2005). Environmental justice scholars only recently have begun to examine inequitable distributions over time. Longitudinal studies focus on the temporal sequence of events that result in present day environmental inequalities by assessing social and demographic characteristics of host neighborhoods at the time noxious facilities are sited and by analyzing subsequent changes (Been 1994; Been and Gupta 1997; Krieg 1995; Oakes, Anderton, and Anderson 1996; Pastor, Sadd, and Hipp 2001; Stretesky and Hogan 1998; Szasz and Meuser 2000). This literature asks generally whether minority and low-income neighborhoods "attract" noxious land uses and whether localized negative impacts (e.g., on property values, neighborhood pride, health, and safety) lead to disproportionate demographic changes (Baibergenova et al. 2003; Freudenberg 1997; Nelson, Genereux, and Genereux 1992; Vrijheid et al. 2002). By going beyond merely asking whether environmental inequalities exist, these studies take an important step toward understanding environmental inequity formation processes and associated factors (Pellow 2000). This article tests the proposition that, beginning in the 1970s, historic growth of public environmental concern and opposition to waste facilities, as well as changes in the policy environment increasingly encouraged hazardous waste facilities siting to follow the path of least (political) resistance and resulted in disparate siting in low-income and minority neighborhoods.

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Explanations of Hazardous Facility Location

Environmental justice theory currently is under active development, as researchers consider the myriad factors that may account for disparities in the distribution of environmentally hazardous sites by race and socioeconomic status. Rational choice, sociopolitical, and racial discrimination models have been offered to explain discriminatory siting decisions and post-siting demographic changes that may occur in the surrounding neighborhoods (Saha and Mohai 1997). These models have often been treated as competing explanations, but in fact they may be complementary.

Rational choice models emphasize market rationality in industry site-selection decisions and in household residential-location decisions. Low-income and minority neighborhoods provide the most efficient locations for industry because land prices and compensation costs are relatively low, and industrial zones often coincide with where low-income and minority residents live (Portney 1991a). Neighborhood transition subsequent to siting occurs in response to the siting of noxious facilities and other locally unwanted land uses as relatively high-income residents vote with their feet. Their departure and the subsequent downward pressure on housing costs provide ample affordable housing for disproportionately low-income minorities, thereby creating new disparities or worsening ones that exist at the time of siting (Been and Gupta 1997).

Sociopolitical models focus on social group differences in the ability to resist siting proposals and force the clean-up of contamination (Schlosberg 1999). For example, Robert D. Bullard (1983, 1990) argues that siting follows the "path of least political resistance" because low-income and minority communities lack the power to influence siting decisions. Community resistance may also be lowered by the promise of jobs and tax revenues (Bohon and Humphrey 2000; Bullard and Wright 1987). At the same time, disadvantaged groups are underrepresented in industry and government where siting decisions are made and approved (Mohai and Bryant 1992). Thus, because of their political and economic vulnerability, low-income and minority neighborhoods are less likely to defeat siting proposals and are more likely to receive proposals deflected from more politically powerful (i.e., affluent, white) areas.

Racial discrimination models posit that minority communities are targeted intentionally for reasons of prejudice, beliefs in racial superiority, or a desire to protect racial group position (Pulido 2000). Racial discrimination also can take an institutionalized form not necessarily directly related to racist ideologies; for example, informal or formal land use and siting decision rules of industry and government that might appear race neutral, nevertheless, might lead to racially disparate outcomes (Feagin and Feagin 1986). Moreover, discrimination in various institutional domains, such as housing, education employment, and health care, and interactions thereof, can disadvantage minorities and limit their social and physical mobility (Mohai and Bryant 1992; Pellow 2002; Stretesky and Hogan 1998).

A common assumption underlying all these models is that the undesirability of hazardous waste and polluting industrial facilities and social, economic, and political factors affecting their placement have been constant over time. Testing of these models has produced mixed results. Some studies have reported evidence of racial and socioeconomic siting disparities (Been 1994; Hurley 1997; Pastor et al. 2001). Some have found evidence of post-siting demographic change (Mitchell, Thomas, and Cutter 1999; Stretesky and Hogan 1998). Still others have found evidence supporting neither (Been and Gupta 1997; Oakes et al. 1996).

We believe that part of the ambiguity of these studies relates to inconsistencies produced by relying on census tracts of widely varying sizes and with boundaries that shift from decade to decade (Mohai and Saha 2003). Recently, the problem of shifting tract boundaries, and hence of the shifting size of neighborhoods around hazardous sites, has been overcome by examining consistent geographic areas around such sites using Geographic Information Systems (GIS) technology (e.g., see Pastor et al. 2001). Another possible explanation for the ambiguous results may be the different temporal scopes of these studies. Despite implicit assumptions that the social, economic, and political factors affecting siting decisions are constant over time, factors in one historical period may have been more or less influential than in another. In this article we argue that the historical context of hazardous waste facility siting, in fact, has been changing significantly over the last 50 years, as public concerns about toxic contamination have grown and as industry and government responses have evolved.

By historical context, we mean the sociopolitical conditions at any given time that may affect siting outcomes. These include public attitudes and behaviors regarding hazardous waste, institutional arrangements of siting decision-making authority, and political opportunity structure for public participation in siting decisions. We argue that the latter two factors largely have been shaped by the policy environment (i.e., the laws governing the siting process, which in turn have been shaped by the emergence of mass environmental concern).

Our purpose then is to explain how and why the historical context of hazardous waste facility siting has been changing and to explore the consequences of these changes for racial and socioeconomic disparities in siting. We do so through an empirical analysis of temporal patterns of commercial hazardous waste siting in Michigan from 1950 to 1990. As Manuel Pastor, Jr., Jim Sadd, and John Hipp (2001) have done, we attempt to remove spatial ambiguity across census decades by mapping precise facility locations and controlling the geographic areas examined around their locations by using GIS methods. In considering the various factors influencing siting decisions that have changed over time, we analyze the historical development of environmental concern about waste facilities and the anti-toxics and environmental justice movements (Gottlieb 1993; Szasz 1994). We also examine changes in the political opportunity structure (in the narrow sense of "proximate" or "policy specific opportunities") for potential host communities (Tarrow 1996:42). Thus, we consider how changes in federal-state-local institutional arrangements, brought about by the Resource Conservation and Recovery Act (RCRA), channeled and constrained social group participation in governmental siting decisions. We suggest that consideration of historical context can improve the explanatory value of environmental justice research models.

Historical Context and Siting of Hazardous Waste Facilities

We provide below an historical account of the development of public environmental concern about solid and hazardous wastes and the associated Not-in-My-Backyard (NIMBY) phenomenon. We delineate three distinct periods relevant to understanding public attitudes and anxieties about hazardous waste, social group political participation in siting decisions, and their effects on facility siting outcomes. These periods include: (1) the pre-NIMBY/pre-RCRA era (pre-1970); (2) the early NIMBY era (1970–1980); and 3) the post-Love Canal era (post-1980). We hypothesize that disparate siting patterns did not exist for facilities sited in the pre-NIMBY/pre-RCRA era, but that such patterns emerged in the early NIMBY era, and increased in severity in the post-Love-Canal era.

Pre-NIMBY/Pre-RCRA Era (Pre-1970)

The unprecedented growth in public awareness and concern during the 1960s and early 1970s about a wide range of environmental issues likely had a primary influence on the siting process. In addition to growing public concern about air and water pollution, population control, and natural resource protection, concern about waste disposal also developed during the 1960s, and would later expand in the 1970s (Dunlap 1992; Kanagy, Humphrey, and Firebaugh 1994). To address concerns about adverse health and environmental impacts of ever-growing amounts of solid waste, Congress passed the Solid Waste Disposal Act of 1965 and the Resource Recovery Act of 1970, which together created a limited federal role in solid waste management. These laws encouraged states and municipalities to shift from open dumping to sanitary landfills by providing grants, training programs, and technical standards. Prior to 1965, few states participated in waste management activities (Blumberg and Gottlieb 1989).

Although solid waste issues were squarely on the public agenda, hazardous wastes were not, and would not be until the Love Canal story broke in 1979 (see below). Prior to the enactment of RCRA of 1976 and the Hazardous and Solid Waste Amendments of 1984 no national policies regulated the siting of hazardous waste facilities. A similar situation existed at the state level. For example, in Michigan, no specific state policies provided oversight of hazardous waste facility siting until the passage of the state Hazardous Waste Management Act (Act 64) of 1979. The so-called Superfund Act (Comprehensive Environmental Remediation, Compensation, and Liability Act of 1979, or CERCLA) and its list of abandoned, contaminated sites are testimony to prior decades of unregulated handling of hazardous waste.

For waste facilities sited prior to RCRA and Act 64, governmental siting decisions rested with the appropriate local governmental approval bodies (e.g., city building departments and planning offices or zoning boards), which assured that standard building code, zoning requirements, and the like were met. Even in areas where zoning may have precluded siting in certain locations, zoning could be changed or variances issued. For example, Detroit was known for the "flexibility" of its ordinances (Sugrue 1996). There were typically no specific requirements pertaining to design safety, operating conditions, or public participation in siting decisions beyond those required for any other industrial facility. Due to the lack of public awareness of the risks of hazardous waste and a similar lack of development of environmental and health sciences, public and governmental involvement in siting decisions was minimal, and many facilities "functioned with an absolute minimum of technical safeguards or provisions for community input or oversight of facility management" (Rabe 1994:28). Prior to the NIMBY phenomenon and RCRA, pollution was more generally accepted as a necessary price of economic prosperity, local approvals were routine, public opposition was rare, and the legal or regulatory context allowed little democratic deliberation in siting decisions (Davy 1997).

Early NIMBY Era (1970–1980)

Although sanitary landfills offered a significant improvement over open dumping in protecting public health and the environment, growing concern over the risks of old dump sites (many that were later to be designated Superfund sites) transferred to the new landfills and other disposal facilities, such as incinerators. According to the U.S. Environmental Protection Agency (EPA), community opposition to the siting of waste facilities grew throughout the 1970s and threatened to undermine governmental efforts to improve solid waste management (Bacow and Milkey 1982; U.S. EPA Office of Water and Waste Management 1979). Thus, public concern about waste facilities appears to have contributed to widespread growth of community organizing as environmental concern became expressed through local citizen action. This phenomenon became widely recognized and somewhat pejoratively labeled as the Not-In-My-Backyard (NIMBY) syndrome, fueled by highly visible events such as the Three-Mile Island nuclear accident of 1979.[1]

Despite the early emergence of mass environmental consciousness and growth in concern and citizen activism regarding solid waste facilities, accounts suggest that specific concern related to hazardous waste did not develop until around the time of Love Canal. These concerns

1. The apparent parochial nature of NIMBY does not suggest that participants in NIMBY campaigns all view the siting of facilities in other communities besides their own as acceptable. The term NIMBY is used here mainly for convenience to refer to the recent historical period in which vigorous opposition has been prevalent. NIMBY groups have grown in their sophistication and understanding of the broad context of hazardous waste problems (Szasz 1994). Some groups redefine the problem of "where to put it" by advocating, instead, for more comprehensive solutions such as source reduction and recycling (Bryant 1995).

centered around potential health risks, the impact on property values, the inability to keep out other undesirable land uses, and overall declines in the quality of life in a host community (Edelstein 1988). Environmental public opinion surveys by the EPA in 1973 and by the Council on Environmental Quality and Resources for the Future in 1980 show a shift in attitudes during the 1970s from disinterest and acceptance to extreme concern and opposition in regard to the local placement of hazardous waste facilities (Lindell and Earle 1983). Thus, in the late 1970s, public environmental concern over hazardous waste appears to have been increasing.

In the late 1970s and early 1980s, public concern about hazardous waste and grassroots organizing against new facility siting was generated by several well-publicized and controversial cases such as those in Love Canal, New York, and in Times Beach, Missouri (Kasperson 1986). Peter M. Sandman (1985) asserts that prior to Love Canal "citizens were not very involved in, nor knowledgeable about, the siting of landfills and other hazardous waste disposal practices" (p. 439). The significance of Love Canal in catapulting public awareness (and fear) about hazardous waste does not mean that concern did not exist beforehand (Morell and Magorian 1982; U.S. EPA Office of Water and Waste Management 1979).[2] However, what distinguishes the early 1970s from the late 1970s and, more so, from the early 1980s is the extent of social embeddedness of hazardous waste concern. Andrew Szasz (1994) explains that

> As recently as 1976, "toxic waste" was not yet a well-formed social issue. There was no clear public opinion concerning it, no crystallized mass perception that it is a serious threat to people's health. Hazardous waste became a true mass issue between 1978 and 1980, when sustained media coverage made *Love Canal* and *toxic waste* household words. By 1980, the American public feared toxic waste as much as it feared nuclear power after Three Mile Island. (p. 5)

Thus, any public opposition to hazardous waste facilities that existed in the early-NIMBY era might have related more to the type of facility. Local opposition to hazardous waste landfills and incinerators might have stemmed from their being similar technologies to familiar solid waste management facilities, rather than the hazardous wastes themselves. But that would soon change.

Post-Love Canal Era (Post-1980)

Love Canal is a town near Niagara Falls where a residential neighborhood had been built on hazardous wastes dumped by a chemical company and covered with a thin layer of soil. Because of growing health concerns among residents, Lois Gibbs, a mother and housewife, led a lengthy campaign that captured the national spotlight. Her efforts eventually led to government action culminating in a federal buy-out of homes, President Carter visiting the site, and Congress enacting the "Superfund Act" (see Gibbs 1982; Levine 1982). Love Canal heightened public fears that other communities were also unknowingly at risk of exposure to hazardous wastes and, more importantly, added new fuel to the NIMBY phenomenon.

According to Szasz (1994), public opposition to the siting of hazardous waste facilities was "sporadic and isolated" prior to Love Canal but became widespread and vigorous afterward. Those who share this view note that public opposition grew steadily after the late 1970s and early 1980s (Mazmanian and Morell 1994). Studies of local reactions to hazardous waste sites document the emergence of increasing numbers of community groups organized around hazardous waste issues in the early 1980s (Freudenberg 1984; Quarantelli 1989).

2. The U.S. EPA Office of Waste and Waste Management (1979) report, produced by Centaur Associates, provides examples of successful public opposition from early 1970s, including the IT Corporation facility in Brentwood, California; Padre Juan facility in Ventura County, California; and Resource Recovery Corporation in Pasco, Washington. Other unsuccessful campaigns included Wes-Con in Grandview and Bruneau, Idaho; and Calabasas, in Los Angeles, California. The vast majority of cases (16 of 21) met substantial public opposition in the late 1970s.

Concern about hazardous wastes paralleled that of pesticides and other forms of toxic contamination (Brown 1981). For example, in Michigan, contamination of cattle feed with a flame retardant (PBB) heightened concerns about toxic chemicals and food safety in the late 1970s and early 1980s (Reich 1991). In 1984 came news coverage of the Union Carbide (now part of Dow Chemical) factory accident in Bhopal, India, which led to community right-to-know provisions of Superfund Amendments and Reauthorization Act of 1986 (i.e., creation of the Toxic Release Inventory [TRI]).

The growth of groups organized around toxics issues was so sudden and dramatic that a popular social movement with a formal infrastructure developed (Cable and Benson 1993). The emergence of an anti-toxics movement in many middle- and working-class neighborhoods reflected a change in societal views regarding the role of citizen involvement in siting decisions (Portney 1991b). The expansion of the movement is evidenced not only by the explosive growth in the number of grassroots groups during the 1980s, but also by national networks and international organizations such as the Citizen's Clearinghouse for Hazardous Waste (recently renamed the Center for Health, Environment, and Justice), the now-defunct National Toxics Campaign, and Greenpeace (Gottlieb 1993). Dorceta E. Taylor (1998) reports that, although localized opposition existed in the 1970s, throughout the 1980s grassroots organizations increased in number by over three-fold and grew in sophistication (see also Davy 1997).

Various accounts indicate that political mobilization around hazardous waste siting proposals from the 1970s to the 1990s progressively moved from white middle-class, to white working-class, to minority communities (Hurley 1995; Morrison 1986; Taylor 1993, 1997). In fact, surveys of citizens' groups from the early 1980s did not report involvement of minority and low-income populations in opposition campaigns, but noted participation primarily from the white-collar middle class and sometimes the "working class" (Freudenberg 1984; Quarantelli 1989). Nevertheless, mobilization in communities of people of color in the late 1970s and early 1980s has been documented, such as the widely publicized Warren County protests in North Carolina. However, the emergence of a coherent grassroots people of color movement (i.e., the environmental justice movement) does not appear to have occurred until the late 1980s and early 1990s (Taylor 2000), suggesting that minority and poor communities were initially politically vulnerable to waste facility sitings.

The impact of public opposition has been significant, especially regarding the siting of new hazardous waste facilities (Dinkins 1995; Freudenberg and Steinsapir 1991). In the 1980s, some analysts considered public opposition "the single most critical factor in developing new hazardous waste management facilities" (Furuseth 1989:358; see also Daly and Vitaliano 1987). The role of public opposition in unsuccessful siting proposals is well-documented (O'Hare, Bacow, and Sanderson 1983; Rabe 1994). The difficulty of siting new facilities in the face of nearly universal public opposition was cited as evidence of the failure of RCRA (Mazmanian and Morell 1994) and prompted calls for new approaches to siting (NGA 1981; Rabe 1994). Thus, the historic growth of public concern about hazardous waste and resulting growth in grassroots activism has changed fundamentally the sociocultural context in which facility siting occurs.

There are some important implications regarding (1) the steady and increasing environmental concern in response to increasing recognition of the seriousness of environmental problems, and (2) the explosive growth of citizen opposition to siting of environmental hazards, which appeared to have occurred relatively late in minority and working-class communities. These developments suggest that facility siting increasingly followed the path of least resistance throughout the 1970s and 1980s. As middle-class, upper-class, and (later) working-class communities became involved in citizen opposition groups, new facilities were increasingly likely to be deflected or directed to minority and low-income neighborhoods and communities, which were seen as the paths of least resistance due to their need for jobs and their political vulnerability associated with limited access to resources and allies in government

(Bullard and Wright 1987). Because the environmental justice movement did not develop in earnest until the 1990s (see Taylor 2000), siting in minority and low-income communities may have increased throughout the 1970s and 1980s. Although mobilization of people of color has been significant in the 1990s, with the subsequent prominence of "success stories," their ability to resist unwanted facilities appears limited (Cole and Foster 2001; Hurwitz and Sullivan 2001; Moss 2001), suggesting that disparate siting persisted in the 1990s, though perhaps to a lesser degree.

The Legal Context of Siting

Public environmental concern also resulted in RCRA of 1976, the Hazardous and Solid Waste Amendments (HSWA) of 1984, and corresponding state legislation (Davis 1993). These laws fundamentally altered the playing field of siting contestation, particularly in the post-Love Canal era when the laws took effect. We argue below that these changes in the legal and regulatory context of siting, by changing the dynamics of NIMBY-ism, further contributed to racial and socioeconomic siting disparities. We explain how siting laws served as an additional factor to encourage sitings to follow the path of least resistance by shifting authority from the local level to state and federal agencies. By shaping the political opportunity structure for public participation in siting decisions (Tarrow 1996), thereby leading to discriminatory outcomes, these institutional arrangements constitute an indirect form of institutional discrimination.

In enacting RCRA and HSWA, Congress sought for states, rather than the EPA, to administer their own hazardous waste programs. States were encouraged to pass their own legislation modeled after RCRA and to develop programs at least as stringent as the EPA's. Since passage of RCRA and Michigan's corresponding legislation, Act 64, decision-making authority in Michigan shifted from local government to the Michigan Department of Environmental Quality (DEQ).[3] Local government authority under Act 64 is minimal, and merely consists of verifying that siting proposals comply with local zoning. At the same time, Act 64 gives pre-emptive decision-making authority to the DEQ to override local opposition to siting. This authority also exists in the majority of other states managing RCRA programs (Rabe 1994).

State siting decisions are made through permitting systems prescribed under RCRA. The purpose of permitting programs is to ensure government oversight and protection of human health and the environment in the construction, operation, and closure of facilities. In Michigan, waste facility developers must obtain a permit from the DEQ before construction can begin. Although developers can be denied a permit, the DEQ is obligated to approve a permit if a proposal meets legal and technical requirements (Davy 1997). Prior to issuance of a final permit, the agency issues a draft permit, which starts a 45-day public comment period. In Michigan, if a public hearing is requested (they are not required), a Site Review Board oversees them and subsequently advises the DEQ (Fletcher 2003). The draft permit signals imminent state approval provided that no "substantial new questions concerning the permit are raised" (U.S. EPA Office of Solid Waste 1990:III-79). Thus, public participation in siting decisions under RCRA occurs essentially after the decision has been made (Cole and Foster 2001; Kraft and Kraut 1988). Nevertheless, the provisions provide limited access points for the public to influence final permitting decisions, and these changes and state pre-emption alter the political opportunity structure for collective action in proposed host communities (McAdam 1982).

Public participation rules allow certain communities to delay or curtail the siting process. Administrative and legal challenges at the state and federal levels, and even local zoning dis-

3. This state agency was created in 1996 as a result of a reorganization of the Department of Natural Resources (DNR). Functions related to Act 64 that were previously carried out by the DNR are now performed by the DEQ. To avoid confusion, the subsequent discussion refers only to the DEQ.

putes, may also stall the process, thereby encouraging facility sponsors to withdraw their applications and to seek more receptive locations (Cerrell Associates, Inc. 1984; Daly and Vitaliano 1987). For facilities such as incinerators that also must obtain Clean Air Act (CAA) permits, citizen groups may file CAA appeals or law suits. However, bringing such challenges or delaying permit approvals by taking advantage of the public participation provisions of Act 64, RCRA, or other environmental laws requires considerable technical, legal, and financial resources that often are available only to affluent, politically well-connected communities. This policy environment, in disadvantaging minority and low-income communities and leading to disparate outcomes, is a form of indirect institutional discrimination (Feagin and Feagin 1986; Lake 1996; Stretesky and Hogan 1998). In fact, Thomas H. Fletcher (2003) documents affluent white communities' effective use of delay strategies to oppose hazardous waste facility siting in Michigan during the 1980s. However, less empowered communities tend to lack the political clout and resources needed to mount effective public opposition campaigns (Hurwitz and Sullivan 2001). In fact, evidence such as a report commissioned by the California Waste Management Board, entitled "Political Difficulties Facing Waste-to-Energy Conversion Plant Siting," indicates that opposition from low-income and minority neighborhoods might be less likely than from other areas (Cerrell Associates 1984; Portney 1991a).

In summary, we posit that a historical convergence of several interacting factors has contributed to disparate siting in recent decades. These developments include the growth of public concern about hazardous waste, laws to manage it, growth in local opposition to the placement of it, as well as concern about the failure to successfully site new facilities. Changes in the historical context of siting in the 1970s and 1980s contributed significantly to sociopolitical conditions in which the siting of new waste facilities followed the path of least resistance that allowed patterns of disparate siting of hazardous waste facilities during the early NIMBY era (in the 1970s). Conversely, facilities sited in the pre-NIMBY/pre-RCRA era (prior to 1970) would not necessarily have been sited disproportionately in areas least able to resist them. Furthermore, the consequences of new siting laws and policies favoring affluent communities, along with the progressive growth of environmental concern and NIMBY behaviors ignited by public fears about hazardous waste in the wake of Love Canal, suggest that disparate siting has been more prevalent and severe in the 1980s than in the 1970s.

Temporal Patterns Revealed by Previous Studies

Although not explicitly considering the role of historical context, at least six empirical studies have examined the past demographics of hazardous waste sites to determine whether minorities or low-income persons were overrepresented, relative to the wider community, in areas near these facilities around the time of siting (Been 1994; Been and Gupta 1997; Hamilton 1993; Hurley 1997; Oakes et al. 1996; Pastor et al. 2001). The temporal spans examined by these studies vary considerably, as do the methodologies employed. For example, all but two of the studies essentially examined individual host census tracts, zip codes, townships, or counties, and thus did not necessarily geographically standardize the host areas into consistent areas over time or among facilities (Mohai and Saha 2003). Despite these limitations, the findings can be used to assess temporal patterns in disparate siting. This is accomplished by examining siting disparities in the pre-NIMBY/pre-RCRA, early NIMBY, and post-Love-Canal eras as delineated above.

Vicki Been (1994) conducted two longitudinal studies that were extensions of a 1983 U.S. General Accounting Office (GAO) study of four hazardous waste landfills in the Southeast and Bullard's 1983 study of ten municipal waste facilities and mini-incinerators in the Houston area (Harris County, Texas). Three of four facilities examined in the GAO study (U.S. GAO 1983) sited in neighborhoods with disproportionately high percentages of African Americans were sited in the 1970s. Of the 10 facilities from the Bullard study, two were sited in the 1950s and the remaining eight in the 1970s. Been found five of the eight facilities sited in the 1970s were sited disproportionately with respect to race. None of the facilities sited in the pre-NIMBY/pre-RCRA era (pre-1970) evidenced disparate siting.

Similarly, in a national study, James T. Hamilton (1993) found minority percentages to be a positive predictor and mean housing values to be a negative predictor of counties that received new commercial hazardous waste facilities sited in the 1970s. In a more refined zip code area study, Hamilton (1995) found that facilities that expanded their capacity between 1987 and 1992 were disproportionately located in zip codes with higher percentages of minorities, lower housing values, and, to a lesser extent, lower incomes. In both studies, Hamilton's multivariate analyses showed an independent and significant effect (as predicted) relative to measures of public opposition. Although expansion plans are different than new sitings, Hamilton's findings are consistent with the supposition that the emergence of vigorous public opposition influenced siting decisions in the early-NIMBY and post-Love-Canal eras.

Andrew Hurley (1997) used census tracts within one mile of 56 hazardous waste sites in St. Louis, Missouri. The sites included abandoned toxic waste sites, waste recycling facilities, and other facilities that posed known health risks. A distinct historical pattern was found. Prior to 1975, African-Americans were underrepresented or proportionally represented in hazardous waste tracts compared to the metropolitan area, but after 1975, waste sites were located in predominantly African-American neighborhoods. Pastor and associates (2001) examined census tracts within one-quarter mile and one mile of 38 high-capacity hazardous waste facilities sited in the 1970s and 1980s in Los Angeles County. These host neighborhood tracts had significantly higher minority percentages (of both African Americans and Latinos) and lower incomes, housing values, and educational attainment levels prior to siting than other tracts in the county. Both Hurley (1997) and Pastor and associates (2001) show siting disparities in the early-NIMBY and post-Love-Canal eras.

Social and Demographic Research Institute (SADRI) researchers at the University of Massachusetts (Oakes et al. 1996) conducted a national study of commercial hazardous waste facilities sited in the 1960s, 1970s, and 1980s. The SADRI researchers limited their analysis to metropolitan areas with at least one facility and examined socioeconomic and housing conditions during the decade of siting. They found tracts with facilities did not have significantly higher minority percentages, poverty rates, or housing values than tracts without facilities in "areas with significant industrial employment" (Oakes et al. 1996:137). In a previous analysis of the same facilities, SADRI researchers compared host tracts to census tracts without facilities, regardless of levels of industrial and manufacturing employment (Anderson, Anderton, and Oakes 1994). As in the subsequent study, they found no significant differences in minority percentages or poverty rates, but they did find significant housing value disparities for facilities sited in the 1970s and 1980s as well as differences in levels of industrial and manufacturing employment.

Vicki Been and Francis Gupta (1997) conducted another national study that made comparisons using single host tracts but a slightly different universe of commercial hazardous waste facilities than SADRI. Been and Gupta found race, poverty, and housing disparities in the early-NIMBY era, and poverty and housing disparities in the post-Love-Canal era (see Table 1). However, they did not examine siting disparities in the pre-NIMBY/pre-RCRA era.

Another study that used counties and incorporated areas as the unit of analysis examined the location of 73 facilities on the EPA's Toxic Release Inventory sited in South Carolina from the 1930s through the 1980s (Mitchell et al. 1999). In separately examining urban, suburban, and rural areas, compared to overall state averages, Mitchell and associates (1999) found that host areas did not have significantly higher minority percentages, regardless of the decade sited. Host areas of rural facilities sited in the 1970s and 1980s did, however, exhibit disproportionately lower income levels.

Table 1 summarizes the results of this review of previous studies. Table 1 shows that racial, socioeconomic, and housing disparities at the time of siting have not been in evidence

Table 1 • *Review of Existing Quantitative Studies of Racial, Socioeconomic, and Housing Disparities at Time of Siting*

ERA	*Decade*	*Study*	*Scope/Area*	*Race/ Ethnicity*	*Income/ Poverty*	*Housing Costs*
PRE-NIMBY/PRE-RCRA ERA	1930s and earlier	Mitchell et al. 1999	South Carolina	No	No	n/a
		Hurley 1997	St. Louis, MO	No	n/a	n/a
	1940s	Mitchell et al. 1999	South Carolina	No	No	n/a
		Hurley 1997	St. Louis, MO	No	n/a	n/a
	1950s	Mitchell et al. 1999	South Carolina	No	No	n/a
		Been 1994; Bullard 1983	Harris Co., TX	No	No	n/a
		Hurley 1997	St. Louis, MO	No	n/a	n/a
	1960s	Oakes et al. 1996	U.S.	No	No	No
		Mitchell et al. 1999	South Carolina	No	No	n/a
		Hurley 1997	Gary, Indiana	No	n/a	n/a
EARLY NIMBY ERA	1970s	Hamilton 1993	U.S.	Yes	No	Yes
		Oakes et al. 1996	U.S.	No	No	No
		Been and Gupta 1997	U.S.	Yes	Yes	Yes
		Been 1994; GAO 1983	Southeast U.S.	Yes	Yes	Yes
		Mitchell et al. 1999	South Carolina	No	No	n/a
		Pastor et al. 2001	Los Angeles Co., CA	Yes	Yes	Yes
		Hurley 1997	St. Louis, MO	Yes	n/a	n/a
POST-LOVE CANAL ERA	1980s	Hamilton 1995	U.S.	Yes	Yes	No
		Oakes et al. 1996	U.S.	No	No	No
		Been and Gupta 1997	U.S.	No	Yes	Yes
		Mitchell et al. 1999	South Carolina	No	No	n/a
		Pastor et al. 2001	Los Angeles Co., CA	Yes	Yes	Yes
		Hurley 1997	St. Louis, MO	Yes	n/a	n/a
	1990s	Been and Gupta 1997	U.S.	No	Yes	n/a

for noxious facilities sited in the pre-NIMBY/pre-RCRA era. However, in the early-NIMBY era the phenomenon appears in national-, regional-, county-, and city-level studies. Although disparities have also been found for facilities sited in the post-Love Canal era, the results appear to be less robust. Nevertheless, despite the methodological variations, a clear pattern is evident. Siting disparities appear subsequent to the emergence of widespread public environmental concerns, the concomitant rise of public opposition to waste facility siting, and changes in the policy environment of siting.

Temporal Analysis of TSDF Siting in Michigan

A more purposeful assessment of the importance of historical context to the incidence of disparate siting was conducted by examining commercial hazardous waste treatment, storage, and disposal facilities (TSDFs) sited in Michigan from the 1950s through the 1980s. We tested the hypothesis that discriminatory siting patterns did not exist for facilities sited in the pre-NIMBY/pre-RCRA era (pre-1970), but that such patterns emerged in the early NIMBY era (1970s), and increased in severity in the post-Love Canal era (post-1980).

Methods

Siting conditions were examined for 23 commercial hazardous waste TSDFs operating in Michigan in 1989. The TSDFs were identified from lists obtained from the EPA Resource Conservation and Recovery Act Information System (RCRIS) under a Freedom of Information Act request. The TSDF names and locations from RCRIS were compared to lists obtained from the Michigan Department of Natural Resources (DNR). Opening dates were either obtained from or confirmed by the DNR (Sliver 1993). The TSDFs were sited throughout the state in both metropolitan and non-metropolitan areas. Appendix A lists the geographic locations and current status of the facilities, and shows that some facilities have ceased operations since 1989.[4] No new commercial TSDFs have been sited from 1989 to the time of our analysis.

The locations of facilities were digitally mapped by making site visits and using Topographically Integrated Graphic Encoding and Referencing System (TIGER) files and Geographic Information Systems software (ArcView GIS v. 3.2). This was accomplished by using the street layer of the TIGER files as a guide (GeoLytics Inc. 1999; Wessex Inc. 1995). Standardized host neighborhood areas were created with circular "buffers" of a 1.0-mile radius centered at the TSDF locations, and demographic and housing characteristics of these areas were estimated through area-weighting procedures described below.[5] Delineating consistently sized circular host neighborhood areas served to control for proximity between the TSDFs and nearby populations and surmounted the difficulties of managing census tract boundary changes across multiple decades. For 1950, 1960, and 1970, high quality digitized census tracts were not available. Therefore, these were created by using printed maps as a guide and by "dissolving" the boundaries of sets of 1990 census blocks such that digital shapes produced corresponded to each of the 1950, 1960, and 1970 tracts. In some cases, it was necessary to adjust vertices of the 1990 blocks to correspond precisely to 1950, 1960, or 1970 tract boundaries. For 1980 and 1990, commercially available digitized block groups were used (GeoLytics Inc. 1998). These smaller constituent units of census tracts allowed more accurate estimation of population and housing characteristics in circular host-neighborhood areas. Block groups were not used for earlier censuses because data were not sufficiently reported at that level.

4. Three other TSDFs were excluded from the analyses because they were sited at the same location as existing facilities. These TSDFs were not treated as separate sitings, since they were essentially on-site expansions.

5. Circular areas within 2.0 miles were also examined, but the results were not substantially different than those for the 1.0-mile host neighborhoods. Therefore, the results for the 2.0-mile areas are not reported, but can be requested from the authors.

To estimate the demographic composition of host neighborhoods, 1.0-mile radius circular buffers were "intersected" with the digitized census tracts or block groups corresponding to the census immediately preceding and following siting, using the Xtools extension for ArcView GIS (v. 3.2) and a Lambert's Conformal Conic Projection.[6] The percentage of each tract's (or block group's) area within the buffers was computed, and raw census data were weighted according to the proportion of area within each circle. For example, demographic and housing data for blocks groups 10 or 50 percent within the circle were weighted (multiplied) by 0.10 and 0.50. Thus, if a block group had a population of 3,000 and was 30 percent within the 1.0-mile buffer, its contribution to the population of the 1.0-mile host neighborhoods would be 900. If an entire tract or block group was contained within the buffer, then a weighting factor of 100 percent was used (i.e., the demographic and housing characteristics for the entire tract or block group were used). Using this area-weighting method, raw data for all 1950, 1960, and 1970 tracts, and 1980 and 1990 block groups that were completely or partially intersected by the 1.0-mile circles were aggregated. These values were used to calculate percentages and means for host neighborhoods (see Appendix B).[7]

Some areas within the circular buffers were not "tracted" because they were not designated by the Census Bureau as census tracts. For areas not covered by tracts, the same area-weighting procedures were applied to Minor Civil Divisions (MCDs), which are the primary incorporated and unincorporated political divisions of a county, including cities, towns, and townships. On average, MCDs are larger than census tracts, but smaller than counties. Area-weighted MCD data for untracted areas within circular buffers were aggregated with those of tracted areas to compute estimated population and housing characteristics of all areas (tracted and untracted) within a 1.0-mile radius. These steps were required for three facilities located in or near untracted areas—one sited in the 1970s and two sited in the 1980s.

The area-weighting method was employed to test two basic propositions: (1) disparate siting was less prevalent and severe prior to 1970, and (2) the severity of disparate siting (i.e., the magnitude of racial, socioeconomic, and housing disparities) were greater for TSDFs sited in the 1980s than for TSDFs sited in the 1970s. Racial, socioeconomic, and housing disparities were assessed by examining demographic conditions at or near the time of siting to determine whether disparate siting occurred. Socioeconomic conditions in host neighborhoods were assessed by examining mean family incomes, poverty rates, and employment variables such as unemployment rates and labor force participation rates.[8] These data also served as an indicator of household- and neighborhood-level economic conditions. Housing disparities were assessed by examining mean owner-occupied housing values, homeownership rates, and housing vacancy rates. In addition, changes in the size of the housing stock and new residential housing construction rates were examined (see Appendix B for a list of data sources and construction of the variables). These data provided insights into neighborhood investment, housing quality and demand, shifts in residential land use patterns, and the overall economic vitality of host neighborhoods. These analyses were done separately for TSDFs sited in each decade before 1970 and after 1970.

Because census data are reported in ten-year intervals corresponding to the beginning of each decade, it was only possible to assess demographic conditions at the exact time of siting for those facilities that were sited at the turn of a decade (i.e., 1950, 1960, 1970, etc.). Although it could be argued that decennial data might be appropriately used for facilities

6. See Oregon Department of Forestry (2003) for documentation about Xtools.

7. This method is becoming widely accepted. Other studies that have employed this type of technique include Chakraborty and Armstrong 1997; Glickman 1994; Glickman, Golding, and Hersh 1995; Hamilton and Viscusi 1999; Mohai and Saha 2003; Sheppard et al. 1999; and U.S. GAO 1995.

8. Reliable poverty rates were not available for the 1950 and 1960 censuses and thus could not be used to assess socioeconomic disparities for TSDFs sited in the 1950s and 1960s. However, for TSDFs sited after 1970, family poverty rates were available. Educational attainment levels were also examined for TSDFs sited in all decades, but their analysis did not alter the basic conclusions. These data, therefore, are not reported.

sited within a year or two before or after a census date, facilities sited in the middle of the decade would pose a problem in determining from which census data should be considered. The approach taken was to examine conditions for the census immediately preceding siting and the census immediately following siting. By doing so, demographic and housing conditions at or near the time of siting were assessed. For example, if a facility was sited in 1962 or 1965, then data from the 1960 and 1970 censuses were used. If disparities were noted in the location in both 1960 and 1970, then it could be reasonably assumed that disparities existed at the time of siting, since it would be highly unlikely that the disparities in 1960 would disappear in 1962 or 1965 and then reappear in 1970.

Disparities were assessed by comparing the demographic and housing conditions in 1.0-mile host neighborhoods to all areas beyond 1.0 mile in the host metropolitan areas and non-metropolitan host counties. Alternate assessments were made using the entire State of Michigan as the comparison area, but these data were not reported for a few reasons. First, many areas in Michigan, especially remote regions, were likely not suitable for siting TSDFs because, for example, they were located far from the centers of hazardous waste production and lacked necessary transportation infrastructures. These areas are not appropriate to include in the comparison area when the objective is to assess demographic and housing disparities between areas that reasonably could have received TSDFs. Second, the entire state has lower minority percentages and higher percentages of persons of low socioeconomic status than host metropolitan areas and non-metropolitan host counties, making the likelihood of finding racial and socioeconomic disparities greater. Thus, the most conservative comparison area, least likely to yield disparities, was used.

Results

Two facilities were sited in the 1950s, five in the 1960s, eight in the 1970s, and eight in the 1980s (see Appendix A). To determine whether historical context has influenced siting as hypothesized, we first consider TSDFs sited before 1970.

Pre-NIMBY and Pre-RCRA Era Sitings (Prior to 1970). Racial, socioeconomic, and housing disparities at the time of siting were assessed for Michigan TSDFs sited in the 1950s and 1960s, prior to the time during which significant changes occurred in the sociocultural and legal context of siting. Table 2 shows demographic and housing data in the censuses before and after siting for TSDFs sited in the 1950s. These TSDFs were sited in the Detroit metropolitan area, which at the time included Wayne, Oakland, and Macomb counties. Table 2 shows that during the decade of siting, the total population in 1.0-mile host neighborhoods of TSDFs sited in the 1950s decreased slightly (about 5 percent) from 43,209 to 41,072. The relatively high population density indicates that these TSDFs were located in or near residential areas in urbanized areas of metropolitan Detroit.

Table 2 also shows that host neighborhoods of TSDFs sited in the 1950s were nearly entirely white. The percentage of nonwhites in the 1.0-mile host neighborhoods was less than 1 percent in both 1950 and 1960, while areas beyond 1.0 mile in the Detroit metropolitan area were 12 percent and 15 percent nonwhite in 1950 and 1960, respectively.[9] Because TSDFs that were classified as being sited in the 1950s for this study were sited in 1948 and 1952, the 1950 Census data corresponds to conditions closest to the time of siting. Regardless,

9. Nonwhites are nearly entirely African-American, but include all persons who did not identify as white on the race question of census questionnaires. Therefore, nonwhites may also include Asians, Pacific Islanders, and Native Americans. Because some Hispanics, or Latinos, might identify as whites, only some Hispanics are included in the nonwhite total. However, because Hispanics were only a very small percentage of the total, nonwhite percentages would not have differed if all Hispanics could be counted among the nonwhites. Making this correction was not possible prior to the 1990 Census.

Table 2 • *Racial, Socioeconomic, and Housing Disparities for Pre-NIMBY, Pre-RCRA (pre-1970) TSDFs*[a]

	Sited in 1950s				*Sited in 1960s*			
	1950 Census		*1960 Census*		*1960 Census*		*1970 Census*	
Variable	*1.0 Mile Circle*	*Beyond 1.0 Mile*	*1.0 Mile Circle*	*Beyond 1.0 Mile*	*1.0 Mile Circle*	*Beyond 1.0 Mile*	*1.0 Mile Circle*	*Beyond 1.0 Mile*
Total population	43,209	2,972,988	41,072	3,721,288	21,423	4,104,124	31,232	4,579,743
Number of housing units	12,895	845,132	14,663	1,138,580	5,975	1,260,409	8,769	1,444,513
Population density (persons per square mile)	6,912 (4.66)	1,483	6,570 (3.54)	1,856	1,381 (0.96)	1,434	2,014 (1.26)	1,600
Percent black	0.54% (0.04)	12.0%	0.46% (0.03)	15.0%	1.14% (0.08)	14.0%	1.06% (0.06)	16.8%
Percent nonwhite	0.62% (0.05)	12.2%	0.78% (0.05)	15.2%	1.25% (0.09)	14.2%	1.58% (0.09)	17.2%
Mean family income	$4,472 (1.11)	$4,036	$7,513 (0.95)	$7,887	$7,499 (0.96)	$7,836	$12,890 (0.96)	$13,400
Percent persons 14 years and over in labor force	58.3% (1.04)	56.2%	56.0% (1.00)	56.0%	56.9% (1.01)	56.1%	62.9% (1.07)	58.9%
Percent unemployed civilians 14 years and over	3.97% (0.64)	6.15%	6.36% (0.82)	7.79%	6.71% (0.89)	7.56%	4.82% (0.85)	5.70%
Mean owner-occupied housing value	$9,531 (0.95)	$10,007	$11,641 (0.79)	$14,656	$13,101 (0.90)	$14,531	$22,712 (1.03)	$22,073
Percent owner-occupied housing units	68.8% (1.11)	61.7%	67.7% (0.95)	71.1%	84.7% (1.19)	71.5%	81.0% (1.12)	72.4%
Percent vacant housing units	1.92% (0.56)	3.43%	5.36% (0.85)	6.31%	4.80% (0.76)	6.32%	2.96% (0.71)	4.14%

[a] Numbers in parentheses are ratios of values within 1.0-mile host neighborhoods to values in areas beyond 1.0-mile in host metropolitan areas.

nonwhites were underrepresented in these host neighborhoods at the time of siting, and during the entire decade of siting.

In 1950, mean family income in 1.0-mile host neighborhoods was 11 percent greater than that in areas beyond 1.0 mile in the Detroit metropolitan area: $4,472 vs. $4,036, respectively (see Table 2). Thus, mean family income in host neighborhoods of TSDFs sited in the 1950s was disproportionately high at the time of siting. Employment conditions in host neighborhoods of TSDFs sited in the 1950s also appeared relatively good. In 1950, labor force participation rates in the host neighborhoods were slightly higher than those in areas beyond 1.0 mile (58 percent vs. 56 percent). Table 2 also shows lower civilian unemployment rates in host neighborhoods than in more distant non-host areas (4.0 percent vs. 6.2 percent). The 1960 data show that employment conditions remained robust throughout the 1950s.

Mean housing value in host neighborhoods, however, appeared to decline relative to the comparison areas. For example, in 1950, mean owner-occupied housing value within 1.0 mile ($9,531) was 5 percent lower than that in areas beyond 1.0 mile ($10,007). However, in 1960 the mean within 1.0 mile was 21 percent lower than in the comparison areas. Although housing value was not disproportionately low at the time of siting, neighborhood changes occurred in the decade of siting that appear to have had an adverse impact on housing values. Appreciation and new home building in other parts of the county can also explain the increasing housing value disparity. Nevertheless, homeownership rates remained relatively robust throughout the 1950s, while housing vacancy rates in host neighborhoods stayed relatively low (see Table 2). In addition, the number of housing units increased 14 percent, from 12,895 to 14,663. Growth in the housing stock indicates that TSDFs sited in the 1950s were in thriving residential areas.

In fact, overall economic, employment, and housing conditions in host neighborhoods of TSDFs sited in the 1950s appear to have been relatively good during the entire decade of siting. The only remarkable finding regarding these host neighborhoods was the extremely low representation of minorities.

Siting conditions were remarkably similar for TSDFs sited in the 1960s, all but one of which were also sited in the Detroit metropolitan area (see Appendix A). In 1960, the nonwhite percentage in 1.0-mile host neighborhoods was about 1 percent, compared to 14 percent in areas beyond 1.0 mile in the host metropolitan area (see Table 2). In 1970, the nonwhite percentage in these host neighborhoods was still less than 2 percent, while in comparison areas it was 17 percent.

In 1960 and 1970, mean family income in host neighborhoods was similar to (only 4 percent lower than) that in comparison areas. Thus, no pattern of income disparities at the time of siting could be discerned. Although mean housing value in 1960 within 1.0 mile was approximately 10 percent lower than the mean value in areas beyond 1.0 mile ($13,101 vs. $14,531), it rebounded by 1970, when it was 3 percent higher ($22,712 vs. $22.073). Thus, neither a strong nor consistent pattern of housing value disparities is evident. Table 2 shows that host neighborhoods of TSDFs sited in the 1960s had relatively high homeownership rates and low housing vacancy rates, indicating relatively good housing conditions in these neighborhoods. In addition, from 1960 to 1970, the number of housing units increased 47 percent, compared to a 15 percent increase in comparison areas. These findings are generally consistent with those of TSDFs sited in the 1950s.

Employment conditions in host neighborhoods of TSDFs sited in the 1960s were also favorable relative to the rest of the host metropolitan area. For example, Table 2 shows that labor force participation rates in 1.0-mile host neighborhoods were 57 and 63 percent in 1960 and 1970, respectively, compared to 56 and 59 percent in areas beyond 1.0 mile. Unemployment rates were also slightly lower in host neighborhoods than in comparison areas in 1960 and 1970.

Overall racial, socioeconomic, and housing conditions in host neighborhoods of TSDFs sited in the 1960s were very similar to those of TSDFs sited in the 1950s. Minorities were underrepresented in host neighborhoods of TSDFs sited in both decades. These facilities were sited disproportionately in non-minority or white areas. Using mean income as an indicator, overall socioeconomic status in host neighborhoods of pre-1970 TSDFs sited was comparable to those in more distant areas in the host metropolitan area. Parity in employment conditions and relatively high homeownership rates demonstrate that host neighborhoods of TSDFs sited in the 1950s and 1960s were not economically depressed. Housing vacancy rates and increases in the number of housing units also indicate relatively high housing demand. Thus, in nearly all respects, neighborhoods of TSDFs sited before 1970 appear to have been vibrant, affordable, and desirable places to live when the hazardous waste facilities were sited.

Population density data show some differences between the TSDFs sited in the 1950s and 1960s. Table 2 shows a much higher population density in the decade of siting in host neighborhoods of TSDFs sited in the 1950s than those sited in the 1960s (6,912 vs. 1,381 persons per square mile, respectively). These data are consistent with the more urban location of TSDFs sited in the 1950s (see Appendix A). Table 2 also shows that, during the 1950s, population density decreased in host neighborhoods of TSDFs sited during the 1950s, whereas population density increased rapidly during the 1960s in host neighborhoods of TSDFs sited during the 1960s. Thus, during the decade of siting, there appear to be inherent demographic differences between host neighborhoods of TSDFs sited in the 1950s and 1960s, the former showing population decline and the latter exhibiting population growth.

These changes suggest that host neighborhoods of TSDFs sited during the 1950s underwent a slight economic decline during the decade of siting, whereas host neighborhoods of TSDFs sited during the 1960s did not. This conclusion is reinforced by data on rates of home ownership (i.e., the percentage of owner-occupied housing). Table 2 shows that the homeownership rate in 1.0-mile host neighborhoods of TSDFs sited in the 1950s was greater than that in non-host areas beyond 1.0 mile in 1950 (69 percent vs. 62 percent). However, during the 1950s homeownership rate remained static in these host neighborhoods, but increased dramatically elsewhere, such that the homeownership rate became slightly lower than that in non-host areas in 1960 (68 percent vs. 71 percent). In contrast, the homeownership rate in host neighborhoods of TSDFs sited in the 1960s was much higher (85 percent) and remained consistently above rates in non-host areas throughout the decade of siting (i.e., in both 1960 and 1970; see Table 2). A similar pattern can be noted with regard to mean family income changes.

Despite these differences, Michigan TSDFs sited before 1970 exhibited no consistent or strong racial, income, or housing disparities at the time of siting. However, if our proposition that historical context is important to the incidence of disparate siting is correct, then disparities will be in evidence with respect to TSDFs sited after 1970.

Early NIMBY Era Sitings (in the 1970s). Eight TSDFs were sited in Michigan during the 1970s, four in the Detroit area, three in the Grand Rapids-Muskegon-Muskegon Heights area, and one in a non-metropolitan area. Because TSDFs sited in the 1970s were located in two different metropolitan areas and a non-metropolitan county (Allegan), areas beyond 1.0 mile in the host metropolitan areas and non-metropolitan host county were used as the comparison area. For TSDFs sited in the 1970s, Metropolitan Statistical Area boundaries (MSAs) as defined in 1970 were used to ensure that comparison areas consisted of the same geographic areas for the 1970 and 1980 censuses. The Detroit MSA included, Macomb, Oakland, and Wayne counties. The Grand Rapids and Muskegon MSAs included Kent, Muskegon, and Ottawa Counties.[10] For TSDFs sited in the 1980s, MSA boundaries were used as defined in 1980. This entailed adding Lapeer and St. Clair counties for the Detroit MSA and substituting a different non-metropolitan county (Alpena).

10. Livingston County was excluded from the Detroit MSA because it became part of the Ann Arbor Primary MSA (PMSA) in 1990. To be consistent, only counties in 1980 MSAs that were also part of an MSA in 1990 were used. As a result, Oceana County was excluded from the Muskegon MSA.

Table 3 shows that host neighborhoods of TSDFs sited in the 1970s had a disproportionately high percentage of nonwhites at or near the time of siting. In 1970, the nonwhite percentage in 1.0-mile host neighborhoods was 2.9 times greater than that in areas beyond 1.0 mile in the host MSAs and non-metropolitan host county (46 percent vs. 16 percent). In 1980, the nonwhite percentage within 1.0 mile was 3.4 times greater than that in areas beyond 1.0 mile (67 percent vs. 20 percent). Thus, large racial disparities at the time of siting are evident.

Table 3 also shows that income disparities existed at the time of siting for TSDFs sited in the 1970s. In 1970, mean family income in 1.0-mile host neighborhoods was 23 percent less than that in areas beyond 1.0 mile ($10,167 vs. $13,289). In 1980, mean family income within 1.0 mile was 35 percent less than that beyond 1.0 mile ($17,681 vs. $27,110). Thus, there were not only substantial income disparities, but the magnitude of these disparities increased during the decade of siting. Table 3 shows a similar pattern for family poverty rates in 1970, which in 1.0-mile host neighborhoods were 2.0 times greater than those in the area beyond 1.0 mile (18 percent vs. 9.1 percent). In 1980, the family poverty rate was 2.6 times greater (18 percent vs. 6.7 percent). These data show that the poverty rate in host neighborhoods of TSDFs sited in the 1970s remained static, while it decreased in comparison areas. Disparities were also found with respect to employment conditions. In 1970, the unemployment rate in host neighborhoods was 1.4 times greater than that in comparison areas (8.1 percent vs. 5.7 percent). However, by 1980 the unemployment rate was 1.8 times greater in the same host neighborhoods (20 percent vs. 11 percent). A similar pattern can be noted with respect to labor force participation rates. The above data demonstrate that socioeconomic conditions in host neighborhoods of TSDFs sited in the 1970s were disproportionately low.

These host neighborhoods exhibited housing value disparities that increased during the decade of siting. Table 3 shows that mean housing value in 1.0-mile host neighborhoods in 1970 was 37 percent less than values in areas beyond 1.0 mile ($13,767 vs. $21,831). By 1980, mean housing value had become 54 percent less in host neighborhoods ($22,489 vs. $48,961). The homeownership rate was also consistently lower in host neighborhoods. For example in 1970, the homeownership rate was 65 percent, compared to 73 percent in non-host areas. In 1980, the homeownership rate in host neighborhoods declined considerably to 57 percent, while in comparison areas it had declined very slightly to 72 percent. Table 3 shows that host neighborhoods of TSDFs sited in the 1970s also had a higher housing vacancy rate. In 1970, the vacancy rate in host neighborhoods was lower than that in non-host areas (7.1 percent vs. 4.1 percent). In 1980, the vacancy rate in host neighborhoods was 9.1 percent, but only 4.9 percent in comparison areas. Because housing vacancy rate in host neighborhoods grew much more rapidly during the decade of siting than in non-host areas, the magnitude of disparities increased during this period.

The lower housing values, lower homeownership rates, and higher housing vacancy rates as well as worsened employment conditions indicate that household- and neighborhood-level economic conditions were relatively depressed in host neighborhoods at the time of siting. The depressed economic conditions in host neighborhoods of TSDFs sited in the 1970s also are evidenced by the loss of population and residential housing. Table 3 shows that, from 1970 to 1980, the population in 1.0-mile host neighborhoods declined by over 22,000 persons (18 percent). The number of housing units also declined by 3,853 (9.1 percent) during the decade of siting. These declines occurred while the population remained stable and the number of housing units increased over 16 percent in the comparison areas. This finding suggests that housing units in some residential areas were falling into disrepair and being demolished. It appears that TSDF host neighborhoods were being converted to other land uses, such as industrial, or were just outright abandoned. In fact, little new housing construction occurred in host neighborhoods of TSDFs sited during the 1970s: 6.5 percent of all housing units in 1.0-mile host neighborhoods were built during the 1970s, compared to nearly 20 percent of those in areas beyond 1.0 mile. The loss of housing and low rates of new housing

Table 3 • *Racial, Socioeconomic, and Housing Disparities for Early NIMBY and Post-Love-Canal Eras (post-1970) TSDFs*[a]

	Sited in Early NIMBY Era (1970s)				*Sited in Post-Love-Canal Era (1980s)*			
	1970 Census		*1980 Census*		*1980 Census*		*1990 Census*	
Variable	*1.0 Mile Circle*	*Beyond 1.0 Mile*	*1.0 Mile Circle*	*Beyond 1.0 Mile*	*1.0 Mile Circle*	*Beyond 1.0 Mile*	*1.0 Mile Circle*	*Beyond 1.0 Mile*
Total population	124,754	4,838,403	102,711	4,782,397	71,724	4,213,715	52,709	4,110,950
Total housing units	42,234	1,515,866	38,381	1,747,245	29,880	1,537,803	22,850	1,615,757
Population density (persons per square mile)	5,083 (5.03)	1,010	4,179 (4.19)	999	4,490 (4.24)	1,058	3,300 (3.20)	1,032
Percent black	45.1% (3.08)	14.6%	65.6% (3.60)	18.2%	50.6% (2.50)	20.2%	52.8% (2.38)	22.2%
Percent nonwhite	45.6% (2.93)	15.6%	67.3% (3.36)	20.0%	53.3% (2.43)	21.9%	55.9% (2.27)	24.6%
Mean family income	$10,167 (0.77)	$13,289	$17,681 (0.65)	$27,110	$17,155 (0.62)	$27,570	$26,725 (0.55)	$48,414
Percent families below poverty level	17.9% (1.97)	9.1%	17.7% (2.64)	6.7%	22.4% (3.23)	6.9%	34.2% (3.27)	10.5%
Percent 16 years old and over in civilian labor force	57.9% (0.98)	58.8%	56.0% (0.89)	62.6%	49.2% (0.79)	62.1%	49.7% (0.77)	64.2%
Percent unemployed civilians 16 years old and over	8.05% (1.42)	5.65%	19.52% (1.81)	10.78%	22.0% (1.89)	11.6%	21.4% (2.41)	8.9%
Mean owner-occupied housing value	$13,767 (0.63)	$21,831	$22,489 (0.46)	$48,961	$24,059 (0.48)	$49,675	$39,295 (0.47)	$83,468
Percent owner-occupied housing units	65.0% (0.89)	73.2%	57.1% (0.80)	71.7%	41.9% (0.59)	71.6%	40.9% (0.59)	69.7%
Percent vacant housing units	7.1% (1.74)	4.1%	9.1% (1.86)	4.9%	11.4% (2.33)	4.9%	10.1% (1.80)	5.6%

[a] Numbers in parentheses are ratios of values within 1.0-mile host neighborhoods to values in areas beyond 1.0-mile in host metropolitan areas and non-metropolitan host counties.

construction indicate that these host neighborhoods were undergoing residential decline in the decade of siting. Moreover, the finding of racial, socioeconomic, and housing disparities at the time of siting for TSDFs sited in the 1970s supports the hypothesis that siting disparities would be found for TSDFs sited after 1970 and the advent of mass environmental concern and the NIMBY phenomenon.

Post-Love Canal Era Sitings (in the 1980s). Racial, socioeconomic, and housing disparities were also evident at the time of siting for the eight TSDFs sited in Michigan during the 1980s. Six were sited in the Detroit metropolitan area, and five of these were sited in the City of Detroit. Two were located in the City and County of Alpena in the northeast lower peninsula of Michigan.

The nonwhite percentage in 1.0-mile host neighborhoods of TSDFs sited in the 1980s was consistently higher than that in non-host areas. Table 3 shows that, in 1980, the nonwhite percentage in 1.0-mile host neighborhoods was 2.4 times that in non-host areas beyond 1.0 mile (53 percent vs. 22 percent). In 1990, the nonwhite percentage in these host neighborhoods was 2.3 times greater than that in comparison areas (56 percent vs. 25 percent). Although the nonwhite percentage increased slightly in both host neighborhoods and comparison areas during the 1980s, the magnitude of racial disparities did not increase; rather, it actually decreased slightly. These findings indicate that the minority percentage in host neighborhoods of TSDFs sited in the 1980s was not growing rapidly or disproportionately during the decade of siting, in contrast to host neighborhoods of TSDFs sited in the 1970s. In fact, racial disparities for more recent sitings appear to be slightly smaller in magnitude than for those sited in the 1970s, running contrary to the hypothesis that disparities would increase from the 1970s and 1980s. Nevertheless, the high percentage of nonwhites in host neighborhoods suggests that racial transition occurred prior to the decade of siting. These host neighborhoods were well-established African-American areas, which is consistent with the preponderance of these TSDFs being located in the City of Detroit.

Income disparities at the time of siting are also in evidence for TSDFs sited in the 1980s. Table 3 shows that in 1980 mean family income in 1.0-mile host neighborhoods was 38 percent lower than that in areas beyond 1.0 mile ($17,155 vs. $27,570). In 1990, mean income was 45 percent lower in host neighborhoods than in comparison areas ($26,725 vs. $48,414). Poverty rates appear to follow a similar trend. Thus, income disparities appeared to be increasing during the decade of siting, suggesting that host neighborhoods were undergoing relative economic decline. In fact, the magnitude of these disparities was greater than that for TSDFs sited in the 1970s.

Similarly, disparities in employment conditions were greater for TSDFs sited in the 1980s. For example, unemployment rate disparities were greater for TSDFs sited in the 1980s than in the 1970s: 1.9 to 2.4 times greater in host neighborhoods of the 1980s-sited TSDFs, compared to 1.4 to 1.8 times greater for the 1970s-sited TSDFs. In both 1980 and 1990, the unemployment rate for 1980s-sited TSDFs exceeded 20 percent. In addition, disparities in the labor force participation rate were considerably greater for TSDFs sited in the 1980s than for TSDFs sited in the 1970s. In fact, the labor force participation rates for censuses immediately preceding and following siting in host neighborhoods of 1980s sitings (49–50 percent) were much lower than those of 1970s sitings (56–58 percent). Thus, socioeconomic conditions in host neighborhoods of TSDFs sited in the more recent decade were less favorable than those in host neighborhoods of TSDFs sited in the 1970s. These results provide additional evidence that the magnitude of disparities at the time of siting has increased over time, despite the aforementioned findings regarding racial disparities.

Table 3 also reveals housing value disparities. For example, in 1980, mean owner-occupied housing value in host neighborhoods was 52 percent less than that in areas beyond 1.0 mile ($24,059 vs. $49,675). These disparities are far greater in magnitude than those of TSDFs sited in the 1970s, for which values for the pre-siting census were 37 percent lower in host neighborhoods. In 1990, the magnitude of housing value disparities for the 1980s TSDFs remained virtually unchanged. The homeownership rate was also relatively low. The 1980 homeownership rate in host neighborhoods was 42 percent, compared to 72 percent in non-host areas. In 1990, these disparities persisted. The homeownership rate in host neighborhoods was 41 percent versus 71 percent in comparison areas. These homeownership rates were considerably lower than analogous pre-siting and post-siting rates for host neighborhoods of TSDFs sited in the 1970s, which were 65 percent and 57 percent in 1970 and 1980, respectively (see Table 3).

The lower mean housing value and homeownership rate relative to those of TSDFs sited in the 1970s suggest that TSDFs sited in the 1980s were located in declining residential neighborhoods with relatively low housing demand. In fact, the population in these host neighborhoods decreased more than 20 percent during the decade of siting, while population in non-host areas decreased 2.4 percent. Housing vacancy rate data reinforce this conclusion. Table 3 shows extremely elevated vacancy rates in both 1980 and 1990 in host neighborhoods of TSDFs sited in the 1980s. In 1980, the vacancy rate of 11 percent was 2.3 times greater than the 4.9 percent rate in areas beyond 1.0 mile. Housing vacancy rate disparities can also be noted in 1990. In contrast, host neighborhoods of TSDFs sited in the 1970s had a vacancy rate of 9.1 percent in 1980, or 1.9 times greater than areas beyond 1.0 mile. In fact, of the vacant housing units in host neighborhoods of TSDFs sited in the 1980s, 14 percent were boarded up in 1990 and, therefore, were uninhabitable.

These data suggest that many housing units had fallen into disrepair during the 1980s. Table 3 also provides evidence of the abandonment of residential housing during the decade of siting: 24 percent of the housing units within 1.0 mile of TSDFs sited in the 1980s were lost from 1980 to 1990. This severe housing loss occurred against the backdrop of a 5.1 percent housing unit increase in the comparison areas. In contrast, 9.1 percent of housing units were lost during the decade of siting within 1.0 mile of TSDFs sited in the 1970s. This finding provides additional support for the hypothesis that TSDFs would be sited in increasingly impoverished and declining neighborhoods over time as public opinion and opposition regarding new facility siting increasingly galvanized and the policy environment of siting evolved. Overall, disparities among economic indicators increased in magnitude between the 1970s and 1980s, while the magnitude of racial disparities did not. Possible reasons are explored below.

Discussion

Models of environmental injustice tend to assume that public opposition, attitudes that drive the NIMBY phenomenon, and government and industry responses have been constant over time; therefore, they predict siting disparities regardless of the historical context of siting. However, we found evidence of disparate siting in the early NIMBY and post-Love Canal eras, but not in the pre-NIMBY/pre-RCRA era. This finding is consistent with the proposition that growth of environmental concern, public opposition, and changes in the policy environment—and thus the political opportunity structure—prompted hazardous waste facilities sitings to follow the path of least resistance. Although widespread concern about hazardous waste did not develop until the late 1970s, general public awareness in the late 1960s and early 1970s about waste facilities, pollution, and other environmental issues may have spilled over to siting of hazardous waste facilities. Following Love Canal, specific concern about hazardous waste, hazardous waste facilities, and related NIMBY behaviors expanded greatly, particularly in the 1980s when RCRA provided new opportunities for neighborhoods with high levels of political clout and technical know-how necessary to influence siting decisions. Industry, in turn, altered its site-selection strategy through the permitting process; as the anti-toxic movement emerged and public opposition posed a serious threat to siting, minority and low-income neighborhoods were increasingly attractive locations (Bruelle 2000; Cerrell

Associates, Inc. 1984; Daly and Vitaliano 1987). Thus, the basic factors driving the sociopolitical and rational choice explanations have changed dramatically over recent decades. While it is less clear how factors underlying racial discrimination explanations have changed over time, institutional discrimination may have been relatively constant in its presence, if not its exact character or causal mechanisms (see discussion below).

The increased magnitude of economic disparities from the 1970s to 1980s supports the hypothesis that the burgeoning NIMBY phenomenon and new opportunities for public participation in siting decisions, coupled with the assertion of pre-emptive state authority, increasingly encouraged disparate siting. Although the magnitude of racial siting disparities did not increase from the 1970s to 1980s, they remained significant. Host neighborhoods of TSDFs sited in the 1980s were predominantly African-American. Sitings in both the 1970s and 1980s exhibited signs of progressively worsening economic and housing conditions, as new commercial hazardous waste facilities were increasingly located in the deteriorating urban core of Detroit. Consequently, host neighborhoods exhibited increasingly lower housing values, lower new home construction rates, and larger and more pervasive losses of population and housing. In fact, in these recent decades, neighborhood demographic and housing changes took place prior to and during the decade of siting.

The Detroit metropolitan area includes a highly segregated central city and smaller African-American enclaves (such as parts of the City of Pontiac), which appear to have been targeted for new TSDFs sited in the 1980s, by a process very similar to that which Laura Pulido, Steve Sidawi, and Robert O. Vos (1996) describe in detail regarding the Mobil refinery and other industry in Torrance, California. The siting of new TSDFs in older residential areas with aging and deteriorating housing occurred at a time when Detroit experienced de-industrialization and white flight, processes that further concentrated people of color and the poor in the central city (Sugrue 1996; Wilson 1992). Host neighborhoods of TSDFs sited in the 1970s underwent dramatic racial transition and economic decline during the 1970s, whereas host neighborhoods of TSDFs sited in the 1980s already had undergone such changes. By reducing neighborhood social cohesion and political capacity, as Pastor and associates (2001) also observed, demographic instability could make such neighborhoods particularly vulnerable to new facility sitings. While this last observation is consistent with sociopolitical models, racial discrimination explanations also apply.

For example, a history of industrial and residential development in the East Los Angeles area similarly notes how housing segregation and disinvestment helped to concentrate minorities in areas with the least desirable types of land uses (Pulido et al. 1996). The limited redevelopment options of blighted areas, the courting of polluting industry, and the establishment of industrial zoning in minority enclaves paved the way for siting of waste and other polluting facilities—a case of siting following the "path of most assistance" rather than the path of least resistance. Christopher Boone and Ali Modarres (1999), Robert Hersh (1995), Hurley (1995), Chad Montrie (2005), David N. Pellow (2002), and Andrew Szasz and Michael Meuser (2000) have documented similar examples of how racial segregation, economic decline, uneven redevelopment, and industrial zoning concentrated low-income populations and segregated minorities where environmental hazards were then located in Commerce, California; Pittsburgh, Pennsylvania; Gary, Indiana; Memphis, Tennessee; Chicago, Illinois; and San Jose, California, respectively. The racial disparities and increasing magnitude of disparities in economic and housing conditions associated with TSDFs sited in Michigan supports a similar conclusion. In fact, nationwide, factors increasing such vulnerability to siting were particularly virulent in the 1970s and 1980s (Jargowsky 1997; Massey and Denton 1993; Wilson 1987). Because the breadth of social forces contributing to these temporal patterns have a decidedly institutional character, disparate siting can be viewed as a form of indirect institutional discrimination.

The slight decrease in the magnitude of racial disparities in the 1980s is consistent with the early emergence of the environmental justice movement and growth in the capacity of minority and low-income communities to oppose new facility siting effectively. However, because no new commercial hazardous waste facilities were sited in Michigan during the 1990s, the decade in which the movement came to the fore, this possibility was not assessed.

Conclusions

Our longitudinal study of disparate siting in Michigan reveals temporal patterns that correspond to historic changes in sociopolitical conditions (i.e., pubic attitudes and actions, institutional arrangements, and the policy environment of siting). Pre-NIMBY/pre-RCRA era facilities were located in economically vibrant neighborhoods with relatively good housing and employment conditions. In contrast, host neighborhoods of TSDFs sited in the early NIMBY and post-Love Canal eras exhibited progressively more depressed economic and housing conditions. Furthermore, host neighborhoods of these TSDFs, sited in the 1970s and 1980s, had increasingly severe income and poverty disparities, low housing demand, and high rates of residential housing decline at the time of siting. These findings are generally consistent with the review of previous studies of disparate siting and facility expansion plans (e.g., Hamilton 1995; Hurley 1997).

However, to firmly establish the role that historical context plays in disparate siting, more longitudinal studies are needed. These studies should examine other states and regions and the nation as a whole, as well as other types of locally unwanted land uses. If possible, they should extend their temporal scopes to before 1970, and assess effects of the environmental justice movement on siting decisions since 1990. We also suggest that future environmental justice studies, both cross-sectional and longitudinal, not assume that sociopolitical conditions and policy environment in the past were the same as they are today or that conditions in previous periods were uniform. Better understanding is also needed of how changes in the types of racial discrimination—overt and subtle, individual and institutional—have influenced siting decisions over time. Finally, we encourage greater exploration than was possible in this study of ways to integrate rational choice, sociopolitical, and racial discrimination models, for example, by further understanding how they may be mutually reinforcing, or interacting, over time (Pulido 1996).

Over the past several decades, siting decisions have occurred in a highly contested political landscape. Our findings support the argument that siting increasingly has followed the path of least resistance as a result of unprecedented growth in public environmental concern and citizen action. Institutional factors also are likely to have contributed to the historical patterns. As state and federal agencies assumed responsibility for approving siting proposals of industry, legislatively mandated permitting processes have provided new political opportunities for public involvement, both administrative and judicial. Distributional politics appear to have prevailed such that those segments of the population with fewer political, organizational, and technical resources have borne a disproportionate share of the society's environmental burdens.

Moreover, the historic patterns found in this study suggest that discriminatory siting is here to stay, given the current sociopolitical and legal terrain. As long as the most polluted and disempowered communities are seen and remain as paths of least resistance, attention to post-siting neighborhood changes that may exacerbate siting disparities might only serve as a diversion from the difficult task of addressing institutional forms of discrimination that pervade industry and governmental siting decisions. Government and industry policies that equalize the playing field and pay attention to the racial and socioeconomic composition and existing pollution burden of proposed host neighborhoods could help. Also helpful would be reform of economic development policies and practices by which local officials court or assist polluting industries in locating in already overburdened areas and overlook such areas for more benign forms of redevelopment.

Appendix

Table A • *Geographic Location and Current Operating Status for Commercial TSDFs Operating in Michigan in 1989, by Decade Opened*

#	Decade Opened	Closed or Closing as of 2002	Metropolitan Area	County Census Division (CCD)	Urbanized Area in 1990	Central City Location
1	1950s[a]	No	Detroit	Detroit	Yes	Yes
2	1950s	Yes	Detroit	Dearborn	Yes	No
3	1960s	No	Detroit	Van Buren Township	No	No
4	1960s	No	Detroit	Romulus	Yes	No
5	1960s	Yes	Detroit	Roseville	Yes	No
6	1960s	No	Detroit	Brownstown Township	No	No
7	1960s	No	Grand Rapids-Muskegon	Grandville	Yes	No
8	1970s	No	Detroit	Detroit	Yes	Yes
9	1970s	Yes	Grand Rapids-Muskegon	Grand Rapids	Yes	Yes
10	1970s	Yes	Detroit	Inkster	Yes	No
11	1970s	Yes	Grand Rapids-Muskegon	Muskegon Heights	Yes	No
12	1970s	No	Detroit	Detroit	Yes	Yes
13	1970s	No	Detroit	Van Buren Township	No	No
14	1970s	No	Non-metropolitan	Plainwell	No	No
15	1970s	No	Grand Rapids-Muskegon	Dutton	No	No
16	1980s	Yes	Detroit	Detroit	Yes	Yes
17	1980s	Yes	Detroit	Pontiac	Yes	No
18	1980s	No	Detroit	Detroit	Yes	Yes
19	1980s	No	Detroit	Detroit	Yes	Yes
20	1980s	No	Non-metropolitan	Alpena	No	No
21	1980s	No	Detroit	Detroit	Yes	Yes
22	1980s	No	Non-metropolitan	Alpena	No	No
23	1980s	Yes	Detroit	Detroit	Yes	Yes

[a] Sited in 1948, but treated as 1950s siting.

Table B • *Census Data Sources by Census Year and Geographic Area*

Year	*Variable*	*Geographic Area*	*Source*	*Census Table(s)*
1990	Total population	Metropolitan Areas (MAs); counties; block groups	[a]	Table P 1: Persons
1990	Black and white population	MAs; counties; block groups	[a]	Table P-8: Persons by Race
1990	% black and % nonwhite	MAs; counties; block groups	Calculated[a]	From Table P-8: Persons by Race
1990	Mean family ncome	MAs; counties; block groups	Calculated[a]	From Tables P-108: Aggregate Family Income and P-4: Families
1990	Family poverty rates	MAs; counties; block groups	Calculated[a]	From Table P-123: Poverty Status in 1989 by Family Type and Presence and Age of Children
1990	% unemployed in civilian labor force	MAs; counties; block groups	Calculated[a]	From Table P-70: Sex by Employment Status for Persons 16 Years and Over
1990	% in civilian labor force	MAs; counties; block groups	Calculated[a]	From Table P-70: Sex by Employment Status for Persons 16 Years and Over
1990	Mean value of owner-occupied housing units	All areas	Calculated[a]	From Tables H-24: Aggregate Value, Specified Owner-Occupied Housing Units and H-25: Race of Householder, Specified Owner-Occupied Housing Units
1990	Total number of year-round housing units	All areas	[a]	Table H-1: Housing Units
1990	Vacant housing units	All areas	[a]	Table H-2: Occupancy Status Housing Units
1990	Vacancy rate	All areas	Calculated[a]	From Table H-1 Housing Units and H-2: Occupancy Status
1990	Owner-occupied housing units	All areas	[a]	Table H-9: Tenure by Race of House-holder, Occupied Housing Units
1990	Percentage of owner-occupied housing units	All areas	Calculated[a]	From Tables H-1 Housing Units and H-3: Tenure, Occupied Housing Units
1990	% housing structures built 1980–1989	All areas	Calculated[b]	From Table H-25: Year Structure Built
1990	% boarded up or vacant units	All areas	Calculated[a]	From Table H-6: Boarded-up Status, Vacant Housing Units and Table H-22: Occupancy Status
1980	Total, black, and white populations	MSAs (Metropolitan Statistical Areas); counties; Municipal Civil Divisions (MCDs); block groups	[c]	Table 2: Persons, Urban and Rural and Table 22: Persons by Race
1980	% black and % nonwhite	MSAs; counties; MCDs; block groups	Calculated[c]	From Table 22: Race

(*Continued*)

Table B • (*Continued*)

Year	*Variable*	*Geographic Area*	*Source*	*Census Table(s)*
1980	Mean family income	MSAs; counties; MCDs; block groups	Calculated[c]	From Table 9: Families and Table 77: Aggregate Family Income by Race of Householder in 1979
1980	Family poverty rates	MSAs; counties; MCDs; block groups	Calculated[c]	From Table 86: Family Type by Poverty Status in 1979 by Presence and Age of Related Children
1980	% unemployed in civilian labor force	All areas	Calculated[c]	From Table 55: Race by Sex by Labor Force Status
1980	% in civilian labor force	All areas	Calculated[c]	From Table 55 (see above)
1980	Total year-round housing units	All areas	[c]	Table 21: Occupancy Status, Year-round Housing Units
1980	Mean value of owner-occupied housing units	All areas	Calculated[c]	From Table 240: Aggregate Value of Specified Owner-Occupied Non-condominium Housing Units and Table 238: Mortgage Status and Year Householder Moved into Unit for Specified Owner-Occupied Non-condominium Housing Units
1980	% owner occupied housing units	All areas	Calculated[c]	From Table 21 (see above) and Table 97: Tenure of Occupied Housing Units
1980	Vacancy rate	All areas	Calculated[c]	From Table 21 (see above)
1980	% housing units built 1970–80	All areas	Calculated[c]	From Table 209: Tenure and Occupancy Status by Year Structure Built, Year-round Housing Units
1980	% boarded up housing units	All areas	Calculated[c]	From Table 96: Vacancy Status, Vacant Housing Units
1970	% black and % nonwhite	MSAs; counties; MCDs; tracts	Calculated[d]	From Table P-105: Race
1970	Mean family income	MSAs; counties; MCDs; tracts	Calculated[d]	From Table P-1: Aggregate Family Income of Families, and Table P-19: Families by Type, Presence and Age of Own Children
1970	Family poverty rate	MSAs; counties; MCDs; tracts	Calculated[d]	From Table P-19: Families by Type, Presence and Age of Own Children and Table P-84: Families by Presence of Related Children Under 18, Type of Family, and Poverty Status
1970	% unemployed in civilian labor force	All areas	Calculated[d]	From Table P-54: Population 16 Years Old and Over by Labor Force Status, Selected Characteristics, and Sex
1970	% in civilian labor force	All areas	Calculated[d]	From Table P-54 (see above)
1970	Total housing units	All areas	[d]	Table H-7: Total Housing Units
1970	Mean value of owner-occupied housing units	All areas	Calculated[d]	From Table H-1: Aggregate Housing Value for Units for Which Value is Tabulated and Table H-52: Value, Occupancy Status, and Race of Head
1970	% owner-occupied housing units	All areas	Calculated[d]	From Table H-8: Year Structure Built, Tenure, and Race of Head

1970	Housing vacancy rate	All areas	Calculated[d]	From Table H-35: Occupancy/ Vacancy Status of Occupied and Vacant Year-round Housing Units
1970	% housing units built 1960–1970	All areas	Calculated[d]	From Table H-8 (see above)
1960	% black and % nonwhite	MSAs; counties	[e]	Table 38: Characteristics of the Population, for Counties
1960	% black and % nonwhite	Tracts	[f, g, h]	Table P-1: General Characteristics of the Population, by Census Tracts
1960	Mean family income	MSAs; counties	Calculated[e]	From Table 86: Income in 1959 of Families and Persons, and Weeks Worked in 1959, for Counties
1960	Mean family income	Tracts	Calculated[f,g,h]	From Table P-1: General Characteristics of the Population by Census Tracts: 1960
1960	Total housing units	MSAs; counties	[e]	Table 27: Financial Characteristics and Duration of Vacancy for SMSAs, Constituent Counties, Places of 50,000 Inhabitants or More, Urban Balance, Rural Total, and Urbanized Areas
1960	Total housing units	Tracts	[f, g, h]	Table H-1: Occupancy, Structural Characteristics of Housing Units, by Census Tract
1960	Mean value of owner-occupied housing units	MSAs; counties	Calculated[e]	From Table 27 (see above)
1960	Mean value of owner-occupied housing units	Tracts	Calculated[f,g,h]	From Table H-2: Year Moved into Unit, Automobiles Available, and Value or Rent of Occupied Housing Units, by Census Tracts
1960	% owner-occupied housing units	MSAs; counties	[e]	Table 22: Tenure, Vacancy Status, and Conditional Plumbing Facilities for SMSAs, Constituent Counties, Places of 50,000 Inhabitants or More, Urban Balance, Rural Total, and Urbanized Areas and Table 27 (see above)
1960	% owner-occupied housing units	Tracts	[f, g, h]	Table H-2 (see above)
1960	Vacancy rate	MSAs; counties	[e]	Tables 12 and 17 (see above)
1960	Vacancy rate	Tracts	[f, g, h]	Table H-2 (see above)
1950	% black and % nonwhite	MSAs; counties	[i]	Table 42: General Characteristics of the Population for Counties
1950	% black and % nonwhite	Tracts	[j]	Table 2: Characteristics of the Population, by Census Tracts: 1950
1950	Mean family and unrelated individuals income	MSAs; counties	Calculated[i]	From Table 45: Income in 1949 of Families and Unrelated Individuals, for Counties
1950	Mean family and unrelated individuals income	Census tracts	Calculated[j]	From Table P-1: Characteristics of the Population, by Census Tracts: 1950
1950	Total housing units	MSAs; counties	[i]	Table 2: Summary of Selected Housing Characteristics for the State (Urban and Rural, Standard Metropolitan Statistical Areas, Urban Places of 10,000 or More, and Counties

(*Continued*)

Table B • (*Continued*)

Year	*Variable*	*Geographic Area*	*Source*	*Census Table(s)*
1950	Total housing units	Tracts	[j]	Table 4: Characteristics of Dwelling Units, by Census Tract
1950	Mean value of owner-occupied housing units	MSAs; counties	Calculated[i]	From Table 38: Financial Characteristics of Urban and Rural-Nonfarm Dwelling Units, for Counties
1950	Mean value of owner-occupied housing units	Tracts	Calculated[j]	From Table 4: Characteristics of Dwelling Units, by Census Tract
1950	% owner-occupied housing units	MSAs; counties	Calculated[i]	From Tables 1 and 28 (see above)
1950	% owner-occupied housing units	Tracts	Calculated[j]	From Table 4: Characteristics of Dwelling Units, by Census Tract
1950	Vacancy rate	MSAs; counties	Calculated[i]	From Tables 1 and 28 (see above)
1950	Vacancy rate	Tracts	Calculated[j]	From Table 4: Characteristics of Dwelling Units, by Census Tract

[a] Wessex, Inc., 1994: File 3.
[b] Wessex, Inc., 1994: File 1.
[c] U.S. Bureau of Census 1984b.
[d] Geolytics 2001: File 4.
[e] U.S. Bureau of the Census 1961d.
[f] U.S. Bureau of the Census 1961a.
[g] U.S. Bureau of the Census 1961b.
[h] U.S. Bureau of the Census 1961c.
[i] U.S. Bureau of the Census 1950b.
[j] U.S. Bureau of the Census 1950a:Ch. 17.

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An Index for Assessing Demographic Inequalities in Cumulative Environmental Hazards with Application to Los Angeles, California

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Researchers in environmental justice contend that low-income communities and communities of color face greater impacts from environmental hazards. This is also of concern for policy makers. In this context, our paper has two principal objectives. First, we propose a method for creating an index capable of summarizing racial–ethnic and socioeconomic inequalities from the impact of cumulative environmental hazards. Second, we apply the index to Los Angeles County to illustrate the potential applications and complexities of its implementation. Individual environmental inequality indices are calculated based on unequal shares of environmental hazards for racial–ethnic groups and socioeconomic positions. The illustrated hazards include ambient concentrations of particulate matter, nitrogen dioxide, and estimates of cancer risk associated with modeled estimates for diesel particulate matter. The cumulative environmental hazard inequality index (CEHII) then combines individual environmental hazards, using either a multiplicative or an additive model. Significant but modest inequalities exist for both individual and cumulative environmental hazards in Los Angeles. The highest level of inequality among racial–ethnic and socioeconomic groups occurs when a multiplicative model is used to estimate cumulative hazard. The CEHII provides a generalized framework that incorporates environmental hazards and socioeconomic characteristics to assess inequalities in cumulative environmental risks.

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Introduction

Objectives. Researchers and policy-makers concerned about environmental justice argue that low-income communities and communities of color face a higher frequency and magnitude of impact from environmental hazards as well as psychosocial stressors (*1*–*3*). These disparities are increasingly recognized as potential determinants of health inequalities (*4, 5*) and additional research is needed to assess the cumulative impact of multiple environmental hazards and their toxic effects on these vulnerable communities (*6*). The potential interaction of elevated environmental hazards and socioeconomic stressors have been described as a form of "double jeopardy" (*2, 7*). As a result, environmental justice advocates have urged the regulatory and scientific communities to integrate cumulative impacts in their decision-making and enforcement activities. Regulatory agencies are beginning to grapple with the methodological challenge of developing transparent, yet scientifically valid, indicators of cumulative impacts and to examine and address environmental health inequities (*7, 8*). Recent reports from the National Research Council have also advocated "cumulative risk frameworks" (*9*).

This paper proposes an index to assess the cumulative environmental hazard inequalities in socially disadvantaged groups and neighborhoods. There are two principal objectives: (1) to develop an index capable of summarizing inequalities of impact from cumulative environmental hazards; and (2) to apply the index to the Los Angeles region of California, the case of ambient environmental pollution, to illustrate the potential applications and complexities in implementing the index.

Cumulative Environmental Hazard Inequality Index. Derivation of an index capable of characterizing inequalities in cumulative environmental hazards has two major components: (1) a measure to characterize inequality, and (2) an estimate of cumulative environmental hazards. To measure inequality related to racial–ethnic or socioeconomic measures, we modify a "concentration index" measure that is commonly used in the fields of social science and health planning (*10*). The concentration index was developed to assess inequality of health distributions across socioeconomic groups, with the term "concentration" in this context referring to the concentration of health (compared to poor health) in a small number of people (*11, 12*). The concentration index can also be used to assess inequalities in impact from environmental hazards between different social groups. To our knowledge, concentration indices have only been used in one study to assess inequalities in exposure to individual environmental hazards (*13*), and no index has attempted to characterize inequalities to cumulative environmental hazard.

In this paper we extend the concentration index to summarize the inequality in the distribution of multiple pollutants across socioeconomic and racial–ethnic groups. Because the term "concentration" has a different meaning in environmental health science, we refer to our extension of the concentration index as the "cumulative environmental hazard inequality index (CEHII)". Specifically, the CEHII measures socioeconomic and racial–ethnic inequalities in exposure to cumulative environmental hazard. The index uses the cumulative proportion of the population, ranked by area-based racial, ethnic or socioeconomic composition, starting from the most disadvantaged—against the cumulative environmental hazard aggregated with the aid of various weighting functions. This methodological approach for

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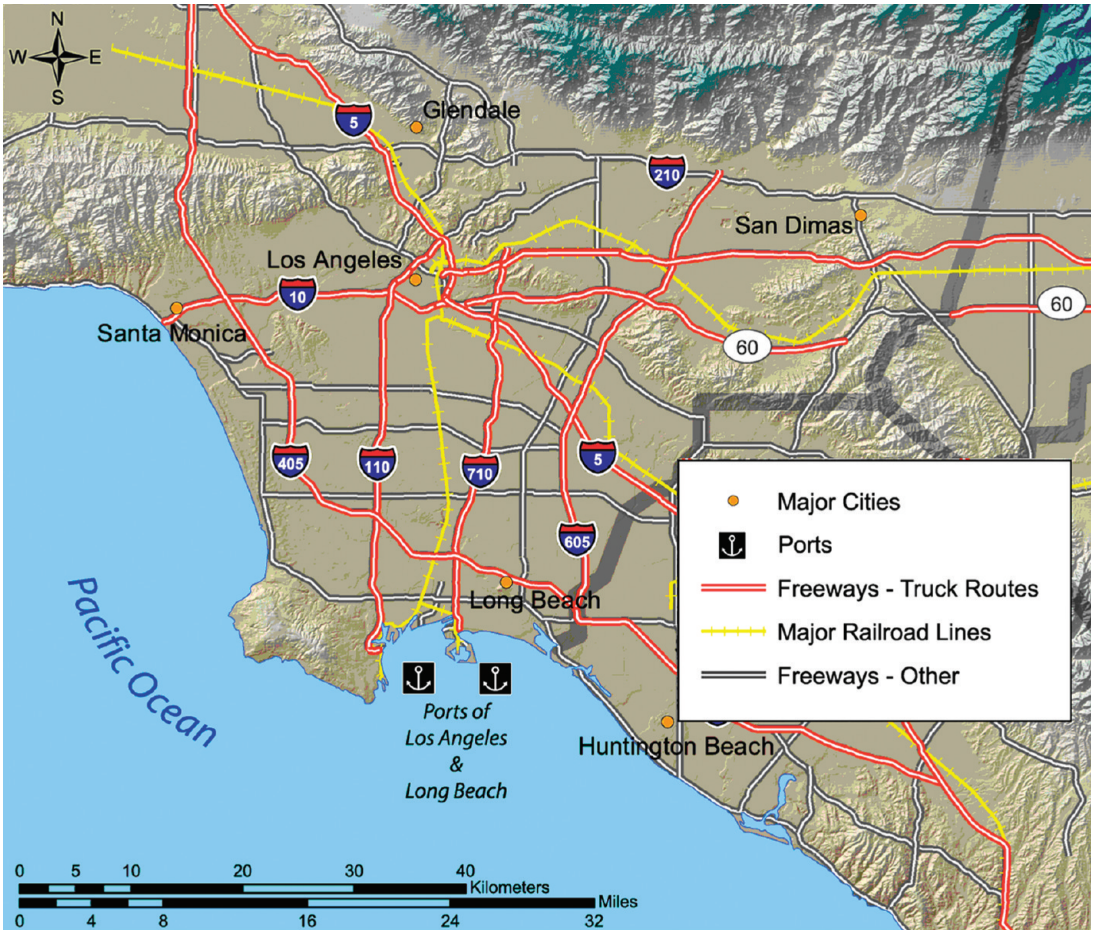

FIGURE 1. The Los Angeles study area, covering central and southern Los Angeles County areas south of the Angeles National Forest Park, with major roads and ports shown.

deriving a CEHII is the first attempt to characterize cumulative impact in a way that integrates environmental hazard and social data.

Materials and Methods

This section describes the study site of Los Angeles, the data used to demonstrate the CEHII, and the algorithms used to estimate cumulative environmental hazards.

Study Site. With a population of 16.7 million in 2006, the Los Angeles metropolitan area is the largest urban area in the state of California and the second-largest in the United States. Los Angeles is consistently ranked as one of the most polluted metropolitan areas in the U.S., partially due to heavy reliance on automobiles for transportation. It is these features plus the region's diverse racial composition, which includes Hispanic, non-Hispanic black, and Asian populations that place Los Angeles in a unique position for research on environmental justice issues. Figure 1 shows the site map of Los Angeles County, south of Angeles National Forest. A previous environmental injustice study in Los Angeles (*14*) demonstrated that concentrations of benzene, butadiene, chromium particles, and diesel particles were higher than average for people who are nonwhite, are from lower-income households, and live in high population density areas. Hazmat spills during transport were also found to disproportionately occur in Hispanic neighborhoods in Los Angeles (*15*). Other ambient pollutants investigated elsewhere in the environmental justice literature include total suspended particulates (*16*), toxic chemicals (*17*), and criteria pollutants such as nitrogen oxides and carbon monoxide (*18*). The one exception is ozone, which is usually higher in suburban areas and in wealthier neighborhoods (*14*).

Selecting and Modeling Environmental Hazards. Selection of the air pollutants used for this study was aimed at examining the potential cumulative and unequal impacts of important air pollutants in the region, while also illustrating how the CEHII metric can incorporate various pollution measures with different spatial, reactive and health risk characteristics. In this case we combined pollutants with a National Ambient Air Quality Standard (NAAQS) (i.e., NO_2, nitrogen dioxide and $PM_{2.5}$, particles less than or equal to 2.5 μm in aerodynamic diameter) or a widely accepted regulatory benchmark (i.e., 1 per million cancer risk for the diesel particulates). NO_2 is a marker of traffic pollution (*19*) with high spatial variation. $PM_{2.5}$ in Los Angeles is emitted directly from incomplete combustion of fossil fuels from transportation, heating/cooling and industry. $PM_{2.5}$ is also formed through secondary atmospheric reactions, and in Los Angeles this secondary formation leads to regional patterns over large areas. EPA has concluded that diesel exhaust poses the greatest health risks such as increased lung cancer and respiratory effects. We applied these criteria and toxic air pollutants to demonstrate the flexibility in the derivation of the CEHII, but other environmental hazards can be incorporated into this index as well.

We used land use regression modeling (*20, 21*), a technique for estimating spatial variation in traffic pollutants, to estimate exposures to NO_2 using pollution data from an earlier study (*22*). Because there are a limited number of government monitoring sites available (*23*) and $PM_{2.5}$ varies over larger

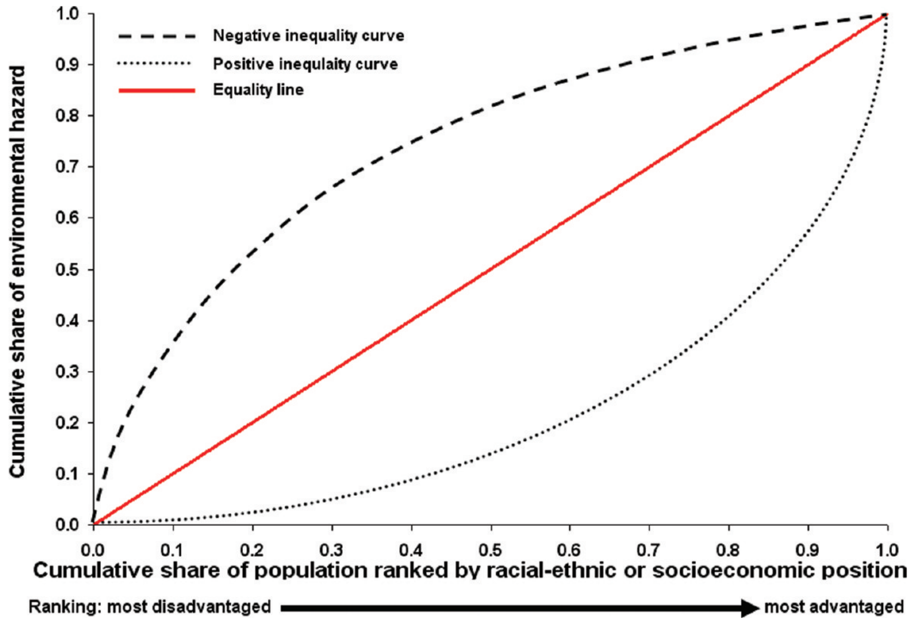

FIGURE 2. Positive and negative inequality curves. Note: Modified from Kakwani et al. (*11*). On these hypothetical graphs, a positive curve indicates census tracts with a higher percentage of a specific racial−ethnic group or lower socioeconomic position have lower shares of environmental hazard. The negative curve portrays the opposite case. The equality line indicates that there is no environmental inequality related to the racial−ethnic or socioeconomic composition measures.

areas, geostatistical interpolation was used to estimate exposure to this more regionally distributed pollutant. Census tract level NO_2 and $PM_{2.5}$ mean concentrations were extracted from corresponding modeled surfaces. We then calculated ratios by dividing each census tract concentration estimates by the NAAQS, respectively, of 53 ppb for NO_2 and of 15 μg m^{-3} for $PM_{2.5}$ (*24*). Diesel PM data were acquired from the U.S. Environmental Protection Agency for 1999. The tract-level diesel PM-related cancer risks were compared to the regulatory benchmark concentration of 1 in a million lifetime cancer risk (*25*). More information on the methods used to estimate NO_2, $PM_{2.5}$, and diesel PM cancer risk surfaces is included in Supporting Information no. 1.

Defining Individual Inequality Index. To estimate the unequal distribution of an environmental hazard, for each census tract we plotted the cumulative proportion of the population, ordered by area-based percentage racial-ethnic or socioeconomic composition, from the most disadvantaged—against the cumulative share of the environmental hazard (See Figure 2). In the case for which each population group has the same share of the cumulative impact of environmental hazards, the curve coincides with the equality (i.e., 45 degree or diagonal) line. If the curve lies above the equality line (inequality index is negative), then the most disadvantaged groups experience higher cumulative environmental hazard burdens. A curve below the equality line (inequality index is positive) implies that the least disadvantaged groups carry a higher proportion of cumulative environmental hazard burdens. A summary measure of inequality is defined as twice the area between the curve and the equality line:

$$I = 1 - 2\int_1^n e(s)\mathrm{d}s \tag{1}$$

This measure gives a quantitative summary of inequality among groups, in which 0 is the lowest level of inequality where all groups have equal exposure to an environmental hazard and 1 is the highest level of inequality, where one group bears the burden of all of the exposures.

Characterizing Cumulative Environmental Impact. There are many aggregation methods available for constructing cumulative environmental impact (*26*−*30*), including additive, multiplicative, and mixture approaches.

The multiplicative approach, also known as the geometric mean method, is one of the most commonly used aggregating methods for constructing the cumulative environmental impact measure (*29*). It can be represented as follows:

$$C_j = \prod_{i=1}^{N} (w_i x_{i,j}) \tag{2}$$

where $x_{i,j}$ is environmental hazard x_i at community/region j, and w_i a weight attached to x_i. To construct a multiplicative index of cumulative environmental impact, the variables are usually normalized to allow comparison without scale effect; however, this is not always the case. The individual variables do not need to be in the same scale and the CEHII remains unchanged if multiplied or divided by a constant.

The additive approach, also known as the weighted-sum method, can also be used to derive an estimate of cumulative impact (*29*). It is built as follows:

$$C_j = \sum_{i=1}^{N} w_i x_{i,j} \tag{3}$$

where $x_{i,j}$ is a normalized variable at community/region j, and w_i also a weight attached to x_i, with $\sum_{i=1}^{N} w_i = 1$ and $0 \le w_i \le 1$, $i = 1, 2, \ldots, N$. w_i is weighted by experts or estimated through regression coefficients. The additive approach entails a weighted linear aggregation rule applied to a set of variables. The main technical steps needed for its construction are (a) standardization of the variables to allow comparison without scale effect, and (b) weighted summation of these variables (*27*).

Measuring Race−Ethnicity and Socioeconomic Position. Although there are numerous ways to measure social disadvantage, we selected two widely used metrics for illustrative purposes. The first metric, based on the 2000 U.S. Census, is tract-level racial−ethnic composition and is defined as the percentage of nonwhites. This measure includes the proportion of Hispanic, non-Hispanic Asian, and non-Hispanic African American population. The second

TABLE 1. Descriptive Statistics for Census Tracts Included in the Analysis for the Los Angeles Area

measures	minimum	mean	maximum	SD
% of population that is nonwhite	0.00	32.18	99.96	28.51
% of population under twice the poverty level	0.00	40.28	96.20	22.37
NO_2 (ppb)	1.50	22.30	47.69	5.03
$PM_{2.5}$ (μg m^{-3})	13.35	20.22	24.25	2.85
diesel PM (cancer risk per million)	37	344	2463	169

metric is poverty. It estimates the proportion of the population with an income less than 200% of the federal poverty level (FPL). The reason for using household income less than 200% of the federal poverty level was because the poverty measure (single household income = $21 000) the U.S. government uses today was established in the 1960s, and on average, families need an income of about twice the federal poverty level to meet their basic needs (*31*). Though other metrics such as deprivation indices could also be applied, only racial−ethnic and socioeconomic composition are used as an example.

Constructing Cumulative Environmental Impact. The cumulative environmental impact of the multiplicative approach entailed multiplying the ratios for the two criteria air pollutants and diesel PM cancer risk for each census tract. The cumulative environmental impact (r_j) to the criteria pollutants and diesel PM cancer risk at census tract j was modified from eq 2 and estimated as follows:

$$r_j = p_j \times \left(\prod_{k=1}^{s} r_{k,j} \right) \tag{4}$$

$r_{k,j}$ is the normalized (ratio or rate) environmental impact at census tract j of hazard k. p_j is the population at census tract j, and s is the total number of environmental hazards being considered, where in this research $s = 3$. We assumed that a census tract of greater population of the same cumulative effect would have higher environmental risk; therefore eq 4 is population weighted.

The second illustration assumed an additive effect and entailed adding the ratios for each air pollutant and diesel PM cancer risk at the census tract level. The additive approach requires each individual environmental hazard to be on the same scale (e.g., all values between 0 and 1 or with a mean of 1). Therefore, the ratios were further normalized to have a mean of 1 using formula 5:

$$r_{k,j}^{\text{norm}} = \frac{r_{k,j}}{\sum_{j=1}^{N} (r_{k,j} \times p_j) / \sum_{j=1}^{N} p_j} \tag{5}$$

N is the total number of census tracts for the region of interest. The metric for cumulative environmental impact (r_j) to the criteria pollutants and diesel PM cancer risk at census tract j in an additive scenario in eq 3 was modified and estimated as shown below:

$$r_j = p_j \times \left(\sum_{k=1}^{s} r_{k,j}^{\text{norm}} \right) \tag{6}$$

Similar to the multiplicative scenario, the additive approach was also population weighted. The variables in eqs 5 and 6 have the same definitions as in eq 4. The population data for each census tract were drawn from the U.S. Census Bureau for year 2000.

Computing Environmental Inequality Indices. We calculated individual inequality indices for NO_2, $PM_{2.5}$ and the diesel PM cancer risk, and then the CEHII to the two criteria pollutants and the diesel PM cancer risk by the multiplicative and additive approaches described above. We derived the following measures: (1) individual inequality indices based on proportion of nonwhite residents for NO_2, $PM_{2.5}$, and diesel PM cancer risk and (2) CEHII based on the proportion of nonwhite residents for NO_2, $PM_{2.5}$, and diesel PM cancer risk combined using both the multiplicative and additive methods. We also calculated the same metrics for the individual pollutants and for the cumulative environmental impact using proportion of residents living below twice the federal poverty level.

Standard errors and significance tests (available in Supporting Information no. 2) were calculated to assess whether inequalities by the single and cumulative metrics significantly differed from the equal distribution (where no inequality exists). Other tests of difference were performed to assess whether differences in inequality existed between various pollutants and social measures.

Results

This section first describes census tract level characteristics of racial−ethnic and socioeconomic measures, followed by NO_2 and $PM_{2.5}$ levels, and diesel PM cancer risk. The individual and cumulative environmental hazard inequalities by race/ethnicity were then summarized and followed by poverty. Finally, t tests for difference in inequality between the racial−ethnic and socioeconomic measures were applied, followed by the inequality difference test between the three environmental hazards and the cumulative hazard.

For racial−ethnic population composition, the highest census tract had 99.96% nonwhites, whereas the lowest census tract had 0.00% nonwhites with a standard deviation of 28.51% (Table 1). Figure 3a shows that nonwhite residents are mainly populated in the downtown area and along the major traffic corridors. For poverty, the highest census tract had 96.20% of the population living at less than 200% of the federal poverty level and the lowest being 0.00% with a standard deviation of 22.37% (Table 1). Figure 3b shows that populations living at less than 200% federal poverty level have a similar geographic pattern to the nonwhite population composition (higher percentage in downtown area and the two ports) but are less clustered.

NO_2 and $PM_{2.5}$ levels and diesel PM cancer risk for Los Angeles are also listed in Table 1. The annual mean of NO_2 concentration for the metropolitan area was 22.30 ppb, with census tract level annual concentrations ranging from 1.50 (minimum) to 47.69 ppb (maximum) and a standard deviation of 5.03 ppb. The NO_2 concentrations were high in the downtown area and most traffic corridors, suggesting that traffic was a major source of NO_2. The minimum, mean, maximum, and standard deviation for $PM_{2.5}$ were 13.35, 20.22, 24.25, and 2.85 μg m^{-3}, respectively. For diesel PM cancer risk, the corresponding values were 37, 344, 2463, and 168 cases per million. The spatial distribution of $PM_{2.5}$ showed a general trend of areas between downtown Los Angeles and San Bernardino corridor having the highest concentrations, reflecting the influence of traffic, topography and meteorology. Diesel PM was similar to NO_2, but also showed high cancer risks at the Los Angeles/Long Beach port complex

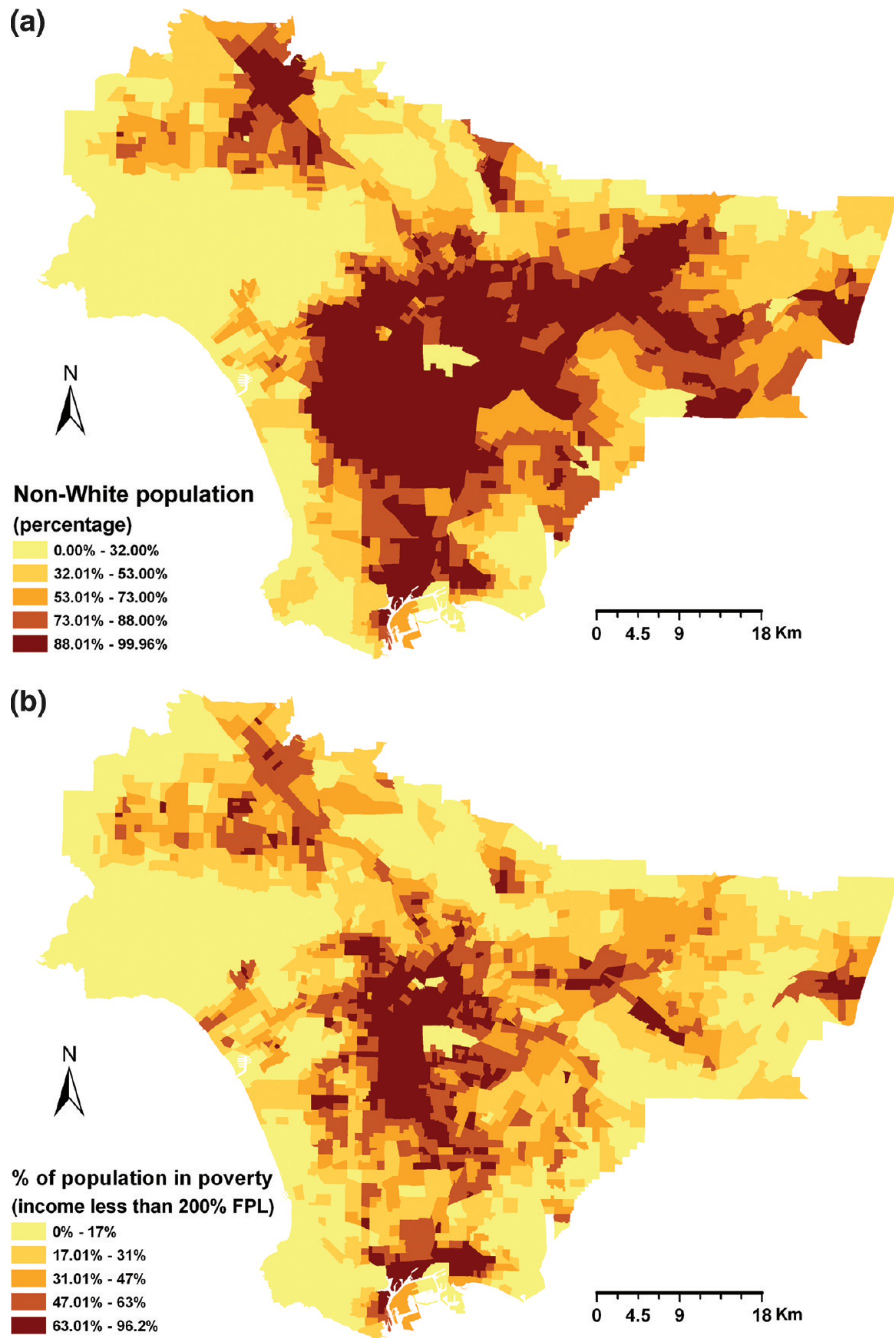

FIGURE 3. Census tract level nonwhite population composition (3a) and percent of population at less than 200% of the federal poverty level (3b).

and the Los Angeles International Airport. If we consider the cumulative environmental hazard, the multiplicative approach showed that high cumulative impacts were clustered in the downtown area, followed by the Los Angeles/Long Beach port complex (Figure 4).

Inequality curves for each of the three individual environmental hazards and for the cumulative environmental hazard, using the multiplicative approach are displayed in Figure 5a−d, showing differences with regard to racial−ethnic composition. Their corresponding individual and cumulative environmental hazard inequality indices and significance test results are listed in the top portion of Table 2. We saw the greatest environmental inequalities from diesel PM cancer risk ($C = -0.085$), followed by NO_2 ($C = -0.067$) and then $PM_{2.5}$ ($C = -0.031$). Although different in size, all three indices demonstrated inequality that is significantly different from equality. The cumulative environmental hazard inequality index using the multiplicative approach (CEHII-A1 = −0.167) had the highest value. By contrast, the CEHII using the additive approach (CEHII-A2 = −0.061) fell between the highest and lowest inequality values for the individual pollutants. As a methodological matter, it is generally expected that the multiplicative method produces greater differences than the additive approach. The individual and cumulative environmental hazard inequalities related to socioeconomic position as well as the results for their statistical significance using both the multiplicative and additive approaches are shown in the lower portion of Table 2. These findings are similar to the racial−ethnic composition results as all the individual and cumulative environmental inequalities were significant. The CEHII using the multiplicative approach for the three environmental hazards (CEHII-A1 = −0.167) was greater than environmental inequalities for each individual pollutant for the poverty strata. Similar

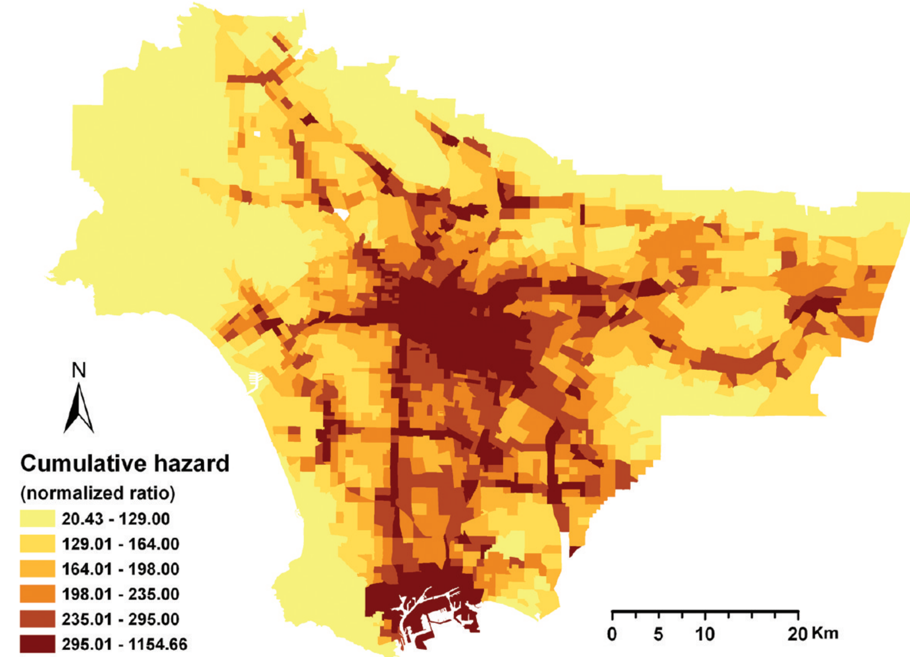

FIGURE 4. The cumulative environmental hazard using the multiplicative approach. Census tract level cumulative environmental hazard = $(NO_2)/(53) \times (PM_{2.5})/(15) \times (DPM)/(1)$.

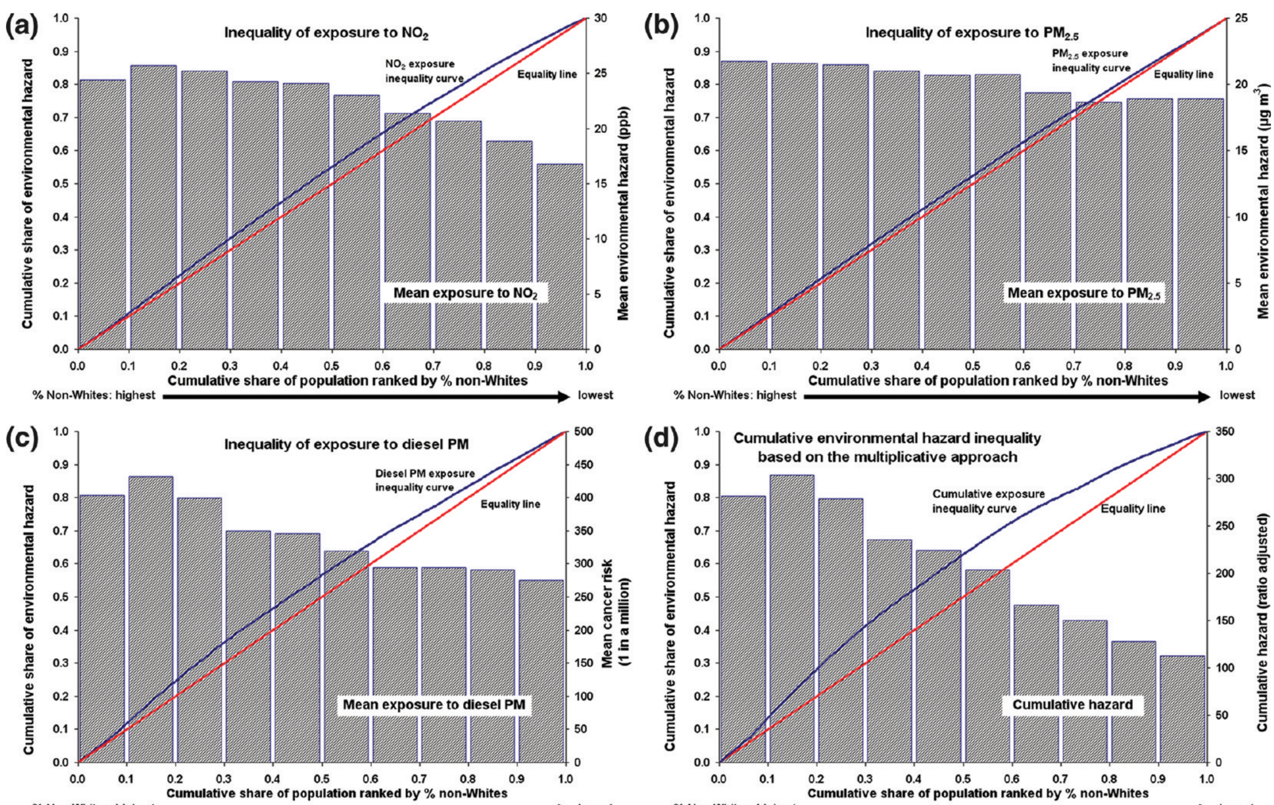

FIGURE 5. The environmental inequality of individual and cumulative impact to three environmental factors using the multiplicative approach based on the nonwhite population composition. Note: The *x*-axis represents the cumulative proportion of the population ranked by a specific demographic measure (e.g., % of tract residents living below the poverty line or % of nonwhite residents) from the highest percentage on the left to the lowest percentage on the right. The *y*-axis on the left represents the cumulative proportion of environmental hazard. For example the curve in Figure 5a shows the inequality in NO_2 exposure based on the proportion of nonwhite residents. On the *x*-axis where the cumulative proportion of the population is 10%, those census tracts with the highest percentage of nonwhites bear a disproportionate share of NO_2 exposure of 11%; when the cumulative proportion of the total tract population is 50%, those census tracts have a cumulative proportion of environmental hazard of 55.5%. The *y*-axis on the right is for the bar charts and represents the average pollutant concentration for each 10% of the population. For example the first bar on the left in Figure 5a indicates that 10% of the population living in tracts with the highest percentage of nonwhites has an average NO_2 concentration of 24 ppb. Similarly, the last bar on the right indicates that 10% of the population living in tracts with lowest percentage of nonwhite residents has an average NO_2 concentration of 17 ppb.

TABLE 2. Significance Tests of Inequality in Racial–Ethnic and Socioeconomic Measures for Both Individual and Cumulative Environmental Hazards

category of inequality		t test result on environmental inequality index	
		environmental inequality index	95% CI[a]
proportion of nonwhite residents	NO_2	−0.067	(−0.072, −0.062)
	$PM_{2.5}$	−0.031	(−0.034, −0.028)
	DPM[b] cancer risk	−0.085	(−0.095, −0.075)
	CEHII-A1[c]	−0.167	(−0.178, −0.156)
	CEHII-A2[d]	−0.061	(−0.065, −0.057)
proportion of residents living two times below poverty	NO_2	−0.066	(−0.072, −0.061)
	$PM_{2.5}$	−0.020	(−0.023, −0.017)
	DPM[b] cancer risk	−0.090	(−0.102, −0.079)
	CEHII-A1[c]	−0.167	(−0.179, −0.154)
	CEHII-A2[d]	−0.059	(−0.064, −0.054)

[a] 95% CI = 95% confidence interval. [b] DPM = diesel particular matter. [c] Cumulative environmental hazard inequality using the multiplicative approach (CEHII-A1). [d] Cumulative environmental hazard inequality using the additive approach (CEHII-A2).

to the results by the racial–ethnic composition, the cumulative environmental hazard inequality index for socioeconomic position using the additive approach (CEHII-A2 = −0.059) was between the highest and lowest environmental inequality indices for the individual pollutants.

While *t* tests for inequality between the racial–ethnic and socioeconomic measures were statistically insignificant ($p < 0.05$) for each of the three environmental hazards, the inequalities between the three environmental hazards for racial–ethnic or socioeconomic measures were statistically significant. The CEHIIs using the multiplicative approach were greater and significantly different from its individual environmental hazard inequalities for racial–ethnic and socioeconomic composition. The CEHIIs using the additive approach were, by contrast, statistically insignificant compared to individual inequalities in exposure to NO_2.

Discussion

We sought to derive an index for assessing racial/ethnic and socioeconomic disparities in cumulative environmental hazards. After deriving the method, we analyzed single and cumulative environmental inequalities in exposure to NO_2, $PM_{2.5}$ and diesel PM cancer risk for the poverty measure and racial/ethnic population composition in Los Angeles County. All environmental inequality curves for individual and cumulative environmental hazards are significantly different from the equality line. This demonstrates that modest environmental inequalities exist for nonwhite populations and for poorer populations in Los Angeles, and more importantly that the new CEHII may supply useful information to environmental justice debates.

Individual and cumulative exposure indices are presented in the literature on environmental health and justice; however, these indices generally do not address inequality and cumulative effects together. Their application for environmental justice analysis relies on further analysis of socioeconomic or racial–ethnic data. For example, Bolin et al. (*32*) used the cumulative hazard density index (CHDI) to reveal disproportionate distribution of risk burdens in urban census tracts. The resulting CHDI provides an aggregate hazard score for each tract, which was then correlated statistically with demographic data in order to measure levels of environmental inequity. Here we present a novel framework that quantitatively assesses inequality and cumulative exposures in an integrated manner. This approach can estimate inequalities across regions and by different demographic groupings. This offers new opportunities to understand sources of inequalities and to develop strategies to address them.

Los Angeles was used as an illustrative example for application of the index. Though NO_2, $PM_{2.5}$, and diesel PM cancer risk were used to demonstrate the application of the CEHII, this metric is also capable of incorporating additional environmental hazard measures, such as water pollution, traffic density, noise, proximity to large emission sources, and other potentially hazardous land uses such as agricultural operations. In addition, positive amenities such as green spaces and access to supermarkets or other fresh food sources could be incorporated into the CEHII and provide an integrated way of assessing cumulative environmental inequality for a region of interest.

While inequities in cumulative impact have important implications for distributional patterns at local scales, the index developed in this paper is not conducive to this application. Rather the index characterizes inequities in cumulative impacts of environmental hazards at the regional level and allows for comparisons across large geographic scales. The index can be applied at the regional scale (or counties, metropolitan areas or other large jurisdictional areas) that is of regulatory concern for social inequities in cumulative environmental hazard burdens. Such an application could then identify regions for more detailed analysis of localized patterns and drivers of those inequities. Other indices, such as Theil's Entropy Index (*33*), could be used to further decompose regional inequality into more localized scales. This latter analysis requires a different methodological approach, which is beyond the purview of this paper, but will be the subject of our future research.

An assumption implied by the multiplicative and additive approaches is that environmental variables are preferentially independent. Due to the potential correlation or chemical reaction between individual environmental factors, the potential for double-counting or mixture/interaction of cumulative hazards should be considered. For example, air toxics from diesel PM are likely to be correlated with the traffic marker NO_2, and precursors to nitrogen oxides may contribute to formation of secondary $PM_{2.5}$. If the mixture involves interactions of chemical and physical agents, the primary and secondary hazards should be investigated at the same time. At present, there is no widely accepted method of aggregating environmental hazards with potentially overlapping components. The index could help analysts to confront these issues more transparently.

The inequality index is sensitive to change in several factors. The index depends on the distribution of the individual or cumulative environmental hazard, the distribution of the socioeconomic or racial–ethnic metric used to describe the population, and their joint covariation (for cumulative indices). The index is also sensitive to the level of aggregation used to describe the population and the number of population-based units, in this case census tracts, especially if there are not a large number of aggregation units. In constructing the cumulative impact index using the additive approach, environmental hazards were standardized to allow comparison without scale effect. However, the normalization loses the magnitude of exceedances, which is a potential indicator of impact. A remedy to this is to have a weighting scheme applied for the environmental hazards after adjustment made by the benchmark standard; no further normalization is then needed. To simplify our analysis, we assumed that each environmental hazard had an equal contribution to the cumulative impact, so a mean value of 1 was used to normalize each environmental hazard for the additive approach. For policy making, the weighting scheme might need to be modified by expert opinions or through a deliberative process (*1*).

For the cumulative impact through the multiplicative approach, even though no normalization is required to the environmental hazards after adjusted by the benchmark standard, special attention should be paid to areas of very low levels of environmental hazards or of an environmental hazard not present while other environmental hazard levels are high. The multiplicative approach may inadvertently indicate the cumulative impact in this area is lower, which in fact may not be the case.

Overall, our index allows for analysis of cumulative environmental inequality from multiple hazard exposures, which provides a regional screening assessment that incorporates cumulative impact and social data into one indicator. This type of indicator can be useful for informing regulatory decision-making that seeks to assess geographic and demographic patterns of social inequities in exposures to multiple hazards.

Our research supports previous work in Los Angeles that points to patterns indicating that communities with high proportions of low income residents and populations of color bear significantly greater cumulative environmental burdens than predominantly white and more affluent communities (*14*). The utility of the CEHII highlights those vulnerable communities as a policy concern. Specifically the index can identify opportunities for addressing cumulative exposures in environmental regulation by, for example, integrated source reduction, forms of "cleaner" production, and even placement of more positive amenities such as playgrounds, parks, and green spaces within highly impacted neighborhoods. Future refinements and innovative applications of the index could also supply information critical to interpreting health effects findings from environmental epidemiologic investigations, including the identification of confounding effects ignored by single measures of air pollution. Although scientific evidence on the functional form of cumulative effects remains formative, the framework allows for investigations of scenarios that can be used to demonstrate the impacts of alternate assumptions about whether effects are additive, multiplicative, or both. These contributions may lead to policies that directly target communities of concern and lead to improvements in public health.

Acknowledgments

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Supporting Information Available

Details on modeling pollutant concentrations of NO_2, $PM_{2.5}$ and diesel PM cancer risk can be found from SI no. 1 and the significance test for the cumulative environmental inequality index from SI no. 2. This material is available free of charge via the Internet at http://pubs.acs.org.

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ES901041P

City of Long Beach
Working Together to Serve

Memorandum

Date: January 9, 2012

To: Patrick H. West, City Manager

From: Amy J. Bodek, Director of Development Services

For: Honorable Mayor and Members of the City Council

Subject: **Draft Comment Letter Re: Southern California International Gateway Facility**

On December 6, 2011, the City Council directed staff to prepare a communication from the City Manager to the Los Angeles Harbor Department on the proposed Southern California International Gateway facility (SCIG) by January 17, 2012, in order to provide comments prior to the close of the public comment period for the Draft EIR on February 1, 2012. In addition, the City Council directed staff to obtain more information from the Port of Los Angeles on the following topical issues related to the SCIG project:

- Further explanation of the EIR conclusion that zero emissions technologies are not yet feasible.
- Further analysis of other potential on dock locations, as well as finding of alternative locations, that are not near residential areas or in proximity to schools.
- Further information about any job losses from relocated tenants or property owners.
- Provide further explanation and data on light and noise impact analysis.
- Explanation of the assumptions and selection of the DEIR baseline.

Staff has prepared the following technical comment letter to the Los Angeles Harbor Department. The letter addresses the City Council's issues and other technical concerns regarding the preparation of the Draft EIR. It is the intention of staff for the letter to be submitted by the close of the public comment period on February 1, 2012.

If you have any concerns, comments or suggestions regarding this draft comment letter, please provide them to Amy Bodek, Director of Development Services, as soon as possible, but no later than January 23 so that staff may finalize the letter. For more information, contact Amy Bodek at extension 86428. Thank you.

AJB
P:\ExOfc\TFF\1.6.12 SCIG Draft letter.doc

Attachment

CC: Suzanne Frick, Assistant City Manager
Reginald I. Harrison, Deputy City Manager
Robert ZurSchmiede, Deputy Director of Development
Derek Burnham, Planning Administrator

CITY OF LONG BEACH

Office of the City Manager

333 West Ocean Blvd., 13th Floor, Long Beach, CA 90802 Phone: 562.570.6711 Fax: 562.570.6583

January 18, 2012

Christopher Cannon
Director of Environmental Management
Port of Los Angeles
425 S. Palos Verdes Street
San Pedro, CA 90731

RE: Comments on Southern California International Gateway (SCIG) Draft Environmental Impact Report (Draft EIR)

In reviewing the key environmental challenges facing the City of Long Beach in the new millennium, the growth and expansion of port operations at the Ports of Long Beach and Los Angeles (Ports) are at the top of the list for City planners and policy makers alike. Associated with the growth of these Ports are the expansion of the I-710 Long Beach Freeway, changes to the I-49 Terminal Island Freeway, replacement of the Gerald Desmond Bridge, a proposal to expand the Intermodal Container Transfer Facility (ICTF) directly north of the SCIG project, improvements to Pier S and Pier B, and the proposed new near-dock intermodal rail facility - the SCIG Project.

Balancing the needs of the Ports as they continue to grow, with those of the neighboring communities, is imperative. We believe that working together will yield the best outcomes for all concerned parties.

Overall, City staff are quite disappointed with the underwhelming analytical efforts and false conclusions presented in the SCIG Draft EIR and we believe that the document falls short of meeting California Environmental Quality Act (CEQA) requirements for revealing and evaluating the probable environmental impacts of this new, extremely large, intermodal rail facility, which would be sited adjacent to many sensitive receptors and thousands of residents living nearby. Further, we contend that as this evaluation is flawed and the environmental impacts of this facility on its neighbors are greatly underestimated, the mitigations proposed are found to be inadequate as well. Additionally, we note that the Draft EIR lacks explanation and supporting data for many of the calculations found throughout the document, notably in chapters 3.2 on Air Quality and in 3.9 on Noise, thus making it hard to decipher whether or not the analysis was performed correctly and actually led to the proper conclusions.

Herein, we will address City staff's concerns with the Proposed SCIG Project as presented in the Draft EIR.

Reconfigured Project Boundaries

Since the Notice of Preparation (NOP) in 2005, the project area boundaries have changed. Figures 2-1, 2-2, 2-3a and 2-3b show that now the "project site" only consists of the SCIG rail yard and the north and south rail lead tracks servicing the site. The majority of the Long Beach portion, including the Southern California Edison property, is now outside of the project area boundaries on "relocation sites." In addition, the Union Pacific (UP) rail tracks located east of the SCE property/west of the Terminal Island Freeway are also now excluded from the project area - even though the Proposed Project's north and south lead tracks feed directly into this UP line (Figure 2-3a). Furthermore, as the north and south lead tracks serve the purpose of breaking down trains and their active lengths are probably close to 4,000 feet (as opposed to the 1,000 feet cited in the Draft EIR), the active length of the north lead track extends past multiple Long Beach schools and residential receptors; the Draft EIR needs to consider this in the impact analysis. The Draft EIR needs to establish a maximum active length for the trains to ensure active lengths are fully contained within the "project site."

Bad Baseline
City staff see three major issues with the Draft EIR air quality analysis baseline: (1) use of a 2005 baseline rather than 2011 or a more recent year; (2) provision of other "credits" for current emissions and future regulations and agreements; and (3) the diversion of trips from the Hobart Yard conclusions.

While it is true that the Notice of Preparation (NOP) of an environmental impact document on the SCIG Project was completed in 2005, CEQA Guidelines (Sec. 15125-a) require an EIR to include a description of the physical environmental conditions in the vicinity of the project as they exist at the time the environmental analysis is commenced, from both a local and regional perspective. A six-year delay between issuance of the NOP and release of the Draft EIR is highly unusual. Given this lengthy delay, it is strongly urged that the Draft EIR revisit and update the baseline data to better reflect conditions on the ground at the time of the Draft EIR release. This is particularly true since, as the Draft EIR acknowledges, cargo demand at the Port of Los Angeles (POLA) and economic activity generally in the region, actually declined between 2005 and 2011. This means that the emission levels in 2011 are likely lower than they were in 2005; thus, the reductions in emissions reported in Section 3.2 on Air Quality are overstated. In fact, using a revised baseline in combination with the other re-calculations discussed below could result in increased emissions rather than the reported reductions.

Erroneous Emissions Analysis
In addition to using the 2005 baseline, it appears that the Draft EIR air quality analysis bases current (baseline) emissions on current (presumably 2005) emission rates and bases future emissions from the same facilities on lower rates anticipated in future years as emission rates for individual vehicles decline. This approach suggests that existing facilities will only be subject to future regulations that will reduce emissions if they relocate. Obviously, this is not the case, so the approach used erroneously implies that emissions associated with relocated facilities will actually decline if the project is implemented as compared to what would occur at the same facilities if the project were not implemented. In reality, emissions associated with existing facilities will decline in future years (and by roughly the same amount) regardless of whether or not the project is implemented and the facilities are relocated. Thus, the analysis contained in Impact AQ-3 overestimates the reduction in emissions that would result from the project. The use of a more appropriate approach which recognizes that emissions from existing facilities as a constant for the "no project" and "with project" scenarios could actually

result in an increase in emissions.

The other related problem is that the POLA has allowed the project to take "credit" for regulations and agreements (described in Table 3.2-7) that will be enforced regardless of whether or not the project is implemented. Thus, Section 3.2 of the Draft EIR shows reductions in emissions and associated health risks and attributes these to the project rather than properly attributing such reductions to pending regulations and agreements.

It is reasonable for the Draft EIR to discuss pending regulations and agreements, and their potential effect on emissions associated with project activities. However, the approach used under Impact AQ-3 improperly attributes the positive effects of these regulations/agreements to the proposed new rail yard. A more appropriate approach would be to consider emissions associated with each of the following scenarios:

- Existing conditions
- Existing conditions + the proposed project (and without pending regulations and agreements – presumably, this would show an increase in emissions)
- Future conditions (including changes in Port activity and pending regulations and agreements)
- Future conditions + the proposed project (including pending regulations and agreements + any changes in activity due to the project itself)

The analysis could then compare "existing + project" emissions to "existing" emissions and compare "future + project" emissions to "future without project" emissions. This would allow a realistic analysis of the project's actual impact rather than falsely attributing forecast emission reductions due to regulations, agreements, and technology improvements to the proposed project.

Diversion of Trips from Hobart Yard

Generally, it seems reasonable to discount emissions associated with existing vehicle trips if the project truly would eliminate such trips. However, the Draft EIR states the following regarding diversion of truck trips from the Hobart Yard:

- Truck trips to and from the Hobart Yard total approximately 814,000 annual round trips in the Draft EIR baseline scenario. (Page 3.2-12)
- Implementation of the proposed project would eliminate 95 percent of existing and future intermodal truck trips between the ports and the BNSF's Hobart Yard. (Page 2-11)
- The project would reduce over 1.3 million annual truck trips between the project site and the BNSF Hobart Yard. (Page 3.10-26)

The Draft EIR also specifically acknowledges that one of the project's purposes is to relieve projected future cargo capacity constraints and that, absent the proposed project, cargo demand will exceed capacity sometime between about 2023 and 2035. (Pages 1-19 and 1-20)

The above statements raise several questions:

- If the project would eliminate 95 percent of truck trips to the Hobart Yard and there are currently 814,000 trips to the Hobart Yard, how can 1.3 million trips be eliminated?
- If 95 percent of the truck traffic to Hobart Yard truly were diverted to the project site, what would happen at Hobart Yard? Would that facility not be used for some other purpose? If so, what impacts might the new use(s) have?
- Is it really reasonable to assume that, as the Draft EIR states, cargo demand will be met at other facilities if the project is not approved? If this truly is the case, then the real impact of the project is represented by the difference in impact between the "future without project" and "future with project" conditions (as discussed above).
- If the Port will meet future cargo demand at other facilities if the project is not approved, where are the other facilities and how do the vehicle miles traveled (VMT) and emissions associated with use of these facilities compare to the VMT/emissions associated with use of the project site?

Understated Cumulative Impacts

The analysis presented in Chapter 4 of the Draft EIR does not provide an accurate picture of what the true cumulative impacts of rail operations will be. For example, the discussion of off-site rail operations on page 4 -153 suggests that only noise from SCIG and ICTF rail operations are considered. All rail operations, including existing and other planned future train operations need to be considered in this analysis, especially as many of these rails (and roads) leading to the Proposed SCIG Project site are located within the City of Long Beach.

Another issue with the cumulative impact analysis is the same one that comes up in the project air quality analysis - the baseline. The conclusion that the project would reduce emissions (based on the comparison to the 2005 baseline) leads the authors to similar conclusions with respect to cumulative impacts. Specifically, we believe the following conclusions are inaccurate:

- Item 4.2.2.4 (Page 4-26): The conclusion that the project would not make a cumulatively considerable contribution to significant cumulative emissions is based on the erroneous conclusion that the project would reduce emissions. If calculated appropriately (as discussed earlier), project emissions may be significant and may, therefore, represent a cumulatively considerable contribution to a significant cumulative impact.
- Item 4.2.2.8 (Pages 4-28 and 4-29): Based on the potentially erroneous conclusion that the project would reduce emissions of toxic air contaminants (TACs), the Draft EIR concludes that the project would reduce cancer risks and would not make a considerable contribution to a significant cumulative impact related to TACs. If calculated appropriately (as discussed earlier), project emissions of TACs and associated health risks may exceed established significance thresholds and may therefore represent a cumulatively considerable contribution to a significant health risk impact.

Faulty Health Risk Analysis and Ultra Fine Particulates
As with the analysis of regional air quality impacts, the project appears to be given credit for emission reductions resulting from regulations and agreements that will be enforced regardless of whether or not the project is implemented. Consequently, the Draft EIR reaches the probably erroneous conclusion that implementation of the project would actually reduce emissions of TACs and associated health risks.

In addition, the Draft EIR (Impact AQ-4, page 3.2-73) acknowledges that project operations would exceed the SCAQMD thresholds for one hour and three annual NO2, 24-hour and annual PM10, and 24-hour PM2.5. It would also exceed the four NAAQS for one hour NO2. As these thresholds/standards are intended to be protective of public health, some explanation of why exceedances of these thresholds and standards are not linked to localized health effects is necessary.

To allow the reader to understand the actual impact of the project, the analysis should: (1) compare existing (baseline) conditions to conditions with the project, but without future emission reductions; and (2) compare future conditions with anticipated emission reduction programs to those same future conditions with the project. As performed, the analysis overstates the "benefits" of the project with respect to actual health risks. Although the health risks associated with ultra fine particulates have been a topic of concern for the last several years, they have yet to be regulated at the federal, state, regional or local level. Yet, since evidence is emerging of just how damaging these particulates are to our bodies over time, steps should be taken now to minimize ultrafine particle emissions. For example, the SCAQMD's Draft 2007 AQMP includes some approaches for projects to consider in minimizing ultrafine particle emissions.

- Encourage use of after-treatment technologies combined with oxidation catalyst technology to produce concurrent benefit of ultrafine particle reduction.
- Encourage equipment and vehicle manufacturers to develop diesel particulate filters (DPF) with integrated controls for ultra fines since the additional cost may be relatively minor.
- Work with CARB, US EPA, and other stakeholders in conducting research studies and control strategy development efforts.
- When developing control measures for the reduction of PM10 and PM2.5, consideration should be given for reducing any undesired effects on ultrafine number emissions, where feasible.

We strongly recommend that the POLA adopt these as project mitigation measures.

Inadequate Project Alternatives Analysis
The Draft EIR acknowledges that even if the project is not approved, it is anticipated that cargo demand will be met through the use of existing facilities. This calls into question whether the project is actually needed at all; and suggests that a smaller facility, in conjunction with operational changes at existing facilities, could meet the Port's needs.

Of course, Chapter 5 of the Draft EIR analyzes a reduced project that involves restrictions on the number of operations at the new facility rather than a reduction in the physical size of the facility. Providing a full-sized facility so near to so many sensitive receptors and thousands of residents, with the potential for expansion of operations, makes expansion of the operation at a later date much easier to accomplish. In addition, given that several of the unavoidably significant impacts of the project relate to the construction activity, we find it a major oversight that the Draft EIR does not consider an alternative that would reduce overall construction activity and duration. This needs to be examined.

Staff also has the following comments on the alternatives analysis, focusing primarily on the air quality and greenhouse gas issues:

- No Comparative Analysis – Across the board, the alternatives analysis fails to identify whether the alternatives' impacts are greater than or less than those of the proposed project. Per CEQA Guidelines Section 15126.6, this comparison is a fundamental purpose of the alternatives analysis. Although the matrix at the end of Chapter 5 provides something of a comparative analysis, each discussion should provided a comparison of the impacts of the alternative and the proposed project.
- Alternative 1 Impact AQ-3 - We disagree with the conclusion that the "no project" alternative would have a "significant" impact to regional air quality. By definition, the no project alternative does not involve new development. As such, although it may be true that not building a new near dock facility would result in increased use of more distant facilities (such as the Hobart Yard), increased use of existing facilities would not be a "project" under CEQA insofar as it would not involve discretionary approvals from a government agency. Consequently, the contention that the no project alternative would have a "significant" air quality impact under CEQA is not accurate. Assuming that implementation of the proposed project truly would result in reduced vehicle miles traveled and air pollutant emissions, it would be accurate to state that the no project alternative would not have the proposed project's benefits and may indirectly contribute to long-term increases in air pollutant emissions as cargo demand increases.
- Alternative 1 Impact GHG-1 - We disagree with the conclusion for the no project alternative with respect to greenhouses gases (GHGs) for the reasons described above. Since the no project alternative is not really a "project" under CEQA, it cannot have "significant" impacts. Again, assuming that project implementation really would reduce GHG emissions, it would be more accurate to state that the no project alternative would not have the proposed project's benefits.
- Alternative 2 Impact AQ-3 – The "Impact Determination" on page 5-39 simply states that there are no operational impacts for the alternative. Though not explicitly stated, we presume that this determination is based on the conclusion that the alternative would reduce emissions as compared to the baseline scenario. As noted above, we adamantly disagree with the way the baseline was used in the analysis.

Inadequate Project Mitigations and Lease Conditions
As noted in the Draft EIR (page 3.2-73), the proposed lease measures are merely recommendations and are not required. However, the impact that these measures are intended to address (Impact AQ-4) has been identified as unavoidably significant.

Consequently, the POLA is obligated to adopt feasible mitigation measures. Because the Draft EIR includes no suggestion that the lease measures are infeasible, they should be included as CEQA mitigation measures. Moreover, mitigation measures 1, 3, and 4 on pages 3.2-79 and -80 are not actually infeasible based on the discussion. For example, Measure 4 (Zero Emissions and Hybrid Trucks) has been dismissed as infeasible merely because its benefits cannot be accurately modeled. The inability to accurately quantify the measure's benefits does not make the measure infeasible. Measures 1 and 3 are dismissed as infeasible because they may have constraints. Absent a definitive conclusion that these measures are infeasible, both measures should be considered feasible and included as mitigation for an unavoidably significant impact.

Construction Hours & Duration – Insufficient Noise Conclusions

The mitigation measures for construction noise are generally reasonable; however, we have the following comments:

- The construction hours prescribed in MM NOI-2 (7 AM to 9 PM on weekdays and 8 AM to 6 PM on Saturdays) are not consistent with the limitations prescribed in the City's Noise Ordinance, which limits noise-generating construction activity to the hours of 7 AM to 7 PM on weekdays and 9 AM to 7 PM on Saturdays. Given that the proposed hours allow weekday evening (7-9 PM) and early Saturday morning (8-9 AM) construction outside the City Ordinance's prescribed hours, the hours should either be changed or construction noise should be identified as an unavoidably significant impact unless it can be demonstrated that noise increases would be less than 3 dBA during these hours.
- MM NOI-2 excludes the PCH grade separation from the recommended construction timing restrictions. We understand that this is necessary to minimize traffic impacts, but unless it can be demonstrated that noise associated with construction of this project component can be reduced to below the threshold (3 dBA increase at a sensitive receptor), this should also be identified as an unavoidably significant impact.

Flawed Truck Routes Analysis

Figure 2-4 SCIG Designated Truck Routes is so vague that it can be considered deceptive. For example, northbound Terminal Island Freeway truck traffic will transition along the northeast corner off-rap to westbound Pacific Coast Highway (PCH) within a half block of the Century Villages at Cabrillo (CVC) homeless, transitional and supportive services campus of 1,000 residents. Since the NOP release on the SCIG project in 2005, the CVC has increased its resident population by 41 percent; this is not accounted for in the Draft EIR. As proposed, truck traffic from the Ports to the SCIG will exit the freeway on the PCH cloverleaf that empties next to San Gabriel Avenue, the only ingress and egress to this campus. With so many trucks, it is very likely that this will become a major congestion point with trucks queuing up to go west - in effect blocking access to San Gabriel Avenue. However, this intersection was not even evaluated in the Draft EIR. With future truck traffic to the SCIG site anticipated to exceed 5,500 trips per day, Long Beach is very concerned about CVC residents and their roads to recovery, health and wellness. This Draft EIR oversight is significant and egregious. It must be corrected.

Flawed Traffic Noise Methodology

While in general the approach to noise analysis within the Technical Appendix is reasonable, a review of the report indicates that the traffic analysis was performed using the FHWA Highway Traffic Noise Prediction Model (FHWA-RD-77-108), or "108 model" (see Section 10 of Appendix F-1). This noise model is no longer recommended for use by either FHWA or Caltrans. As stated on the FHWA webpage (http://www.fhwa.dot.gov/environment/noise/traffic_noise_model/):

> "Although an effective model for its time, the "108 model" was comprised of acoustic algorithms, computer architecture, and source code that dated to the 1970s. Since that time, significant advancements have been made in the methodology and technology for noise prediction, barrier analysis and design, and computer software design and coding. Given the fact that over $500 million were spent on barrier design and construction between 1970 and 1990, the FHWA identified the need to design, develop, test, and document a state-of-the-art highway traffic noise prediction model that utilized these advancements. This need for a new traffic noise prediction model resulted in the FHWA TNM."

The updated methodology is the Traffic Noise Model (FHWA TNM®), first released in 1998, with the latest version (2.5) released in April 2004. Caltrans has required the use of TNM ver. 2.5 since the publication of the revised *Traffic Noise Analysis Protocol* in August 2006, and such requirement is also contained in the May 2011 update of this protocol. Use of the "108 model" has potentially resulted in inaccurate estimates of noise levels based on traffic volumes, and inaccurate barrier effect analyses. The TNM is referenced in Appendix F-1, but no rationale as to why the older "108 model" was used, or whether the analysis used the updated source algorithms contained in the TNM or not. The traffic noise predictions have also been based on peak hour conditions which are then used to predict Leq and CNEL. For most cases, this peak hour assumption has resulted in relatively low vehicle speeds, and consequentially, lower predicted noise levels. Further, it is unknown what relationship was used between the estimated peak hour Leq and the CNEL. As illustrated by the various 24-hour noise monitoring data, the difference in peak hour noise levels and nighttime noise levels was less than would typically be the case for most standard "108 model" applications. These relatively higher nighttime noise levels are indicative of an overall higher CNEL than would be typically predicted by the "108 model."

Appendix F-1 lacks any information regarding the methodology or data behind the rail operations, with Section 11 simply stating "Operational and rail noise modeling input and output files are maintained at AGI offices." This is not adequate access of information under CEQA. At the very least, such information should have been available for review at the lead agency's offices.

The lack of a pre-project and post-project noise contour map for the site makes it difficult to envision the extent of noise impact into the City of Long Beach residential neighborhoods. We highly recommend that contour maps be produced, such as those created for the POLA/POLB by I-H. Khoo and T-H. Nguyen (*Study of the Noise Pollution at Container Terminals and the Surroundings, Final Report - Metrans Project 09-09;* July 2011; California State University, Long Beach).

Inadequate Sound Mitigation

In addition to the construction mitigation concerns above, we have the following comments on the proposed operational mitigation measures:

- MM NOI-1 – The 12-foot sound wall proposed is inadequate. There is no evidence it would reduce both construction and operational noise. Given that the rail yard to the north is using a 24-foot-tall barrier, it appears that this barrier is grossly undersized.

In addition to walls, appropriate vegetative buffers should be a required mitigation for any project such as this, located so close to residential neighborhoods. Although Mitigation for Greenhouse Gases mentions including tree plantings to reduce such emissions, an appropriately designed green landscaped berm should also be included as a project mitigation to combat noise and light pollution as well. All parking areas should have appropriate tree species planted, i.e., low Biogenic Emissions, species that help remove pollutants from the air, and have the ability to sequester greenhouse gases; and the area along the eastern edge of the Proposed Project should be bermed and heavily landscaped with trees and understory plants as well. (The CVC has a good example of how this can be achieved.)

The measures proposed do not support the conclusion that construction noise would be reduced to below a level of significance. Table 3.9-27 shows post-mitigation construction noise levels. Comparison of predicted daytime construction noise with sound walls to measured ambient noise reveals the following differences:

Receptor No.	Receptor Location	Measured Ambient Noise Level (dBA)	Predicted Daytime Construction Noise Level with Proposed Sound Walls	Difference Between Predicted Construction Noise and Ambient *
R1	Residence at 2789 Webster – rear yard	49.4 - 55.3	62.2	12.8
R2	Buddhist Temple at Willow and Webster	59.9 – 60.3	65.8	5.9
R3	Hudson Elementary School Playground	54.2 – 57.8	65.5 – 66.2	12.0
R4	Hudson Park	64.1 – 65.3	70.3	6.2
R5	Cabrillo High School building setback	51.0 – 52.0	57.8	6.8
R6	Cabrillo Child Development Center	63.3 – 64.6	68.1	4.8
R7	Bethune School	63.3 – 64.6	65.0	1.7
R8	Villages of Cabrillo	61.0 – 62.5	64.4	3.4
R30	Stephens Middle School Playground	47.2 – 64.0	57.5	10.3
R31	Webster School	49.2 – 55.7	47.0	(2.2)

* Difference between the higher end of predicted and the lower end of the measured daytime ambient range.

As indicated, all of the receptors except R7 and R31 would experience daytime noise level increases of more than 3 dBA during construction. Thus, even with mitigation, construction noise increases would exceed significance threshold NOI-6 on page 3.9-35, which states that noise impacts would be significant if the project would increase ambient noise by 3 dBA or more. Consequently, daytime construction noise impacts should be classified as unavoidably significant. In addition, assuming that nighttime construction at the proposed PCH overpass would be similar to daytime construction noise levels (up to 62.5 dBA), nighttime noise at the Century Villages at Cabrillo (Receptor R8) would be far more than 3 dBA higher than the measured nighttime ambient level of 48 dBA at that location. Thus, nighttime construction noise impacts should also be classified as unavoidably significant.

Other Noise Analysis Issues
Staff have also identified these additional issues relative to the noise analysis:

- The data provided in tables 3.9-19 and 3.9-20 (pages 3.9-42 through 3.9-47) are inconsistent. For example, Table 3.9-19 shows the existing CNEL at Terminal Island Freeway northbound off-ramp and loop on-ramp at PCH as 81 dBA, while Table 3.9-20 shows the existing CNEL at that same location as 71.5 dBA. The reported existing CNELs at many of the study road segments are similarly inconsistent.
- Tables 3.9-19 and 3.9-20 also show inconsistent results. For example, Table 3.9-19 shows many segments of the Terminal Island Freeway as experiencing a reduction in noise with the project since truck activity would be transferred to rail. Table 3.9-10, on the other hand, shows a substantial increase in noise on many of the same segments, with future (2023) project-related noise increases of as much as 23.8 dBA. Why would the project reduce truck traffic and related noise under one scenario and then show a significant increase in another?
- A recording studio is located at 2200 West Esther Street, Long Beach (Mambo Sound & Recording). Recording studios are both noise and vibration sensitive uses and potential impacts to this facility need to be addressed.

Other Project Impacts

<u>Local Job and Business Losses</u>
Apparently, when the POLA redrew the project boundaries to exclude the SCE property in Long Beach from the project site and termed it "Relocation Sites" adjacent to the rail yard, they felt it was appropriate to abandon the existing businesses on the SCIG site. Over 1,200 good local jobs, employing many Long Beach residents, are being sacrificed and replaced by only 400-some new SCIG jobs. Although building the project would provide construction jobs for a while, upward of 800 permanent jobs will be lost; and the tradeoff for Long Beach residents will be worse air quality, more noise, and nighttime sleep disruption. The Draft EIR acknowledges that businesses will be displaced and relocation sites were not identified for all of them. For those businesses where relocation sites are discussed, most are too small to accommodate the business operations needed, and as a consequence, if this project is approved in this location, they most likely will be forced to close their doors. The City of Long Beach is very displeased with the irresponsible and cavalier approach being promulgated by this project and the City of Los Angeles. Losing jobs in these difficult economic times can

force families out of their homes and cause a great deal of distress to neighborhoods. The City of Long Beach is anxious to work with the City of Los Angeles to ensure that these businesses can continue providing the good jobs they offer to local residents.

The City of Long Beach appreciates the opportunity to comment on the Draft EIR for the Proposed SCIG Project. All questions regarding this comment letter should be made to Amy Bodek, Director of Development Services, at (562) 570-6428, or to Derek Burnham, Planning Administrator, at (562) 570-6261.

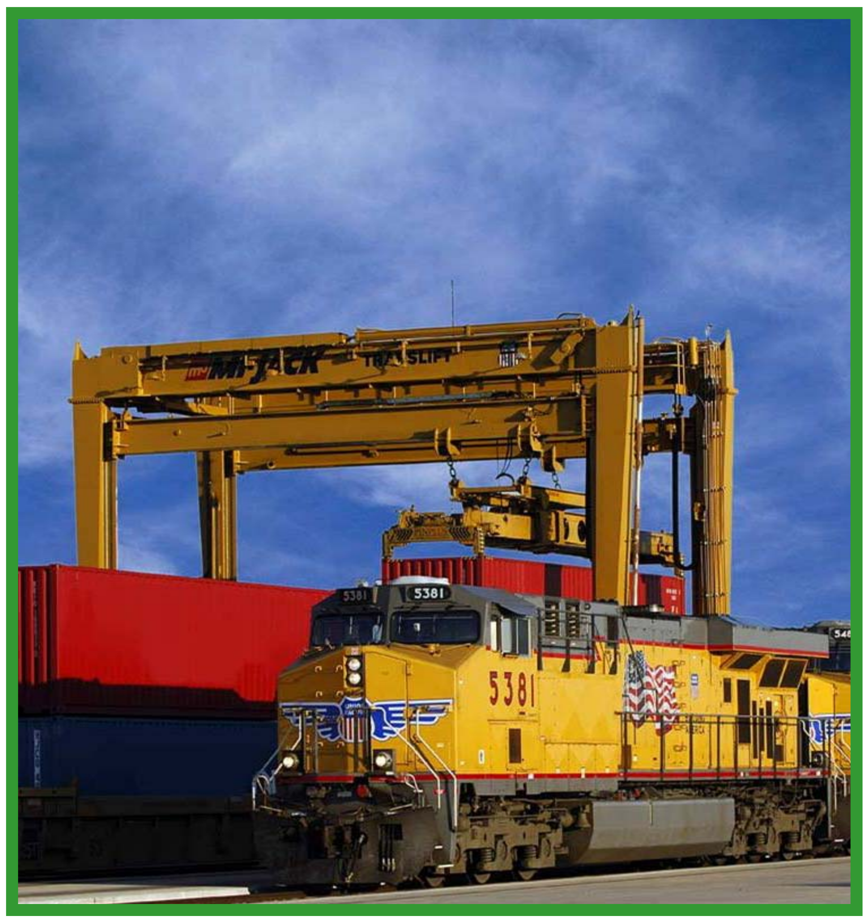
Sincerely,

Patrick H. West
City Manager

PW:AJB:DB:PG

Notice of Preparation and Initial Study

Intermodel Container Transfer Facility Modernization and Expansion Project



ICTF Joint Powers Authority
925 Harbor Plaza
Long Beach, CA 90802

January 2009

INTERMODAL CONTAINER TRANSFER FACILITY JOINT POWERS AUTHORITY

925 Harbor Plaza
Long Beach, CA 90802

CALIFORNIA ENVIRONMENTAL QUALITY ACT NOTICE OF PREPARATION

TO: RESPONSIBLE OR TRUSTEE AGENCY

ADDRESS (Street, City, Zip)

FROM : LEAD CITY AGENCY

Intermodal Container Transfer Facility Joint Powers Authority

ADDRESS (Street, City, Zip)

925 Harbor Plaza
Long Beach, CA 90802

► **SUBJECT:** Notice of Preparation (NOP) of a Draft Environmental Impact Report

PROJECT TITLE:

Intermodal Container Transfer Facility (ICTF)Modernization and Expansion Project

CASE

ADP#

PROJECT APPLICANT:

Union Pacific Railroad Company

The INTERMODAL CONTAINER TRANSFER FACILITY JOINT POWERS AUTHORITY would be the Lead Agency and would prepare an environmental impact report for the proposed Project identified above. We need to know the view of your agency as to the scope and content of the environmental information which is germane to your agency's statutory responsibilities in connection with the proposed Project. Your agency would need to use the EIR prepared by this agency when considering your permit or other approval for the proposed Project

The proposed Project description, location and probable environmental effects are contained in the attached materials.

☒ A copy of the Initial Study **is** attached.

☐ A copy of the Initial Study **is not** attached.

Due to the time limits mandated by state law, your response must be sent at the earliest possible date but not later than 30 days after receipt of this notice. Please send your response to: **Sam Joumblat, Executive Director of the ICTF JPA,** at the address of the Lead Agency as shown above. We would need the name of a contact person in your agency.

Note: If the Responsible or trustee agency is a state agency, a copy of this form must be sent to the State Clearinghouse in the Office of Planning and Research, 1400 Tenth Street, Sacramento, California 95814. A state identification number would be issued by the Clearinghouse and should be thereafter referenced on all correspondences regarding the proposed Project, specifically on the title page of the draft and final EIR and on the Notice of Determination.

SIGNATURE	TITLE	TELEPHONE	DATE
[signature]	Executive Director	562.901.1776	January 8, 2009

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Chapter One

Notice of Preparation Project Description

1.0 Introduction

The purpose of this Notice of Preparation (NOP) and Initial Study (IS) is to inform responsible and trustee agencies, public agencies, and the public that the Intermodal Container Transfer Facility (ICTF) Joint Powers Authority (JPA) will be preparing an environmental impact report (EIR) for the ICTF Modernization Project (proposed Project). The proposed Project EIR will be prepared pursuant to the California Environmental Quality Act (CEQA), California Public Resources Code Section 21000 et seq. The JPA seeks comments from agencies and the public regarding the scope and content of this EIR. For agencies, the JPA seeks comments regarding the scope and content of environmental information that is relevant to each agency's statutory responsibilities in connection with the EIR and the various actions and activities to be evaluated in the EIR.

The ICTF JPA is a public entity created in 1983 to oversee the development of the ICTF to enhance the efficient flow of intermodal (truck and rail) cargo through the Port of Los Angeles (POLA) and the Port of Long Beach (POLB) (collectively, the "San Pedro Bay Ports" or "Ports"). The ICTF is a rail yard designed and operated by the Union Pacific Railroad Company (UP). The JPA is the local agency with jurisdiction over the ICTF and is the lead agency under CEQA for the proposed Project. The JPA is administered by a governing board and is separate and apart from the Cities of Long Beach and Los Angeles.

The San Pedro Bay Ports are the largest manmade harbor in the Western Hemisphere, serving as the largest container port in the United States and the eighth largest in the world. Essentially considered a large industrial complex, the San Pedro Bay Ports are an important hub in the international supply chain, encompassing 7,500 acres of land and water, and include: automobile, container, omni, break-bulk, and cruise ship terminals; liquid and dry bulk facilities; and extensive transportation infrastructure for moving truck and rail cargo.

The existing ICTF operational core is located within the City of Los Angeles on 148 acres of POLA property and operated by UP via a sublease from the JPA. The core parcel is supported by two adjacent parcels to the west within the City of Carson, which provide wheeled container storage and include (1) an approximately 15-acre UP-owned parcel; and (2) an approximately 74-acre Watson Land Company-owned parcel. UP leases the 74-acre Watson Land Company parcel for storage and handling of freight, cargo containers, and truck chassis in conjunction with the ICTF operations. The ICTF operates in conjunction with the UP's Dolores Rail yard located to the west of the ICTF along Alameda Street within the City of Carson.

1.1 Project Summary and Overview

The proposed Project is known as the ICTF Expansion and Modernization Project. The ICTF is a rail yard operated by the UP that currently transfers containerized cargo from the terminals of the Ports to trains for distribution throughout the United States, and transfers cargo to the Ports from locations throughout the United States for export abroad.

The proposed Project would increase the number of containers handled at the ICTF from the current annual average of 725,000 to an estimated 1.5 million annual average. In addition, the proposed Project would modernize existing equipment and rail yard operation methods by replacing the existing diesel-fueled rubber tired gantry (RTG) cranes with electric-powered wide-span gantry (WSG) cranes, which can service several loading tracks and shuttle containers between container stacks and adjacent loading tracks more efficiently than existing equipment. In order to accommodate the WSG cranes, the existing yard tracks must be reconfigured and new tracks added.

1.2 Project Background

Between 1982 and 1986, POLA, POLB, and Southern Pacific Transportation Company (acquired by UP in 1996) jointly developed and bond-financed the ICTF through a public-private partnership. As part of the partnership, POLA issued a permit to the ICTF JPA granting the JPA the right to use the premises for the ICTF. In turn, the JPA sub-leased its interest in the premises to Southern Pacific. As successor-in-interest to Southern Pacific, UP now owns and operates both the sub-lease estate and the facilities located at the ICTF, which comprises approximately 148 acres. In addition, ICTF operations are also conducted on 74 acres of adjacent property that UP leases from Watson Land Company, as well as another adjacent 15 acres that UP owns. The ICTF was specifically designed to provide near-dock infrastructure required to handle the rapidly growing international container shipping demand and to enhance the flow of container traffic through the POLA and the POLB.

1.3 Proposed Project Goals

Project goals included the following elements:

- Reduce emissions at the ICTF by replacing diesel-powered equipment with electric-powered equipment;
- Provide additional near-dock rail capacity and container throughput by increasing operation efficiencies consistent with the Ports' Rail Master Plan Study and minimize surface transportation congestion and/or delays;
- Provide enhanced cargo security through new technologies, including biometrics; and,

- Continue to promote the direct transfer of cargo from port to rail with minimal surface transportation congestion and/or delays.

Project goals will be further defined in the Draft EIR.

1.4 Project Location

The ICTF is located approximately 5 miles from the POLA and the POLB at the terminus of State Highway 103, known as the “Terminal Island Freeway” (see Figures 1 and 2). The ICTF's operational core is located on 148 acres of POLA land sub-leased by UP from the JPA within the City of Los Angeles. The ICTF covers a narrow area between East Sepulveda Boulevard and East 233rd Street, just south of the I-405 freeway. The ICTF operates in conjunction with the UP’s Dolores Rail yard, located west of the ICTF within the City of Carson. The main portion of the Dolores Rail yard covers a narrow area approximately one-half mile in length along the Alameda Corridor, connected to the ICTF with a series of parallel tracks approximately 1.4 miles long on the north end and 0.9 mile long on the south end.

The core ICTF operation is supported by two adjacent parcels to the west, both located within the City of Carson. The adjacent parcels include an approximately 15-acre parcel owned by UP, and an approximately 74-acre parcel owned by the Watson Land Company. UP leases the Watson Land Company parcel for storage and handling of freight and cargo containers and truck chassis in conjunction with ICTF operations.

Land uses surrounding the ICTF are primarily heavy industrial and designated as “Manufacturing, Heavy” by the City of Carson and “Heavy Industrial” by the City and POLA. In addition, medium-density residential areas are located to the east of the ICTF within the City of Long Beach. Surrounding land uses include the following:

- ***North:*** East 223rd Street and the I-405. Heavy industrial land uses extend beyond these roadways.
- ***Northeast:*** Medium-density, single-family residential neighborhoods exist on Hesperian Avenue and East 223rd Street in the City of Long Beach.
- ***East:*** Land owned by Southern California Edison (SCE), containing nursery plants, located to the north and south of an SCE substation, is farmed under high-voltage transmission power lines associated with the SCE substation. A nursery plant truck loading facility also exists to the south of the SCE substation. Land uses including single family dwellings, mobile homes, apartments and schools within the City of Long Beach are located east of the ICTF and SCE properties.

- ***South:*** East Sepulveda Boulevard is located directly south of the ICTF. The Terminal Island Freeway is located to the southeast of the ICTF. Industrial uses, including a storage tank facility, warehousing, container storage, and truck trailer parking and servicing are located further to the south. Medium density residential areas are located to the east of the Terminal Island Freeway within the City of Long Beach.

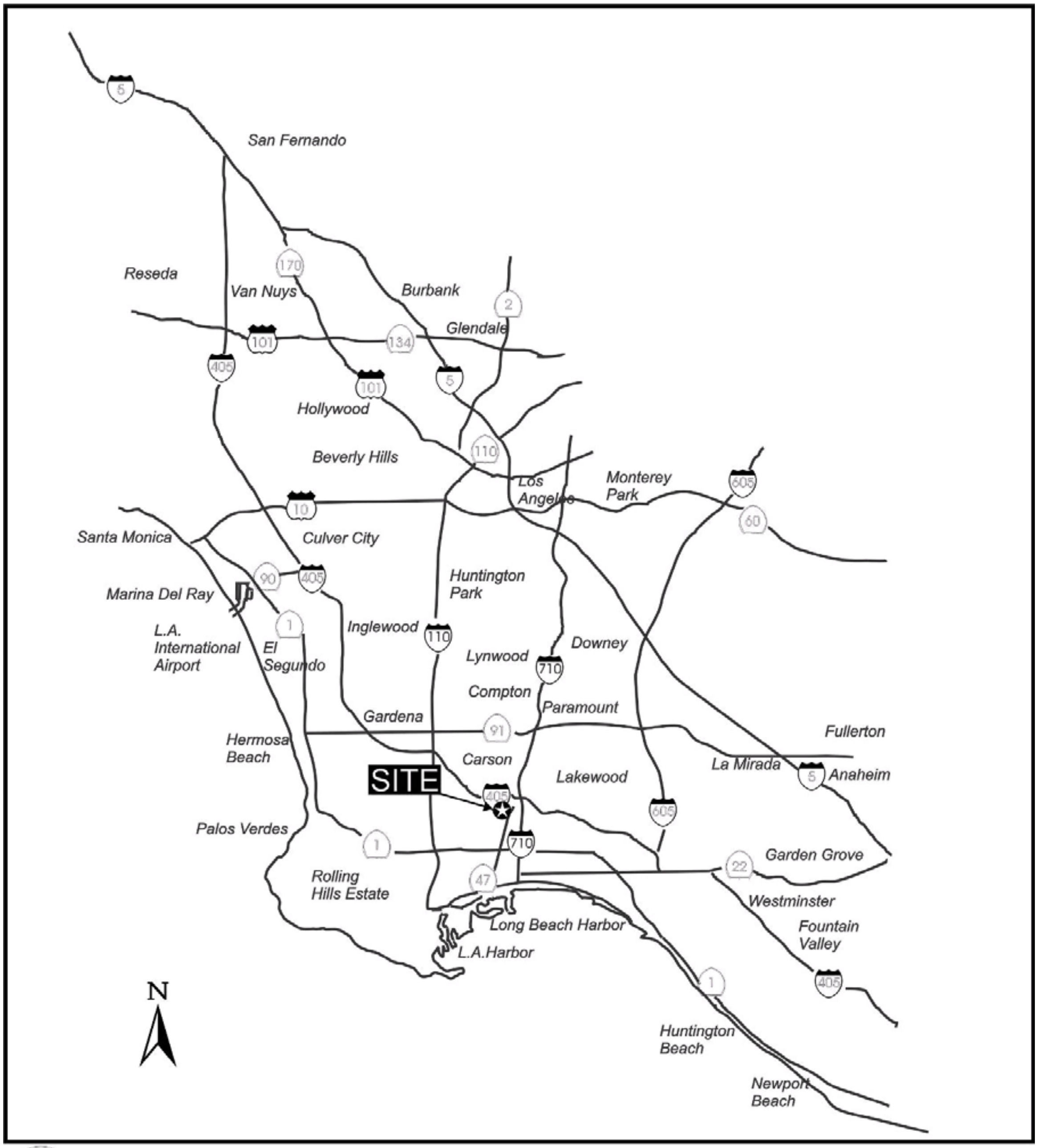
- Also to the south, BNSF Railway has submitted an application to the POLA to develop a property to the south of the ICTF for a new rail loading and unloading facility with operations similar to those at ICTF. This proposed project, referred to as the Southern California International Gateway (SCIG) is in the environmental review process.

- West: A vacant structure, formerly housing a gun club, is located on the far west side of the Watson Land Company property, adjacent to Alameda Street within the City of Carson. The Watson Land Company parcel and the Desser parcel, located immediately to its north, are largely underlain by a former organic refuse landfill. The Watson Land Company parcel is currently used for the storage and handling of cargo containers and truck chassis to support ICTF operations.

1.5 ICTF Proposed Project Details

The proposed Project would increase the capacity to handle containers at the ICTF from the current annual average of 725,000 to an estimated 1.5 million annual average by modernizing existing equipment and equipment operating methods. The truck traffic is currently estimated to be about 1.1 million one-way truck trips per year, and the proposed Project will increase the number of truck trips to about 2.268 million one-way truck trips per year. In addition, the proposed Project will increase the number of annual rail trips from 4,745 to about 9,490. The proposed Project would increase container-handling capacity by reconfiguring existing and adding new train tracks within the ICTF, and replacing the existing diesel-fueled rubber tired gantry (RTG) cranes with electric-powered wide-span gantry (WSG) cranes. These electric WSG cranes can service several loading tracks and shuttle containers between container stacks and adjacent loading tracks more efficiently than existing equipment, while reducing air emissions associated with the use of diesel fuel. A plot plan of the existing ICTF is shown in Figure 3. Figure 4 shows the proposed Project plot plan. As with the existing operation, the ICTF would continue to operate 24 hours per day, seven days per week. A summary of the existing ICTF operations and the proposed Project modifications is provided in Table 1.

Trucks transporting containers (referred to as drayage trucks) currently enter and exit the ICTF via the Sepulveda Boulevard Gate. The existing gate at the northern 223rd Street Facility boundary would continue to be used for emergency ingress and egress only. The proposed Project would alter traffic flow into the ICTF to create a one-way flow of truck traffic within the ICTF. A new gate is proposed at Alameda Street to be used by trucks for entrance (only) to the ICTF. Truck traffic exiting the ICTF would continue to use Sepulveda Boulevard, through a reconfigured gate.



Environmental Audit, Inc.

ICTF REGIONAL MAP

Project No. 2606 Figure 1

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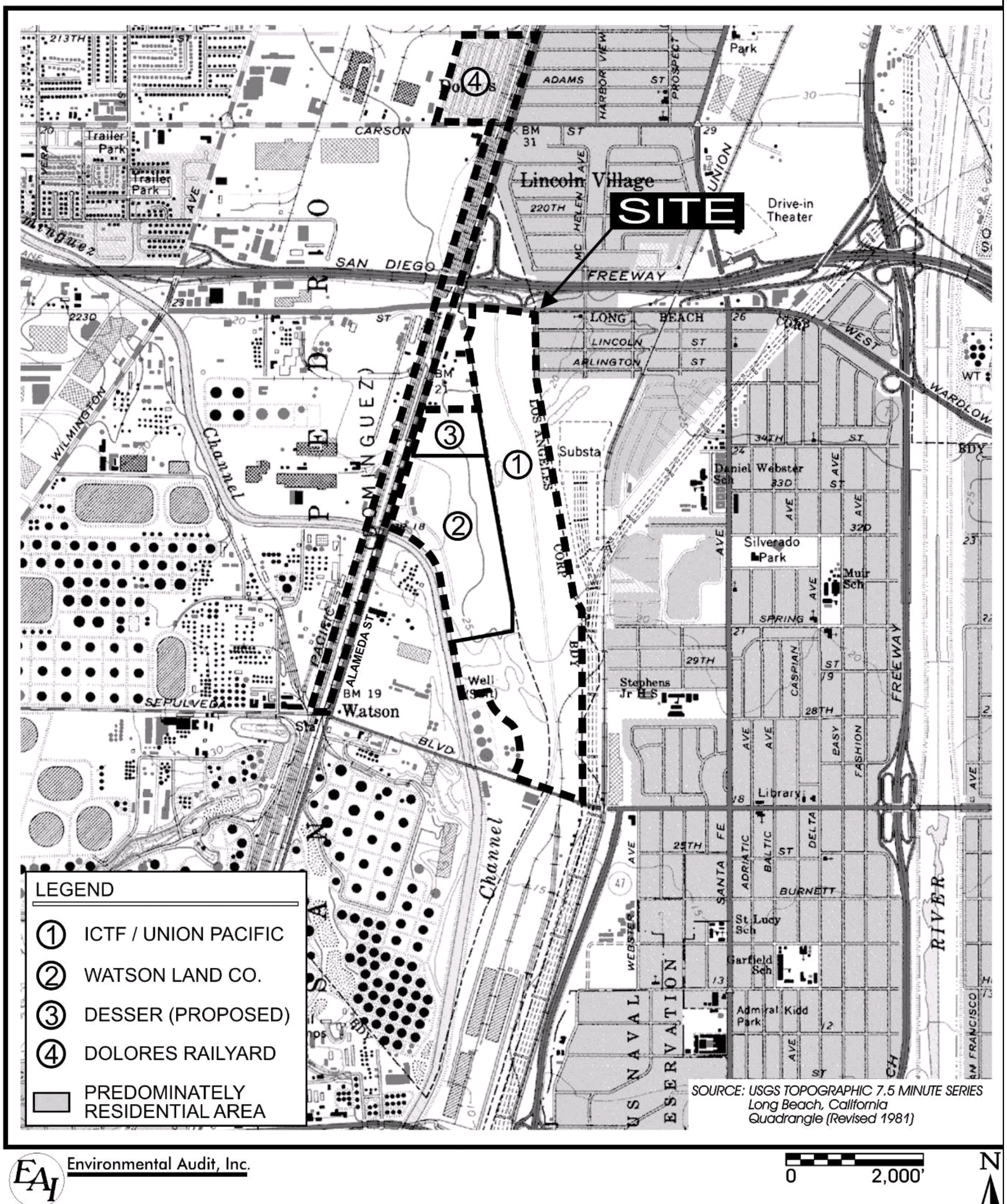

ICTF PROPOSED PROJECT LOCATION

Project No. 2606

Figure 2

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TABLE 1
ICTF Proposed Project Summary

	Existing	Proposed Project
Project Area Gross Acres	233	177 (est., however, Project will preserve access to 74 acre Watson parcel)
Structures	Control Tower Administration Building Inspection Building Customs Office Entrance Office Terminal Contractor Building North-End Gate Emergency Supply Building Emergency Storage Area Hostler Maintenance Equipment Building Crane Maintenance Pad Fueling Station	No Change No Change No Change No Change No Change No Change No Change No Change No Change Removed Removed Removed Removed Six electrical substations* Crane Parts Building and Service Center* Gate house including offices, restrooms, canopies* Alternative Fuels Station*
Railroad Tracks	6 loading, 1 support	12 loading
Yard Hostlers (diesel-fueled)	73	2 (non-diesel)
RTG Crane (diesel-fueled)	10	0
WSG Crane (electric-powered)	0	39
Sideloaders (incl. piggy-packers, top picks and Reach Stackers)	3	1
Annual One-Way Truck Trips	1,087,086	2,268,000
Annual Rail Trips	4,745	9,490
Total Number of Access Gates	1	2
Light Poles	60 100-foot poles	160 40- to 60-foot poles
Fuel Tanks	20,000 gallon diesel storage tank 1,000 gallon gasoline storage tank	1,000 gallon alternative fuel tank

* New Structures

1.5.1 Rail Yard Operations

The ICTF currently receives inbound trains from the Ports and other distribution facilities throughout the United States, loads and unloads intermodal trains, stores intermodal containers and chassis, assembles and ships outbound trains, and repairs freight cars and intermodal containers/chassis.

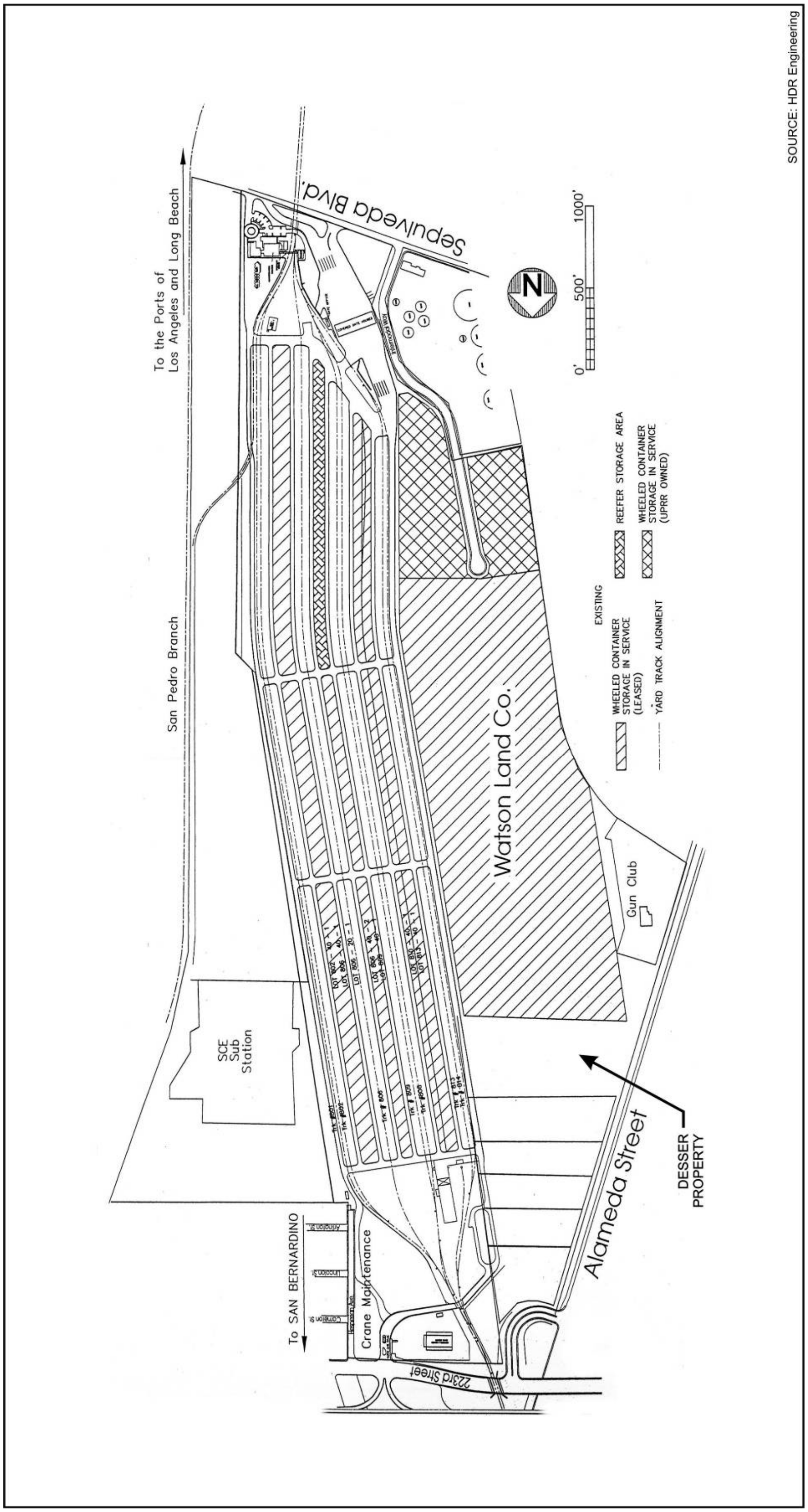
UP performs train switching operations at the adjacent Dolores Yard, which is located between Alameda Street and the Alameda Corridor. The Dolores Yard is used to park trains until they can be brought into the ICTF or until a full train is built and ready to depart. UP operates switcher locomotives within the Dolores Yard and ICTF to support these activities. The Dolores Yard is also used to store, service, inspect and fuel locomotive engines that are used at ICTF.

The ICTF is not long enough to build or store a unit train (train with a single destination), or to store arriving trains carrying containers to the Ports. Arriving trains enter the ICTF from the Dolores Yard via the 223rd Street Bridge and grade separation. Arriving trains are split and held at Dolores, and departing trains are assembled in the Dolores Yard. In addition, smaller trains coming from the on-dock Port facilities or out of the ICTF must be assembled in the Dolores Yard before departing.

The proposed Project does not include physical modifications to the Dolores Yard. However, the Dolores Yard will handle additional ICTF trains and would result in an increase in trains handled at Dolores and other local rail yards. The proposed Project is not expected to alter the movement of trains to and from the ICTF. However, the proposed Project will add six additional tracks within the ICTF and will increase the annual number of rail trips from 4,745 to about 9,490.

1.5.2 Cranes/Lift Equipment

The proposed Project currently includes adding 39 WSG electric cranes configured into three sets or modules each serving four rail loading tracks. New electric WSG crane loading tracks would be constructed in the east electric WSG crane module, leaving existing tracks 801 and 802 in place (see Figure 3). Two additional tracks would be constructed west of existing track 802 to complete the first electric WSG crane module. The second electric WSG crane module includes realignment of existing track 809 to the east; the existing track 810 would remain in place. Construction of two new tracks west of existing track 810 would complete the center electric WSG crane module. The westerly electric WSG crane module would not align with existing railroad track, but includes four new loading tracks constructed just west of the center electric WSG crane module, creating a back-to-back or mirrored electric WSG crane configuration.



EXISTING SITE PLAN
ICTF PROPOSED PROJECT

Figure 3

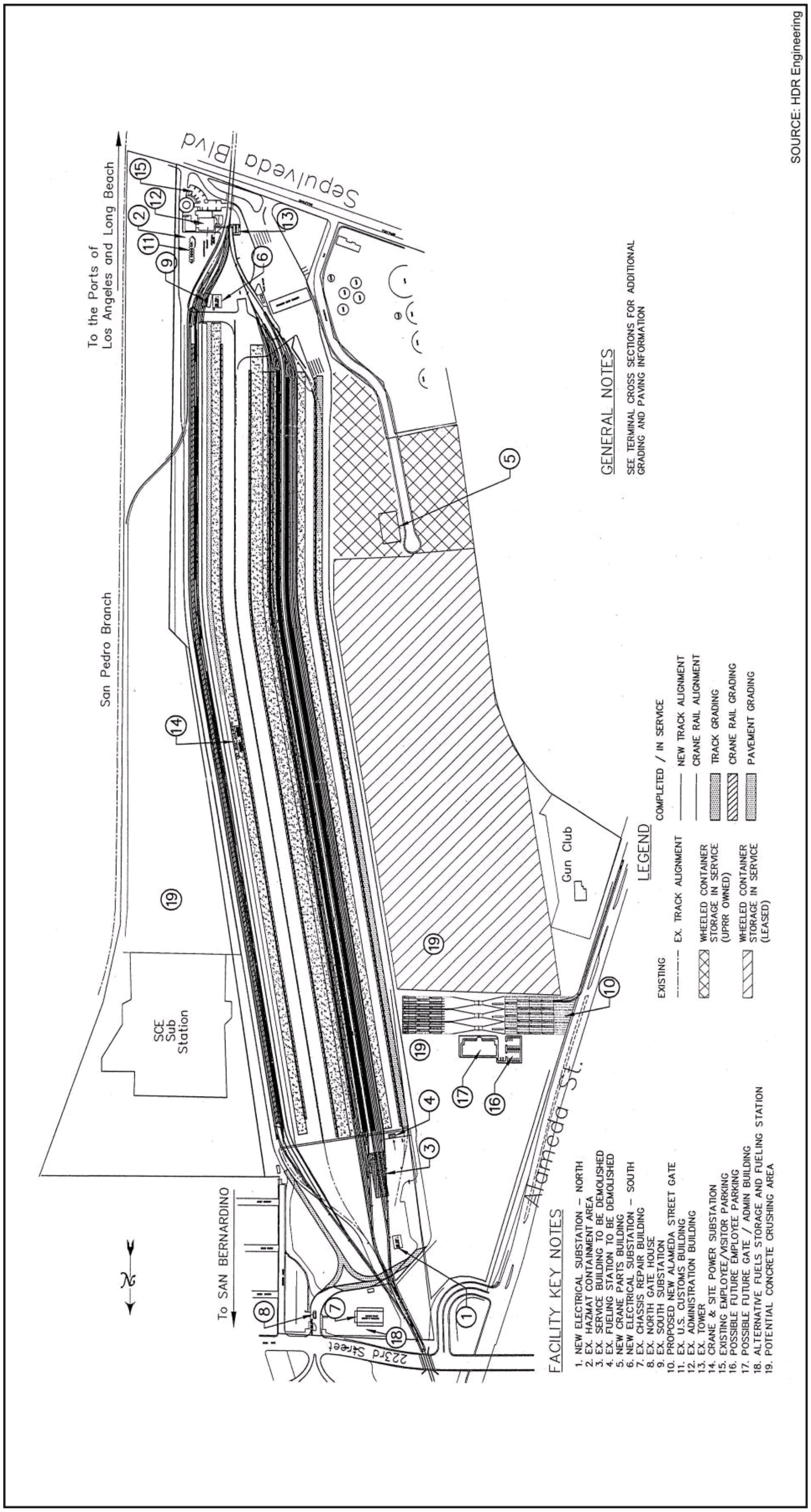
Project No. 2606

Additional railroad track would be constructed in the easterly two-thirds of the ICTF site (see Figure 4). Track turnouts would be closer together in the ladder area, and aisle crossings at the north and south end would require the fabrication and installation of welded steel crossing panels.

Adding track would require partial reconstruction of the north and south lead tracks (see Figure 4). A total of 20 new turnouts (to permit a train to cross from one line to another) would be constructed to reconstruct the ladder and leads used to separate railroad cars onto one of several tracks. The new electric WSG cranes will transfer containers between trucks and the stacking area, as well as between adjacent stacking areas. In addition, this design eliminates the need for 71 of the 73 existing diesel-fueled yard hostlers. The two remaining yard hostlers would use an alternative non-diesel fuel source, such as biodiesel, propane or liquefied natural gas (LNG).

Replacing existing diesel-fueled RTG cranes with electric WSG cranes and reconfiguring the tracks to accommodate these WSG cranes are the central proposed Project components that would allow container throughput to increase from an annual average of 725,000 to 1,500,000, and significantly reduce diesel fuel related emissions.

The WSG cranes would allow containers to be stacked higher than the current configuration. The replacement of wheeled-crane parking operations with container stacking reduces the area required for container storage, which would allow the ICTF to accommodate the increase in overall container storage and throughput while reducing adverse air quality impacts. Also, the efficiency of the electric WSG cranes is expected to reduce the area required for truck chassis and container storage. As a result, the 74 acres that UP currently leases from the Watson Land Company is not expected to be needed for storage and handling of freight and cargo containers. Nevertheless, UP is proposing to keep the leased Watson Land Company parcel for possible other related ICTF uses. Currently, however, no new development or activity is included on the Watson Land Company parcel as part of the proposed Project.



PROPOSED SITE PLAN
ICTF PROPOSED PROJECT

Figure 4

Project No. 2606

1.5.3 Truck Loading

Truck loading and unloading would occur in a truck aisle where vehicles would pull through 45-degree angled stalls. The electric WSG crane slewing (rotating) capability allows containers to be lifted off trucks from any angle and placed in the desired orientation on a platform. Containers not placed on trains or tracks will be stacked.

A new Terminal Operating System (TOS) is proposed to manage the stacking and movement of containers to their train or truck destinations in a timely manner. The TOS would upgrade the existing Optimization Alternatives Strategic Intermodal Scheduler (OASIS) system used to control and track inventory at the ICTF, and would manage trucker appointments, shuttling of containers between modules, and lift operations. Due to the electric WSG crane spacing, the TOS would continuously update service call orders to the crane operators so that the truck, train, and stack service orders would move containers more expeditiously between trucks, trains, and container stacks, increasing the overall ICTF operation efficiency and reducing truck loading/unloading times.

1.5.4 Access and Circulation of Truck Traffic

A paved roadway system would be built to allow truck movements and container loading under the electric WSG cranes. Trucks would follow a prescribed route dictating one-way circulation flow between crane modules to avoid disruptive and inefficient movements. Existing pavement would remain in place where practical.

1.5.5 Structures

Presently, all existing structures are proposed to be retained, with the exception of the service building and the fueling station. The proposed Project includes the following new structures:

- •Crane Repair/Parts Storage Building located at the terminus of Intermodal Way. This building would function as a structure to repair cranes and store parts associated with those cranes.

- Alameda Street Gate including gate house, offices, restrooms, and canopies will serve as the new and only truck entrance into ICTF via Alameda Street. The gate house conceptual building would function as an administrative building with associated employee facilities parking.

1.5.6 Storm Drainage

The proposed Project would modify the existing ICTF storm drainage system. The existing 78-inch reinforced concrete main that runs from east to west in the approximate center of the ICTF and drains to the Dominguez Channel would continue to collect stormwater runoff. The proposed storm drainage system would include a series of sloped, cast-in-place trench drains, or catch basins and curb inlets, constructed along new tracks. New storm drainage improvements will be designed to be consistent with the ICTF's existing Los Angeles County Standard Urban Stormwater Mitigation Plan (SUSUMP), as required under its existing National Pollutant Discharge Elimination System (NPDES) permit.

1.5.7 Lighting

The proposed Project design includes the removal of over 60, 80 to 85-feet tall, high-mounted light poles, and the installation of approximately 160 poles that are 60 feet and 40 feet in height. Similar to procedures used for standard street lighting, proposed fixture spacing of approximately 100-feet would allow the electric WSG cranes to operate above the top of the poles and luminaries, while still allowing illumination at a 2- to 3-foot candle level. Selection of a final electric WSG crane configuration design would determine lighting height, spacing, and other specifications. The new fixtures, similar to those presently used at the ICTF, would be hooded to direct light downward within the ICTF and away from surrounding properties.

1.5.8 Electricity Supply

The proposed Project is expected to require a peak demand of 30 megawatts (MW) of electrical power. The actual peak demand would be dependent on the number of electric WSG cranes, reefer container receptacles, and lights that are in use at any given time. The Los Angeles Department of Water and Power (LADWP) would provide power from a primary power feed on the south side of the ICTF. LADWP or SCE would provide secondary power from a feed on the north side of the ICTF. Each utility feed would provide an estimated 34,500 volts. Each utility feed would connect to a transformer, which would step down the voltage to 12,000 volts for distribution throughout the ICTF.

Each of the six proposed electrical substations would serve one-half of the cranes in each WSG crane module. Selected substations would serve reefer container receptacles and yard lights. The power distribution system would be placed downstream of the substations in trenches running the length of the ICTF. These trenches would house conduits, power cables, and communication cables for the electric WSG cranes. The electric WSG cranes would be linked to a data communication network with fiber optic cables imbedded in each cable reel. Substation equipment for the crane power system would require between 5,000 to 10,000 square feet.

1.5.9 Fuels

The proposed Project would eliminate the need for onsite diesel and gasoline fueling facilities. As a result, the existing 20,000-gallon above-ground diesel storage tank and the 1,000-gallon above-ground unleaded gasoline storage tank would be removed. Potential fuels to be used for the two remaining yard hostlers include biodiesel, propane or LNG. A new tank for storage of biodiesel or alternative non-diesel fuels would be installed. The new tank would include all required secondary containment infrastructure.

The currently proposed location for the new fueling facility and storage tank is near the west wall of the existing chassis repair building in the northern area of the existing ICTF footprint. The tank and fueling facility installation would comply with all federal, state, and local requirements.

A 2-week to 1-month supply of alternative fuel or biodiesel is expected to be stored and dispensed at the ICTF. Fuel deliveries would be undertaken by certified handlers via approved routes. Conservative estimates for biodiesel or alternative fuel volumes are as follows:

- If biodiesel is used, an above-ground, 500-gallon capacity fuel tank with required secondary containment would be constructed. The tank would be mounted on saddles fixed on a concrete pad near the fuel dispenser.
- If propane or LNG is used, an above-ground, 1,000-gallon capacity dispenser tank with required secondary containment would be constructed. The tank would be mounted on a concrete pad.

Project design requires that the fueling of yard trucks (i.e., small rail yard service and personnel trucks) would occur outside of the ICTF at local gas stations in the vicinity of the ICTF. No gasoline or diesel fuel storage would be required or would occur within the ICTF. Any remaining diesel-fueled equipment (such as the top pick) would be fueled, as needed, directly from a fuel delivery truck that would come onto the ICTF periodically for that purpose. Locomotives would continue to be fueled at the Dolores Rail yard. Existing privately-owned pipeline corridors along the southeastern and southern project boundaries would not be disturbed as part of the proposed Project. No other pipelines would be impacted.

1.5.10 Water and Sewer

Existing LADWP drinking water and wastewater disposal services would continue after completion of the proposed Project. New drinking water lines, fire suppression utilities (pipes, valves, hydrants, etc.), and sewer lines serving new buildings and equipment would be linked with existing infrastructure.

1.5.11 Pressurized Air

New air compressors and new air pits are proposed to be constructed to provide adequate air pressure and outlets for proposed additional tracks and trains. The need to retrofit the existing compressed air system would be evaluated if main air pipes require replacement.

1.5.12 Construction Activities

The proposed Project is expected to be constructed over multiple stages, beginning on the east side of the ICTF, while maintaining the number of operational loading tracks at current levels throughout the construction period. Construction of the proposed Project is estimated to take 3 to 4 years for completion.

New loading track construction would progress in pairs from east to west, beginning with construction of new loading tracks 803 and 804 on the eastern ICTF boundary. As new loading tracks are completed and placed into service, the next pair of tracks would be constructed. Each construction stage would take approximately 4 to 6 months.

The operating methods are proposed to be modified to make existing tracks 801 and 802 available to swap lift operations between tracks and to shift associated truck traffic to opposing sides of the tracks. This flexibility, in conjunction with adding the new track 4 in Stage 1, provides a means of completing the east electric WSG module as the first major milestone. The proposed Project would maintain current parking and container storage capacity during construction. The proposed Project requires that some early container stacking be implemented to offset lost surface stalls during construction. The staged construction sequence requires that the parking stalls be converted to container stacking. RTG cranes capable of stacking containers up to three units high and three or four wide would be used on a temporary basis during the construction period to store up to 450 stacked containers, compared with the existing 200 wheeled-parking stall configuration.

Finally, the proposed Project, if necessary, would convert a storage lot to temporary container stacking using 60-foot-wide span RTG cranes, which would be evaluated as part of construction impacts in the EIR. The storage lot is located near the existing Sepulveda Boulevard gate. Temporary asphalt-concrete runways would likely be required in this area, depending on the duration of the container stacking operations.

The various construction stages are based on a conventional 40-hour work week, with crews beginning work between 7:00 and 7:30 a.m., and ending work between 3:30 and 4:00 p.m., Monday through Friday. Peak construction periods would require the employment of between 100 to 150 construction workers. It may be necessary to extend the construction schedule described above to weekend days and/or second shift work that could include two 10-hour work shifts up to 7 days a week for shorter periods of time. However, any such weekend and/or second-shift work will comply with all applicable city ordinances, and appropriate permits will be obtained prior to commencing such work.

1.5.13 Hazardous and Environmentally Sensitive Materials

During the course of Project operations, UP will continue to use its current procedures for the containment and cleanup of any hazardous or environmentally sensitive materials found to be leaking from container cargo, in conformance with all applicable laws.

1.6 Clean Air Action Plan and Other Regulatory Programs

The Clean Air Action Plan (CAAP) has been developed through the collaborative efforts of the Ports, the South Coast Air Quality Management District (SCAQMD), the California Air Resources Board (CARB), the U.S. Environmental Protection Agency (EPA), and other public and industry stakeholders. The CAAP includes industry-specific mitigation measures and incentive programs, including the Clean Trucks Program, to reduce air emissions and health risks associated with operations at the Ports. CAAP control measures applicable to the proposed Project are identified below:

1.6.1 HDV-1 Performance Standards for On-Road Heavy Duty Vehicles (HDV)

The control measure is focused on maximizing the reductions from frequent (7 or more calls per week) and semi-frequent (3.5 to less than 7 calls per week) caller trucks that service both Ports. This control measure sets forth the following "clean" truck definitions:

- All frequent caller trucks, and semi-frequent caller container trucks model year (MY) 1992 and older, calling at the San Pedro Bay Ports will meet or be cleaner than the EPA 2007 on-road emissions standard (0.01 grams per brake horsepower in one hour (g/bhp-hr) for PM) and the cleanest available nitrogen oxides (NOx) at time of replacement.

- Semi-frequent caller container trucks MY1993-2003 will be equipped with the maximum CARB-verified emissions reduction technologies currently available.

The measure then sets target dates by which trucks will either be replaced or retrofitted to meet the above standards. In order to accommodate this massive transformation of the existing truck fleet, Port, SCAQMD, and other public funding will be required. The program also sets forth suggested strategies to maximize the use and emissions reductions of "clean" trucks calling at both ports.

1.6.2 CHE-1 Performance Standards for Cargo Handling Equipment (CHE)

This measure sets fuel neutral purchase requirements for CHE, starting in 2007. The focus is moving the yard tractor fleet to either the cleanest available diesel or the cleanest available alternative fuel engines meeting EPA on-road 2007 or Tier IV PM and NOx standards, and for other equipment for which these engines are not available, the installation of the cleanest CARB VDECs. It also requires that by 2010, all yard tractors operating at the Ports will have the cleanest engines meeting EPA on-road 2007 or Tier IV engine standards for PM and NOx. All remaining CHE less than 750 horsepower (hp) will meet at a minimum the 2007 or Tier IV standards for PM and NOx by 2012. Finally, the measure calls for all remaining CHE greater than 750 hp to meet Tier IV standards for PM and NOx by 2014 and prior to that, be equipped with the cleanest available VDEC.

1.6.3 RL-2 - Existing Class 1 Railroad Operations

This measure effects only existing Class 1 railroad operations on Port property (SPBP-RL3 effects all new or redeveloped rail yards). The goal of this measure is to secure an agreement or Memorandum of Understanding (MOU) with the Class 1 railroads, and use other contractual mechanisms, to reduce emissions from their existing operations on Port properties that do not have a CEQA action pending in the next 5 years (i.e. new or redeveloped rail yard). This measure lays out stringent goals for switcher, helper, and long haul locomotives operating on Port properties. By 2011, all diesel-powered Class 1 switcher and helper locomotives entering Port facilities will be 90 percent controlled for PM and NOx, and will use 15-minute idle restrictors. Starting in 2012 and fully implemented by 2014, the fleet average for Class 1 long haul locomotives calling at Port properties will be Tier III equivalent (Tier 2 equipped with Diesel Particulate Filter (DPF) and Selective Catalytic Reduction (SCR) or new locomotives meeting Tier 3) PM and NOx and will use 15-minute idle restrictors. Class 1 long-haul locomotives operate on USLD while on Port properties as of the end of 2007. Technologies to get to these levels of reductions will be validated through the Technology Advancement Program.

1.6.4 RL-3 Control Measures for New and Redeveloped Rail Yards

Rail facilities include many emission-producing activities, including the operation of switching and line-haul locomotives, idling of switching and line-haul locomotives, loading and unloading of railcars by CHE, and HDVs servicing the yards. New rail facilities, or modifications to existing rail facilities located on Port property, will incorporate the cleanest locomotive technologies, meet the requirements specified in SPBP-RL2, utilize “clean” CHE and HDV, and utilize available “green-container” transport systems. A list of these technologies will be provided for project proponents to consider in developing new facilities or redeveloping existing facilities, and the measures will be formalized in lease requirements.

In addition to the CAAP, CARB and EPA have adopted regulations that require emission reductions from equipment at rail yards such as CHE, HDV, and trains. The resulting emission reductions will be attributed to these existing programs, but will not be considered benefits of the proposed Project. Those emission reductions or environmental benefits that go over and above the existing emission reduction programs will be considered benefits of the proposed Project.

1.7 Cumulative Analysis

In accordance with CEQA, the EIR will include an analysis of past, present, and reasonably foreseeable projects in the area. Included as a subset of this will be an analysis of the synergistic effects of the proposed Project and the adjacent Southern California International Gateway Project being proposed by Burlington Northern and Santa Fe (BNSF) Railroad.

1.8 Alternatives

Consistent with CEQA, the EIR will include an evaluation of a reasonable range of alternatives that would meet most of the Project objectives. In addition to the mandatory No Project Alternative, other alternatives to be evaluated for feasibility and reduction of environmental impacts will include a reduced capacity alternative, alternative locations for the facility, including the use of on-dock and inland Port facilities, alternative transportation system technology, and alternative technology delivery systems from the Port to the Project site.

Chapter Two

Environmental Checklist and Impact Analysis

1.	**Project Title**	**Intermodal Container Transfer Facility Modernization and Expansion Project**
2.	**Lead Agency Name and Address**	**Intermodal Container Transfer Facility Joint Powers Authority**
3.	**Contact Person and Phone Number**	**Mr. Sam Joumblat** 925 Harbor Plaza Long Beach, CA 90802
4.	**Project Location**	The ICTF is located approximately 5 miles from the POLA and the POLB, at the terminus of State Highway 103, known as the "Terminal Island Freeway" (see Figures 1 and 2). The existing ICTF operational core is located on 148 acres of POLA land subleased by UP from the JPA within the City of Los Angeles. Adjacent supporting uses are located in the City of Carson on approximately 15 acres UP purchased from the Watson Land Company, and another approximately 74 acres UP leases from the Watson Land Company.
5.	**Project Sponsor's Name and Address**	**Union Pacific Railroad Company** 1400 Douglas Street, Omaha, NE 68179
6.	**General Plan Designation**	**City of Carson** – Heavy Industrial; City of Long Beach – LUD-9R (Restricted Industries); POLA – General/Bulk Cargo & Commercial/Industrial Uses – Non-Hazardous.
7.	**Zoning**	**City of Carson** – Manufacturing, Heavy; City of Long Beach – Light Industrial; POLA – Heavy Industry.
8.	**Description of Project**	The proposed Project involves the expansion and modernization of the existing ICTF to increase the efficiency and capacity of the facility while reducing environmental impacts associated with the operation. The existing ICTF is a near-dock rail loading and unloading facility that facilitates the movement of container freight in and out of the POLA and the POLB (collectively referred to as "the Ports")by rail. A more detailed description of the proposed Project and its location is provided in Chapter 1.

9.	**Surrounding Land Uses and Setting**	Land uses surrounding the ICTF are primarily heavy industrial and designated as “Manufacturing, Heavy” by the City of Carson and “Heavy Industrial” by the City and POLA. Properties adjacent to the existing ICTF include: a major freeway and residential area to the north; industrial refining facilities, container and trailer parking and servicing facilities, a rail yard and the Alameda Corridor to the west; refining facilities, warehousing container, and trailer parking and servicing facilities to the south; and multi-family residential land uses, including schools, churches to the east in the City of Long Beach. BNSF Railway has submitted an application to the POLA to develop the property to the south of the ICTF for the Southern California International Gateway (SCIG), a new rail loading and unloading facility with operations similar to those of the ICTF.
10.	**Other Public Agencies whose Approval Is Required**	City of Long Beach, CA; City of Carson, CA; California Regional Water Quality Control Board (RWQCB); Los Angeles County Flood Control District.

2.0 Evaluation of Proposed Project

The environmental factors checked below would potentially be affected by this Project (i.e., the Project would involve at least one impact that is a "Potentially Significant Impact"), as indicated by the checklist on the following pages.

☑ Aesthetics	☐ Agricultural Resources	☑ Air Quality
☐ Biological Resources	☐ Cultural Resources	☐ Geology/Soils
☑ Hazards and Hazardous Materials	☑ Hydrology/Water Quality	☐ Land Use/Planning
☐ Mineral Resources	☑ Noise	☐ Population/ Housing
☐ Public Services	☐ Recreation	☑ Transportation/ Traffic
☑ Utilities/Service Systems	☑ Mandatory Findings of Significance	

Determination:

On the basis of this initial evaluation:

☐ I find that the proposed Project COULD NOT have a significant effect on the environment, and a NEGATIVE DECLARATION will be prepared.

☐ I find that although the proposed Project could have a significant effect on the environment, there will not be a significant effect in this case because revisions to the project have been made by or agreed to by the Project proponent. A MITIGATED NEGATIVE DECLARATION will be prepared.

☑ I find that the proposed Project MAY have a significant effect on the environment, and an ENVIRONMENTAL IMPACT REPORT is required.

❒ I find that the proposed Project MAY have an impact on the environment that is "potentially significant" or "potentially significant unless mitigated" but at least one effect (a) has been adequately analyzed in an earlier document pursuant to applicable legal standards, and (b) has been addressed by mitigation measures based on the earlier analysis, as described on attached sheets. An ENVIRONMENTAL IMPACT REPORT is required, but it must analyze only the effects that remain to be addressed.

❒ I find that although the proposed Project could have a significant effect on the environment, because all potentially significant effects (a) have been analyzed adequately in an earlier ENVIRONMENTAL IMPACT REPORT or NEGATIVE DECLARATION pursuant to applicable standards, and (b) have been avoided or mitigated pursuant to that earlier ENVIRONMENTAL IMPACT REPORT or NEGATIVE DECLARATION, including revisions or mitigation measures that are imposed upon the Project, nothing further is required.

Signature

January 8, 2009

Date

2.1 Evaluation of Environmental Impacts:

1. A brief explanation is required for all answers except "No Impact" answers that are adequately supported by the information sources a lead agency cites in the parentheses following each question. A "No Impact" answer is adequately supported if the referenced information sources show that the impact simply does not apply to a Project like the one involved (e.g., the Project falls outside a fault rupture zone). A "No Impact" answer should be explained if it is based on Project-specific factors as well as general standards (e.g., the Project will not expose sensitive receptors to pollutants, based on a Project-specific screening analysis).

2. All answers must take account of the whole action involved, including offsite as well as onsite, cumulative as well as Project-level, indirect as well as direct, and construction as well as operational impacts.

3. Once the lead agency has determined that a particular physical impact may occur, the checklist answers must indicate whether the impact is potentially significant, less than significant with mitigation, or less than significant. "Potentially Significant Impact" is appropriate if there is substantial evidence that an effect may be significant. If there are one or more "Potentially Significant Impact" entries when the determination is made, an EIR is required.

4. "Negative Declaration: Less than Significant with Mitigation Incorporated" applies when the incorporation of mitigation measures has reduced an effect from a "Potentially Significant Impact" to a "Less Than Significant Impact." The lead agency must describe the mitigation measures and briefly explain how they reduce the effect to a less-than-significant level. (Mitigation measures from Section XVII, "Earlier Analyses," may be cross-referenced.)

5. Earlier analyses may be used if, pursuant to tiering, program EIR, or other CEQA process, an effect has been adequately analyzed in an earlier EIR or negative declaration [Section 15063(c)(3)(D)]. In this case, a brief discussion should identify the following:

   (a) Earlier Analysis Used. Identify and state where earlier analyses are available for review.

   (b) Impacts Adequately Addressed. Identify which effects from the above checklist were within the scope of and adequately analyzed in an earlier document pursuant to applicable legal standards and state whether such effects were addressed by mitigation measures based on the earlier analysis.

(c) Mitigation Measures. For effects that are "Less than Significant with Mitigation Incorporated," describe the mitigation measures that were incorporated or refined from the earlier document and the extent to which they address site-specific conditions for the Project.

6. Lead agencies are encouraged to incorporate into the checklist references to information sources for potential impacts (e.g., general plans, zoning ordinances). Reference to a previously prepared or outside document should, when appropriate, include a reference to the page or pages where the statement is substantiated.

7. Supporting Information Sources: A source list should be attached, and other sources used or individuals contacted should be cited in the discussion.

This is only a suggested form, and lead agencies are free to use different formats; however, lead agencies should normally address the questions from this checklist that are relevant to the environmental effects of a Project in whatever format is selected.

The explanation of each issue should identify:

(a) The significance criteria or threshold, if any, used to evaluate each question.

(b) The mitigation measure identified, if any, to reduce the impact to a less-than significant level.

I. AESTHETICS. Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Have a substantial adverse effect on a scenic vista?				☑
b.	Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings along a scenic highway?				☑
c.	Substantially degrade the existing visual character or quality of the site and its surroundings?	☑			
d.	Create a new source of substantial light or glare that would adversely affect daytime or nighttime views in the area?	☑			

Checklist Response Explanation

a. **Would the Project have a substantial adverse effect on a scenic vista?**

No Impact. The ICTF is located on land that is zoned for heavy industrial uses. Land uses surrounding the ICTF are primarily heavy industrial to the west and south. The ICTF is bounded by East Sepulveda Boulevard and the Terminal Island Freeway on the south. Refinery-related activities, a storage tank facility, rail yard, warehousing, container storage and truck trailer parking and servicing are located to the south of the ICTF. A vacant structure, formerly housing a gun club, is located on the far west side of the Watson Land Company property, adjacent to Alameda Street. The Dolores Rail Yard, refinery related activities, and storage tank facility, are located to the west of the ICTF.

To the east of the ICTF is land owned by SCE that contains a commercial nursery and an SCE substation both are under high-voltage transmission power lines associated with the SCE substation. An agricultural truck-loading facility also exists to the south of the SCE facility. A residential area within the City of Long Beach is also located east of the ICTF and SCE property. A medium-density, single-family residential neighborhood exists on the northeast boundary of the ICTF on Hesperian Avenue and East 223rd Street. East 223rd Street and the I-405 Freeway are located north of the ICTF and another predominately residential area is located north of the I-405 Freeway.

Most construction activities associated with the proposed Project will take place within the boundaries of the existing ICTF facilities, except for the construction of a new entrance, which is proposed to be developed along Alameda Street. The proposed Project will add additional structures, including additional electrical substations, service area, and a gate house with offices and related facilities. The land uses surrounding the proposed new entrance are all heavy industrial and would only be visible along Alameda Street, which is not a scenic vista. These structures are not expected to be visible to the surrounding residential area. The tallest new structures are expected to be the electric WSG Cranes, which are expected to be about 100 feet tall and will be visible to the surrounding areas. The modification of the ICTF would not constitute a change to a scenic area or vista in the immediate site vicinity because no designed scenic areas or vistas are located in the vicinity of the ICTF.

No official scenic vistas or state scenic highways are located in the immediate property vicinity (Caltrans, 2008; City of Long Beach, 2005; City of Los Angeles, 1999). In addition, the proposed Project is located in an existing industrial facility and will be industrial in nature. The proposed Project will not change any scenic vistas. No scenic resources are present within the ICTF vicinity. Therefore, adverse effects on scenic vistas or scenic resources are anticipated from the proposed Project. This issue will not be further analyzed in the EIR.

b. Would the Project substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?

No Impact. The proposed Project would not have the potential to damage scenic resources because no scenic resources exist onsite, and the proposed Project would not be located near an eligible or designated state scenic highway. As described above, there are no officially designated scenic routes in the City of Carson, and the Ocean Avenue corridor, a designated scenic route in Long Beach, does not have a view of the ICTF site. The closest officially designated state scenic highway is approximately 33 miles north of the proposed Project (State Highway 2, from approximately 3 miles north of Interstate 210 in La Cañada to the San Bernardino County Line). The closest eligible state scenic highway is approximately 6 miles northeast of the proposed Project (State Highway 1, from State Highway 19 near Long Beach to Interstate 5 south of San Juan Capistrano) (Caltrans, 2008). The proposed Project site is not visible from either of these locations. Therefore, adverse effects on scenic vistas or scenic resources are not expected and this issue will not be further analyzed in the EIR.

c. Would the Project substantially degrade the existing visual character or quality of the site and its surroundings?

Potentially Significant Impact. The proposed Project site currently contains an existing intermodal freight transfer rail yard, as well as industrial warehousing activities and container and trailer parking and servicing in support of the Ports. Surrounding land uses to the west and south consist of similar rail and heavy industrial land uses. An approximately 20-foot-high sound wall separates the ICTF from residences to the east of the facility and blocks views of rail and truck traffic within the Facility. Other residential land uses to the west are separated by SCE property, where transmission towers and lines extend several hundred feet high. The public views of the ICTF are currently limited to views of the 65-foot-high RTG cranes.

Construction activities associated with the proposed Project include, but are not limited to, the new tracks, new paved areas, and new cranes. Most of the construction activities are expected to be near the ground (i.e., not elevated and not visible to the surrounding residential community, with the exception of construction related to the electric WSGs cranes and new light poles).

The proposed Project would add similar heavy industrial and/or rail activities. The proposed Project will replace the existing 10 RTGs cranes (about 65 feet in height) with 39 electric WSG cranes, each about 100 feet in height. The electric WSG cranes are taller than the RTGs and there are more of them, so the electric WSG cranes will be more visible to the surrounding community than the RTG cranes. In light of the presence of residential land uses immediately to the east of the ICTF (including at the northeastern boundary of the site), the aesthetic impacts associated with the proposed Project are potentially significant. Therefore, visual impacts associated with the proposed Project changes on the visual character in the immediate proposed Project site area will be evaluated in the EIR.

d. Would the Project create a new source of substantial light or glare that would adversely affect day or nighttime views in the area?

Potentially Significant Impact. The proposed Project site is in a heavy industrial area that currently operates 24 hours a day, 7 days a week, and has existing nighttime external and internal illumination. Exterior operational lighting, including security nighttime lighting, already exists throughout the proposed Project site and would continue to be present at varying amounts throughout the day and night. An approximately 20-foot-high sound wall separates residents adjacent to the northeastern boundary of the ICTF and helps to block views and light and glare from the ICTF.

Construction activities are expected to occur largely during the daytime hours, although two 10-hour shifts per day are possible during critical construction periods. Existing lighting for construction activities is expected to be sufficient as the site is completely illuminated and most construction activities will occur during daylight. Temporary light fixtures may be necessary for illuminating specific areas. Light and glare impacts are not expected, as construction activities will largely be ground level and temporary lighting would be directed at the ground and is not expected to be elevated.

The proposed Project includes replacing over 60 existing 100-foot-high lighting fixtures with approximately 160 poles ranging from 40 to 60 feet high. High-pressure sodium bulbs that reduce visual contrast will remain. New fixtures will be fitted with hoods, so that illumination will be directed downward onto ICTF surfaces and away from surrounding properties. The number of lighting fixtures located closer to the eastern property boundary will be minimized to the extent possible without impacting worker safety, and will be automatically turned off when cranes are not in use.

Implementation of the proposed Project, however, would reduce lighting impacts by lowering the height of light stanchions and shielding the light to minimize glare but will increase the number of lights and the illuminated area. In light of the presence of residential land uses immediately east of the site, the light and glare impacts associated with the proposed Project are potentially significant and will be evaluated in the EIR.

Conclusion

Potentially significant adverse aesthetic impacts were identified for potential degradation of the existing visual character of the surrounding environment and potential light and glare impacts. Therefore, these aesthetic impacts will be evaluated in the EIR.

II. AGRICULTURAL RESOURCES Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
In determining whether impacts on agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997), prepared by the California Department of Conservation. Would the Project:					
a.	Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland) as shown on maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to nonagricultural use?				☑
b.	Conflict with existing zoning for agricultural use or conflict with a Williamson Act contract?				☑
c.	Involve other changes in the existing environment that, due to their location or nature, could result in conversion of Farmland to nonagricultural use?				☑

Checklist Response Explanation

a. **Would the Project convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to nonagricultural use?**

No Impact. The potential for agricultural resources impacts associated with the proposed Project is expected to be less than significant for the following reasons. All construction and physical modifications associated with the proposed Project will occur within the confines of the existing ICTF or existing industrial facilities adjacent to the ICTF. The proposed Project would be consistent with the heavy industrial zoning of the ICTF and adjacent sites and there are no agricultural resources or operations on, near, or adjacent to the ICTF. No agricultural resources, including Williamson Act contracts, are located within the proposed Project locations or would be impacted by the proposed Project. Based upon the above considerations, agricultural resources impacts are not expected from the proposed ICTF. This issue will not be further analyzed in the EIR.

b. Would the Project conflict with existing zoning for agricultural use, or a Williamson Act contract?

No Impact. As discussed in IIa above, no agricultural resources or operations exist within the proposed Project's limit or adjacent areas. The proposed Project site is not zoned for agricultural use and no Williamson Act contracts apply to the proposed Project site. No significant adverse impacts to agricultural resources are expected and this issue will not be further analyzed in the EIR.

c. Would the Project involve other changes in the existing environment that, due to their location or nature, could individually or cumulatively result in loss of Farmland to nonagricultural use?

No Impact. As discussed in IIa above, no agricultural resources or operations exist within the boundaries of the proposed Project or adjacent areas. The proposed Project site is not zoned for agricultural use and agricultural resources are located within or adjacent to the proposed Project location. Agricultural resources or loss of farmland are not expected and this issue will not be further analyzed in the EIR.

The proposed Project would not disrupt or damage the operation or productivity of any areas designated as Farmland. No Farmland is located within the surrounding area or the proposed Project site that could be affected by changes in land use. No impacts would occur. This issue will not be further analyzed in the EIR.

Conclusion

There are no impacts to agricultural resources as a result of the proposed Project and, therefore, agricultural resources will not be further analyzed in the EIR.

III. AIR QUALITY Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Conflict with or obstruct implementation of the applicable air quality plan?	☑			
b.	Violate any air quality standard or contribute substantially to an existing or Projected air quality violation?	☑			
c.	Result in a cumulatively considerable net increase of any criteria pollutant for which the Project region is a nonattainment area for an applicable federal or state ambient air quality standard (including releasing emissions that exceed quantitative thresholds for ozone precursors)?	☑			
d.	Expose sensitive receptors to substantial pollutant concentrations?	☑			
e.	Create objectionable odors affecting a substantial number of people?	☑			
f.	Result in a cumulatively considerable net increase of Greenhouse Gases?	☑			

Checklist Response Explanation

a. **Would the Project conflict with or obstruct implementation of the applicable air quality plans?**

Potentially Significant Impact. The 2007 Air Quality Management Plan (AQMP) is the applicable air quality plan for the South Coast Air Basin (Basin), which includes the ICTF. The 2007 AQMP demonstrates that the applicable ambient air quality standards can be achieved within the timeframes required under federal law, assuming specific emission reductions goals are reached. It should be noted that the most recent federally-approved air quality plan (i.e., the Applicable state implementation plan [SIP]) is the 1997 AQMP, as amended in 1999.

Construction of the proposed Project would result in a short-term increase in emissions from construction vehicles and equipment used to construct the proposed Project. An estimated 100 to 150 construction workers are expected to be required.

Combustion and fugitive dust emissions during construction will result from construction equipment used for site preparation grading, excavation, and construction of onsite structures. Emissions during construction will also be generated from water trucks used to control dust, welding machines, pickup and diesel trucks used to transport workers and materials around the construction site, diesel trucks used to deliver construction materials, and automobiles used by construction workers for commuting. Construction activities also may include a concrete crushing plant that would generate additional particulate emissions in the local area. Construction of the proposed Project will occur in phases while the existing ICTF is operating so that construction impacts will overlap with existing facility operations. Adverse construction air quality impacts are potentially significant and will be evaluated in the EIR.

Operation of the ICTF proposed Project is expected to double the container cargo handled by the facility. The proposed Project will generate additional emissions into the vicinity of the facility due to an increase in the number of trucks (from about 3,020 to 6,300 one-way truck trips per day). Additionally, an increase in trains (from about 13 to 27 trains per day) that travel to and from the site is also expected. The number of locomotives on each train varies depending on the length of the train, but usually averages about four locomotives (engines). The proposed Project may also have an impact on the movement of trains through the Ports and Southern California areas, shifting the numbers and types of trains that travel from the Dolores Rail Yard and other local railyards. The proposed Project is also expected to use diesel internal combustion engines (ICEs) for air compressors needed at the ICTF. Air quality in the vicinity of the ICTF could be adversely impacted. Operation of the proposed Project, primarily the increase in activity by mobile sources associated with the proposed Project, could conflict with implementation of the applicable SCAQMD AQMP because of potentially significant increases in criteria air pollutants. Over the long term, this is a potentially significant adverse air quality impact and will be evaluated in the EIR.

Emission reductions associated with the proposed ICTF Project will also be evaluated in the EIR. The replacement of existing diesel-fueled RTG cranes with electric WSG cranes and elimination of 71 of the existing 73 yard hostlers is expected to reduce air emissions as compared to current operations. The effect that these emissions reductions would have versus increases in local emissions from the increase in throughput of the proposed Project, which are potentially significant, will be evaluated in the EIR. The EIR will also evaluate the ultimate disposition of the removed equipment (e.g., hostlers and RTG cranes) to determine if the equipment will be removed from service and scrapped or sold to others for use in other locations.

b. **Would the Project violate any air quality standard or contribute substantially to an existing or projected air quality violation?**

Potentially Significant Impact. The proposed Project is located within the Basin, which the EPA has determined is in severe non-attainment for ozone. The Basin is also designated as non-attainment for particulate matter less than 10 microns in diameter (PM10), and particulate matter less than 2.5 microns in diameter (PM2.5), for both state and federal standards. The SCAQMD is requesting that the region be redesignated to extreme non-attainment in the 2007 AQMP. Toxic air contaminants (TACs) have been identified in the area near the proposed Project as part of the SCAQMD MATES III study (SCAQMD, 2008). As described above, the proposed Project could result in an increase in criteria and TAC air emissions in the immediate site area during both construction and once the proposed Project becomes operational. These increases could violate existing air quality standards for ozone and other criteria pollutants generating potentially significant adverse air quality impacts. Therefore, this impact will be addressed in the EIR.

c. **Would the Project result in a cumulatively considerable net increase of any criteria pollutant for which the Project region is non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions that exceed quantitative thresholds for ozone precursors)?**

Potentially Significant Impact. As described in IIIb above, the proposed Project is located within the Basin, which the EPA has designated as severe non-attainment for ozone. The Basin is also designated as non-attainment for PM10, and PM2.5, for both state and federal standards. The SCAQMD is requesting that the region be redesignated to extreme non-attainment in the 2007 AQMP. TACs have been identified in the area near the proposed Project as part of the SCAQMD MATES III study (SCAQMD, 2008). The proposed Project could result in the potential for: (1) A cumulatively considerable net increase in criteria emissions at the site and the immediate surrounding areas that have the potential for violating existing ambient air quality standards; (2) A cumulatively considerable net increase in health risks from air toxic pollutants such as diesel particulate matter; and (3) Cumulatively considerable increase in criteria and toxic air contaminants associated with other proposed Projects in the area, including the Southern California International Gateway Project (SCIG) proposed to be located immediately south of the existing ICTF. The cumulative emission increases in the area are potentially significant and will be evaluated in the EIR. In addition, the replacement of existing diesel-fueled RTG cranes with electric WSG cranes and elimination of 71 of the existing 73 yard hostlers, which is expected to reduce emissions, will be considered in the cumulative air quality impact analysis in the EIR.

d. Would the Project expose sensitive receptors to substantial pollutant concentrations?

Potentially Significant Impact. Sensitive receptors include residential areas, school sites, daycare centers, health care centers, hospitals, senior care facilities, etc. The potential exists for environmental impacts when sensitive receptors are located next to major sources of air pollutant emissions including residential areas and schools located immediately east of the ICTF. For the proposed Project, construction activities could temporarily expose nearby sensitive receptors to increased air pollution concentrations in the form of ozone precursors, diesel particulate exhaust, additional particulate matter emissions associated with the concrete crushing plant, and other criteria and TACs from site construction activities. Proposed Project operational activities could also potentially expose sensitive receptors to substantial concentrations of TACs, most notably diesel particulate matter. A Health Risk Assessment was recently prepared by the CARB for the ICTF and Dolores Railyards (CARB, 2008). The estimated health risks were based on the emission inventory developed for ICTF and Dolores Rail Yard operations in 2005. The estimated cancer risk from the existing operations of the ICTF and Dolores Rail Yard is about 1,200 cancer cases per million at the point of maximum impact, assuming a 70-year exposure duration. The proposed Project will increase the container throughput, number of trucks, and number of railcars that are handled at the ICTF; therefore, impacts on sensitive receptors are potentially significant. The emissions and related health effects to sensitive receptors and adjacent populations associated with the increase in mobile source traffic (trucks and rail), as well as on-site emission sources, will be addressed in the EIR.

e. Would the Project create objectionable odors affecting a substantial number of people?

Potentially Significant Impact. Short-term objectionable odors could occur during proposed Project construction from the use of diesel-powered heavy equipment, and from asphalt operations. Odors produced from actual operation of the ICTF are also possible, including diesel emissions from trucks and locomotives, although they would be similar to other industrial odors in the area. Nevertheless, due to the presence of a residential population adjacent to the proposed Project site, this issue is potentially significant and will be addressed in the EIR as part of the analysis of construction impacts.

f. Would the Project result in cumulatively considerable net increase of Greenhouse Gases?

Potentially Significant Impact. The proposed Project could result in the potential for a cumulatively considerable net increase in greenhouse gas emissions (GHGs) associated with increased truck and rail traffic. Truck and rail traffic is expected to double as a result of the proposed project. Eighty percent of GHG emissions in California from fossil fuel combustion and over 70 percent of GHG emissions are carbon dioxide (CO2). The increase in truck and rail traffic as a result of the proposed project may lead to the increased use of petroleum and diesel fuel consumption.. As a result, there could be an increase in GHG emissions, which could be cumulatively considerable. Therefore, the issue is potentially significant and will be addressed in the EIR.

Conclusion

Potentially significant adverse air quality impacts were identified for potential impacts on the AQMP, potential contribution to impacts on ambient air quality, cumulative air quality impacts (including GHG emissions), impacts to sensitive populations and odors. Therefore, these air quality impacts associated with the proposed Project will be evaluated in the EIR.

IV. BIOLOGICAL RESOURCES Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?				☑
b.	Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?				☑
c.	Have a substantial adverse effect on federally protected wetlands as defined by Section 404 of the Clean Water Act (including, but not				☑

IV. BIOLOGICAL RESOURCES Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
	limited to, marshes, vernal pools, coastal wetlands, etc.) through direct removal, filling, hydrological interruption, or other means?				
d.	Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?				☑
e.	Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?				☑
f.	Conflict with the provisions of an adopted habitat conservation plan; natural community conservation plan; or other approved local, regional, or state habitat conservation plan?				☑

Checklist Response Explanation

a. **Would the Project have a substantial adverse impact, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special-status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or the U.S. Fish and Wildlife Service?**

No Impact. Currently, most of the proposed Project site itself is developed and used for heavy industrial activities. The site is located within an urbanized, developed area, containing mostly industrial facilities and a dense residential area to the east in the City of Long Beach. All construction and physical modifications that would occur as a result of the proposed project will occur within the confines of existing industrial areas. Most of the ICTF site is paved. There is no natural habitat within the proposed Project area because of the development and operation of the industrial facilities. No species identified as a candidate, sensitive, or special-status in local or regional plans, policies, or regulations, or by the California Department of Fish and Game (CDFG)or the U.S. Fish and Wildlife Service (USFWS), is known to occur on the proposed Project site, railroad rights-of-way, or adjacent properties (National Diversity Data Base, 2008). The proposed Project would be consistent with the heavy industrial zoning, and there are no biological resources on or near the ICTF; therefore, no impacts to any species identified as a candidate, sensitive or special status are expected. This issue will not be further analyzed in the EIR.

b. Would the Project have a substantial adverse impact on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or the U.S. Fish and Wildlife Service?

No Impact. See the discussion under IVa above. The proposed Project site contains heavy industrial development. There is no riparian habitat present on the proposed Project site. No other sensitive natural community identified in local or regional plans, policies, or regulations, or by the CDFG or the USFWS is present on the proposed Project site. For these reasons, no impact on riparian or other sensitive habitat is expected. This issue will not be further analyzed in the EIR.

c. Would the Project have a substantial adverse effect on federally protected wetlands as defined by Section 404 of the Clean Water Act (including but not limited to marshes, vernal pools, coastal wetlands, etc.), through direct removal, filling, hydrological interruption, or other means?

No Impact. See the discussion under IVa above. The proposed Project site contains heavy industrial development and does not contain any federally protected wetlands as defined by Section 404 of the Clean Water Act (CWA). As a result, no direct impacts to wetlands or waters of the United States in these areas would occur. For these reasons, no impact on wetlands or other similar habitat is expected. This issue will not be further analyzed in the EIR.

d. Would the Project interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of wildlife nursery sites?

No Impact. See the discussion under IVa above. The proposed Project site contains heavy industrial development; therefore, the proposed Project site does not contain any wildlife migration corridors. There are no wildlife nursery sites on the proposed Project site or in the immediate surrounding area because of the high activity levels (e.g., truck and railcar traffic) associated with the operation of the ICTF. The proposed Project would not involve any activity that could impede the movement of any native resident or migratory fish. For these reasons, no impact on fish or wildlife species is expected. This issue will not be further analyzed in the EIR.

e. Would the Project conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?

No Impact. See the discussion under IVa above. The proposed Project area is designated for industrial uses and there are no policies or ordinances protecting biological resources that are applicable to the proposed Project site. Vegetation is absent from the ICTF site, except for ornamental landscape vegetation near the administration buildings. The Project will not conflict with any policies or ordinance protecting biological resources and this issue will not be further analyzed in the EIR.

f. Would the Project conflict with the provisions of an adopted habitat conservation plan; natural communities conservation plan; or any other approved local, regional, or state habitat conservation plan?

No Impact. See the discussion under IVa above. Neither the proposed Project site nor any adjacent areas are included as part of an adopted Habitat Conservation Plan (HCP), Natural Communities Conservation Plan (NCCP), or any other approved local, regional or state habitat conservation plan. Therefore, the proposed Project is not expected to impact any conservation plan and this issue will not be further analyzed in the EIR.

Conclusion

No biological resources are expected to be impacted, thus this issue will not be further analyzed in the EIR.

V. CULTURAL RESOURCES Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Cause a substantial adverse change in the significance of a historical resource as defined in CEQA Section 15064.5?				☑
b.	Cause a substantial adverse change in the significance of an archaeological resource pursuant to CEQA Section 15064.5?				☑
c.	Directly or indirectly destroy a unique feature?				☑
d.	Disturb any human remains, including those interred outside of formal cemeteries?				☑

Checklist Response Explanation

a. Would the Project cause a substantial adverse change in significance of a historical resource as defined in CEQA Section 15064.5?

No Impact. CEQA Guidelines state that "generally, a resource shall be considered 'historically significant' if the resource meets the criteria for listing in the California Register of Historical Resources, including the following:

1. It is associated with events that have made a significant contribution to the broad patterns of California's history and cultural heritage;
2. It is associated with the lives of persons important in our past;
3. It embodies the distinctive characteristics of a type, period, region, or method of construction, or represents the work of an important creative individual, or possesses high artistic values;
4. It has yielded or may be likely to yield information important in prehistory or history" (CEQA Guidelines §15064.5).

Generally, resources (buildings, structures, equipment) that are less than 50 years old are excluded from listing in the National Register of Historic Places (NRHP) unless they can be shown to be exceptionally important). The buildings, structures, and equipment associated with the proposed Project are not listed on registers of historic resources, and do not meet the eligibility criteria presented above (e.g., associated with historically important events or people, embodying distinctive characteristics of a type, period, or method of construction), and would yield historically important information. The ICTF was built in the early 1980s and structures are less than 50 years old. None of these structures meet the aforementioned historical significance criteria. Therefore, no impacts to historic cultural resources are expected as a result of implementing the proposed Project and this issue will not be further analyzed in the EIR.

b. Would the Project cause a substantial adverse change in significance of an archaeological resource pursuant to State CEQA §15064.5?

No Impact. All construction and physical modifications that would occur as a result of the proposed Project will occur within the confines of the existing heavy industrial areas and the proposed Project would be consistent with the heavy industrial zoning. The site has been graded and developed with tracks, container storage areas, buildings and is largely paved due to the development of the existing ICTF site. The location of the new and modified equipment will be in the same location as the existing facility and equipment. During construction of the existing ICTF, extensive excavation and compaction of previously placed fill and excavation and compaction of native soil was reported (HDR, 2006).

The entire active portion of the ICTF and other adjacent facilities, including the Watson Land and Desser properties have been previously graded and developed. Proposed Project activities will occur in areas where the ground surface has already been graded, disturbed and this past disturbance reduces the likelihood that previously unknown cultural resources or archaeological resources will be encountered. No intact, buried, stratified, archaeological deposits are expected to be located within the zone to be disturbed by the proposed Project. Further, any new track development would be limited to surface disturbances, with little excavation. For the proposed Project site, it is not anticipated that new building foundations would be built lower than existing foundations and expose undisturbed soil. As a result, no impacts to archaeological resources are anticipated.

While the likelihood of encountering cultural resources is low, there is still a potential that additional buried archaeological resources may exist. Any such impact would be eliminated by using standard construction practices and complying with provisions of Section 21083.2 of the Public Resources Code, which requires the following in the event that unexpected subsurface resources were encountered:

- Conduct a cultural resources orientation for construction workers involved in excavation activities. This orientation will show the workers how to identify the kinds of cultural resources that might be encountered, and what steps to take if cultural resources are encountered during exaction activities;

- Monitoring of subsurface earth disturbance by a professional archaeologist and an appropriate representative if cultural resources are exposed during construction;
- Provide the archaeological monitor with the authority to temporarily halt or redirect earth disturbance work in the vicinity of cultural resources exposed during construction so the find can be evaluated and mitigated as appropriate; and,
- As required by state law, prevent further disturbance if human remains are unearthed, until the County Coroner has made the necessary findings with respect to origin and disposition, and the Native American Heritage Commission has been notified if the remains are determined to be of Native American descent.

Based upon the above considerations, no archaeological resources impacts are expected from the proposed Project and this issue will not be further analyzed in the EIR.

c. Would the Project directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?

No Impact. All construction and physical modifications that would occur as a result of the proposed Project will occur within the confines of the existing heavy industrial areas and the proposed Project would be consistent with the heavy industrial zoning. The entire active portion of the ICTF and other adjacent facilities, including the Watson Land and Desser properties, have been previously graded and developed. The geologic formation within the proposed Project area consists of Pleistocene terrace deposits and Palos Verdes sand, which could have the potential for fossil resources. However, due to the grading, excavations and backfill related to previous development, the proposed Project site would not be expected to yield significant paleontological resources. Any new track development would be limited to surface disturbances, with little excavation. Thus, implementation of the proposed Project would not likely disturb any known paleontological resources or unique geological features and this issue will not be further analyzed in the EIR.

d. Would the Project disturb any human remains, including those interred outside of formal cemeteries?

No Impact. All construction and physical modifications that would occur as a result of the proposed Project will occur within the confines of the existing heavy industrial areas and the proposed Project would be consistent with the heavy industrial zoning.

The entire active portion of the ICTF and other adjacent facilities, including the Watson Land and Desser properties, have been previously graded and developed. No prehistoric burials or historic-period cemeteries were located within the proposed Project area during the original development of the site in the early 1980s. Because of the extensive development and grading that has occurred on the proposed Project site and adjacent areas, there are no known human remains and this issue will not be further analyzed in the EIR. Also, see V.b. regarding requirements in the unlikely event that human remains are discovered.

Conclusion

No cultural resources impacts are anticipated from the proposed Project and, therefore, will not be further analyzed in the EIR.

VI. GEOLOGY AND SOILS Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:				
i.	Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42.			☑	
ii.	Strong seismic ground shaking?			☑	
iii.	Seismic-related ground failure, including liquefaction?			☑	

VI. GEOLOGY AND SOILS Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
iv.	Landslides?				☑
b.	Result in substantial soil erosion or the loss of topsoil?			☑	
c.	Be located on a geologic unit or soil that is unstable or that would become unstable as a result of the Project and potentially result in an onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse?			☑	
d.	Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?			☑	
e.	Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems in areas where sewers are not available for the disposal of wastewater?				☑

Checklist Response Explanation

a. **Would the Project expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:**

i) **Rupture of a known earthquake fault, as delineated on the most recent Alquist- Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42, and;**

ii) **Strong seismic ground shaking?**

Less Than Significant Impact. The proposed Project is located in a seismically active region. There is the potential for damage to the new structures in the event of an earthquake. The most significant potential geologic hazard is estimated to be seismic shaking from future earthquakes generated by active or potentially active faults in the region. Table 2.1 identifies those faults in the southern California region considered important to the Project sites in terms of potential for future activity. Seismic records have been available for the last 200 years, with improved instrumental seismic records available for the past 50 years. Based on a review of earthquake data, most of the earthquake epicenters occur along the Whittier-Elsinore, San Andreas, Newport-Inglewood, Malibu-Santa Monica-Raymond Hills, Palos Verdes, Sierra Madre, San Fernando, Elysian Park-Montebello, and Torrance-Wilmington faults (Jones and Hauksson, 1986). All these faults are elements of the San Andreas Fault system. Past experience indicates that there has not been any substantial damage, structural or otherwise to the ICTF as a result of earthquakes. Table 2.2 identifies the historic earthquakes over magnitude 4.5 in Southern California, between 1915 and the present, along various faults in the region.

Whittier-Elsinore Fault Zone: The Whittier-Elsinore Fault is one of the more prominent structural features in the Los Angeles Basin. It extends from Turnbull Canyon near Whittier, southeast to the Santa Ana River, where it merges with the Elsinore fault. Yerkes (1972) indicated that vertical separation on the fault in the upper Miocene strata increases from approximately 2,000 feet at the Santa Ana River northwestward to approximately 14,000 feet in the Brea-Olinda oil field. Farther to the northwest, the vertical separation decreases to approximately 3,000 feet in the Whittier Narrows of the San Gabriel River.

The fault also has a major right-lateral strike slip component. Yerkes (1972) indicates streams along the fault have been deflected in a right-lateral sense from 4,000 to 5,000 feet. The fault is capable of producing a maximum credible earthquake event of about magnitude 7.0 every 500 to 700 years.

TABLE 2.1
Major Active or Potentially Active Faults in Southern California

FAULT ZONE	FAULT LENGTH (Miles)	MAXIMUM CREDIBLE EARTHQUAKE	MAXIMUM ACCELERATION (G)
Malibu-Santa Monica-Raymond Hill	65	7.5	0.49
Newport-Inglewood	25	7.0	0.42
Northridge	12	6.7	0.16
Palos Verdes	20	7.0	0.24
San Andreas	200+	8.25	0.21

FAULT ZONE	FAULT LENGTH (Miles)	MAXIMUM CREDIBLE EARTHQUAKE	MAXIMUM ACCELERATION (G)
San Jacinto	112	7.5	0.11
San Fernando	8	6.8	0.17
Sierra Madre	55	7.3	0.23
Whittier-Elsinore	140	7.1	0.46
Elysian Park – Montebello	15	7.1	0.27

TABLE 2.2
Significant Historical Earthquakes in Southern California

DATE	LOCATION (epicenter)	Magnitude
1915	Imperial Valley	6.3
1925	Santa Barbara	6.3
1920	Inglewood	4.9
1933	Long Beach	6.3
1940	El Centro	6.7
1940	Santa Monica	4.7
1941	Gardena	4.9
1941	Torrance	5.4
1947	Mojave Desert	6.2
1951	Imperial Valley	5.6
1968	Borrego Mountain	6.5
1971	Sylmar	6.4
1975	Mojave Desert	5.2
1979	Imperial Valley	6.6
1987	Whittier	5.9
1992	Joshua Tree	6.3
1992	Landers	7.4
1992	Big Bear	6.5
1994	Northridge	6.7
1999	Hector Mine	7.1
2008	Chino Hills	5.4

San Andreas Fault Zone: The San Andreas fault is located on the north side of the San Gabriel Mountains trending east-southeast as it passes the Los Angeles Basin. This fault is recognized as the longest and most active fault in California. It is generally characterized as a right-lateral strike-slip fault, which is comprised of numerous sub-parallel faults in a zone over 2 miles wide. There is a high probability that Southern California will experience a magnitude 7.0 or greater earthquake along the San Andreas or San Jacinto fault zones, which could generate strong ground motion in the Project area. There is a 5 to 12 percent probability of such an event occurring in Southern California during any one of the next 5 years and a cumulative 47 percent chance of such an event occurring over a 5-year period (Reich, 1992).

The Newport-Inglewood Fault Zone: The Newport-Inglewood fault is a major tectonic structure within the Los Angeles Basin. This fault is best described as a structural zone comprising a series of echelon and sub-parallel fault segments and folds. The faults of the Newport-Inglewood uplift in some cases exert considerable barrier influence upon the movement of subsurface water (DWR, 1961). Offsetting of sediments along this fault usually is greater in deeper, older formations. Sediment displacement is less in younger formations. The Alquist-Priolo Act has designated this fault as an earthquake fault zone. The purpose of designating this area as an earthquake fault zone is to mitigate the hazards of fault rupture by prohibiting building structures across the trace of the fault.

This fault poses a seismic hazard to the Los Angeles area (Toppozada, et al., 1988, 1989), although no surface faulting has been associated with earthquakes along this structural zone during the past 200 years. Since this fault is located within the Los Angeles Metropolitan area, a major earthquake along this fault would produce more destruction than a magnitude 8.0 on the San Andreas fault. The largest instrumentally recorded event was the 1933 Long Beach earthquake, which occurred on the offshore portion of the Newport-Inglewood structural zone with a magnitude of 6.3. A maximum credible earthquake of magnitude 7.0 has been assigned to this fault zone.

Malibu-Santa Monica-Raymond Hills Fault Zone: The Raymond Hills fault is part of the fault system that extends from the base of the San Gabriel Mountains westward to beyond the Malibu coast line. The fault has been relatively quiet, with no recorded seismic events in historic time; however, recent studies have found evidence of ground rupture within the last 11,000 years.

The Palos Verdes Fault Zone: The Palos Verdes fault extends for about 50 miles from the Redondo submarine canyon in Santa Monica Bay to south of Lausen Knoll and is responsible for the uplift of the Palos Verdes Peninsula. This fault is both a right-lateral strike-slip and reverse separation fault. The Gaffey anticline and syncline are reported to extend along the northwestern portion of the Palos Verdes hills. These folds plunge southeast and extend beneath recent alluvium east of the hills and into the San Pedro Harbor, where they may affect movement of ground water (DWR, 1961). The probability of a moderate or major earthquake along the Palos Verdes fault is low compared to movements on either the Newport-Inglewood or San Andreas faults. However, this fault is capable of producing strong to intense ground motion and ground surface rupture. This fault zone has not been placed by the California State Mining and Geology Board into an Alquist-Priolo special studies zone.

Sierra Madre Fault System: The Sierra Madre fault system extends for approximately 60 miles along the northern edge of the densely populated San Fernando and San Gabriel valleys (Dolan, et al., 1995) and includes all faults that have participated in the Quaternary uplift of the San Gabriel Mountains. The fault system is complex and appears to be broken into five or six segments, each 10 to 15 miles in length (Ehlig, 1975). The fault system is divided into three major faults (Dolan, et al.,1995), including the Sierra Madre, the Cucamonga and the Clamshell-Sawpit faults. The Sierra Madre fault is further divided into three minor fault segments the Azusa, the Altadena and the San Fernando fault segments. The Sierra Madre fault is capable of producing a 7.3 magnitude fault every 805 years (Dolan, et al., 1995).

San Fernando Fault: The westernmost segment of the Sierra Madre fault system is the San Fernando segment. This segment extends for approximately 12 miles beginning at Big Tujunga Canyon on the east to the joint between the San Gabriel Mountains and the Santa Susana Mountains on the west (Ehlig, 1975). The 1971 Sylmar earthquake occurred along this segment of the Sierra Madre fault system, resulting in a 6.4 magnitude fault. The San Fernando fault segment is capable of producing a 6.8 magnitude fault every 455 years (Dolan, et al., 1995).

Elysian Park-Montebello System: The Elysian Park fault is a blind thrust fault system, i.e., not exposed at the surface, whose existence has been inferred from seismic and geological studies. The system, as defined by Dolan, et al. (1995), comprises two distinct thrust fault systems: 1) an east-west-trending thrust ramp located beneath the Santa Monica Mountains; and 2) a west-northwest-trending system that extends from Elysian Park Hills through downtown Los Angeles and southeastward beneath the Puente Hills. The Elysian Park thrust is capable of producing a magnitude 7.1 earthquake every 1,475 years.

Torrance-Wilmington Fault Zone: The Torrance-Wilmington fault has been reported to be a potentially destructive, deeply buried fault, which underlies the Los Angeles Basin. Kerr (1988) has reported this fault as a low-angle reverse or thrust fault. This proposed fault could be interacting with the Palos Verdes hills at depth. Little is known about this fault, and its existence is inferred from the study of deep earthquakes. Although information is still too preliminary to be able to quantify the specific characteristics of this fault system, this fault appears to be responsible for many of the small to moderate earthquakes within Santa Monica Bay and easterly into the Los Angeles area. This fault itself should not cause surface rupture, only ground shaking in the event of an earthquake.

In addition to the known surface faults, shallow-dipping concealed "blind" thrust faults have been postulated to underlie portions of the Los Angeles Basin. Because little data exist to define the potential extent of rupture planes associated with these concealed thrust faults, the maximum earthquake that they might generate is largely unknown.

No faults or fault-related features are known to exist at the ICTF. The site is not located in any Alquist-Priolo Earthquake fault zone and is not expected to be subject to significant surface fault displacement. Based on preliminary geological studies completed for the proposed Project, the potential for ground surface fault rupture is low (HDR, 2006). The nearest documented active structures on which ground surface rupture is expected to occur are the Newport-Inglewood Fault (about 4 kilometers to the northeast) and the Palos Verdes Fault (about 7 kilometers to the southwest) (HDR, 2006). Both of these geological structures are located a sufficient distance that surface rupture would not be expected at the ICTF. Therefore, no significant impacts to the proposed Project facilities are expected from seismically-induced ground rupture.

Based on the historical record, it is highly probable that earthquakes will affect the Los Angeles region in the future. Research shows that damaging earthquakes will occur on or near recognized faults that show evidence of recent geologic activity. The proximity of major faults to the ICTF increases the probability that an earthquake may impact the facilities. There is the potential for damage in the event of an earthquake.

The proposed changes to the ICTF are mostly related to construction of additional railroad tracks, new cranes, a crane parts building and service center, and a new gate house including offices, restrooms and canopies. The new structures associated with the proposed Project that will house workers are the crane parts building and the new gate house. The new buildings must be designed to comply with the Uniform Building Code Zone 4 requirements since the proposed Project is located in a seismically active area. The Uniform Building Code is considered to be a standard safeguard against major structural failures and loss of life. The goal of the code is to provide structures that will: (1) resist minor earthquakes without damage; (2) resist moderate earthquakes without structural damage, but with some non-structural damage; and (3) resist major earthquakes without collapse, but with some structural and non-structural damage. The Uniform Building Code bases seismic design on minimum lateral seismic forces ("ground shaking"). The Uniform Building Code requirements operate on the principle that providing appropriate foundations, among other aspects, helps to protect buildings from failure during earthquakes. The basic formulas used for the Uniform Building Code seismic design require determination of the seismic zone and site coefficient (peak ground acceleration of approximately 0.4g), which represent the foundation conditions at the site.

The new buildings at the ICTF will be required to obtain building permits, as applicable, for all new structures at the site. The facilities must receive approval of all building plans and building permits to assure compliance with the latest Building Code adopted by the local agency prior to commencing construction activities. The issuance of building permits from the local agencies will assure compliance with the Uniform Building Code requirements, which include requirements for building within seismic hazard zones. Thus, the proposed Project would not alter the exposure of people or property to geological hazards such as earthquakes, liquefaction, subsidence, landslides, mudslides, ground failure, or other natural hazards. As a result, substantial exposure of people or structures to the risk of loss, injury, or death is not anticipated. No significant impacts from seismic hazards are expected since the Project will be required to comply with the Uniform Building Codes and this issue will not be further analyzed in the EIR.

iii) Seismic-related ground failure, including liquefaction?

Less Than Significant Impact. Portions of the Facility are located within an area where there has been historic occurrence of liquefaction or existing conditions indicate a potential for liquefaction (California Division of Mines and Geology, 1999) and the potential for expansive soils could exist. The City of Los Angeles' Safety Element for its General Plan identifies this area as having the potential for liquefaction (City of Los Angeles, 1994). Specific geological investigations of the site indicate that saturated soil exists below depths greater than 40 to 45 feet below the ground surface. The site soil is relatively dense and is not expected to be susceptible to liquefaction and associated effects (HDR, 2006). Seismically induced landslides at the ICTF are unlikely because the site is relatively flat. The Uniform Building Code requirements consider liquefaction potential and establish more stringent requirements for building foundations in areas potentially subject to liquefaction. Therefore, mandatory compliance with the Uniform Building Code requirements is expected to minimize the potential impacts associated with liquefaction. The issuance of building permits from the local agency will assure compliance with the Uniform Building Code requirements and compliance with the Los Angeles Harbor Department design guidelines. Therefore, no significant impacts from liquefaction or expansive soils are expected and this issue will not be further analyzed in the EIR.

iv) Landslides?

No Impact. The proposed Project site is within a flat topographical area with few unpaved onsite areas and, therefore, would not have significant impacts. Because of the flat topography, landslides are not located within or adjacent to the proposed

Project site. The Safety Element of the Los Angeles General Plan indicates that the proposed Project site is not within the landslide inventory (City of Los Angeles, 1994). Therefore, landslide hazards are not expected from the proposed Project site and this issue will not be further analyzed in the EIR.

b. Would the Project result in substantial soil erosion or the loss of topsoil?

Less Than Significant. The proposed Project is located within the confines of the existing ICTF. Concrete foundations presently support structures and equipment. Most of the ICTF site is currently paved. The operating portions of the facility are relatively flat so no major grading is required to provide flat surfaces. No unstable earth conditions, loss of topsoil, changes in topography or changes in geologic substructures are anticipated to occur with the proposed Project because of the limited grading and excavation involved. No significant adverse impacts on topography and soils are expected.

The proposed Project involves adding new infrastructure throughout the existing facilities in phases so construction activities will include foundation work, removal of existing paving, excavation for foundations, etc. Ground disturbance will include installing foundations for new units, installation of new utilities, and subterranean components for adding railroad tracks and utilities. Construction is expected to occur in phases as it is the goal to keep the ICTF fully operational during construction activities. Since the proposed project will occur in phases, limited grading and exposure of soils will occur at any given time and the major portion of the site will remain paved. Once construction is completed in one portion of the site, construction activities will move to another location. No significant adverse impacts related to soil erosion are expected since the proposed Project will occur within already developed facilities that have been graded and paved No significant change in topography is expected because all new components at the facility will match the existing grade of existing components. The proposed Project will be required to comply with SCAQMD Rule 403 – Fugitive Dust, which imposes requirements to minimize dust emissions associated with wind erosion. Relative to operation, no change in surface runoff is expected because surface conditions will remain relatively unchanged.

Following construction, exposed areas would be paved or landscaped, reducing erosion potential and making significant long-term impacts unlikely. This issue will not be further analyzed in the EIR.

c. Is the Project located on a geologic unit or soil that is unstable, or that would become unstable as a result of the Project, and potentially result in onsite or offsite landslides, lateral spreading, subsidence, liquefaction, or collapse?

d. **Is the Project located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?**

Less Than Significant Impact. Portions of the Facility are located within an area where there has been historic occurrence of liquefaction or existing conditions indicate a potential for liquefaction (California Division of Mines and Geology, 1999) and the potential for expansive soils could exist. The City of Los Angeles' Safety Element for its General Plan identifies this area as having the potential for liquefaction (City of Los Angeles, 1994). Specific geological investigations of the site indicate that saturated soil exists below depths greater than 40 to 45 feet below the ground surface. The site soil is relatively dense and is not expected to be susceptible to liquefaction and associated effects (HDR, 2006). Seismically induced landsliding at the ICTF is unlikely because most of the site is flat. The Uniform Building Code requirements consider liquefaction potential and establish more stringent requirements for building foundations in areas potentially subject to liquefaction. Therefore, mandatory compliance with the Uniform Building Code requirements is expected to minimize the potential impacts associated with liquefaction. The issuance of building permits from the local agency will assure compliance with the Uniform Building Code requirements and compliance with the Los Angeles Harbor Department design guidelines. Therefore, no significant impacts from liquefaction or expansive soils are expected and this issue will not be further analyzed in the EIR.

e. **Would the Project have soils that are incapable of supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater?**

No Impact. The ICTF has existing wastewater treatment systems that will continue to operate and that will be available to handle wastewater produced by the proposed Project. The Los Angeles Department of Public Works Bureau of Sanitation provides sewer service to all areas within its jurisdiction, including the proposed Project site. New wastewater facilities associated with the proposed Project would be connected to this existing sewer system. Therefore, alternative wastewater disposal systems are not a part of the proposed Project and no impacts will occur. These issues will not be further analyzed in the EIR.

Conclusion

The proposed Project impacts on geology and soils are considered to be less than significant with compliance with the Uniform Building Code and all other applicable state and local building codes. Thus, the proposed Project would not substantially increase the exposure of people or property to geological hazards such as earthquakes, liquefaction, subsidence, landslides, mudslides, ground failure, or other natural hazards. As a result, substantial exposure of people or structures to the risk of loss, injury, or death is not anticipated. These issues will not be further analyzed in the EIR.

	VII. HAZARDS AND HAZARDOUS MATERIALS Would the Project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?	☑			
b.	Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?	☑			
c.	Emit hazardous emissions or involve handling hazardous or acutely hazardous materials, substances, or waste within 0.25-mile of an existing or proposed school?	☑			
d.	Be located on a site that is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?	☑			
e.	Be located within an airport land use plan area or, where such a plan has not been adopted, be within 2 miles of a public airport or public use airport, and result in a safety hazard for people residing or working in the Project area?				☑

VII. HAZARDS AND HAZARDOUS MATERIALS Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
f.	Be located within the vicinity of a private airstrip and result in a safety hazard for people residing or working in the Project area?				☑
g.	Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?	☑			
h.	Expose people or structures to a significant risk of loss, injury, or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?				☑

Checklist Response Explanation

a. **Would the Project create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?**

Potentially Significant Impact. Trains using the ICTF may transport potentially hazardous materials. The proposed Project is expected to double the throughput of the ICTF and, therefore, potentially increase the transport of hazardous material. In addition, the proposed modifications to the ICTF would also include the use of fuels, oils and cleaning materials that could qualify as hazardous materials. These types of materials are routinely used and safely transported through the Ports by rail each day using the U.S. Department of Transportation (DOT) regulations governing the procedures and equipment for handling or transporting such materials. The proposed project includes the installation of an aboveground non-diesel alternative fuel (biodiesel, propane of liquefied natural gas) tank and the removal of aboveground gasoline and diesel storage tanks. The increase in the transport of hazardous materials (including contaminated soils from storage tank removal), the change in the storage of potentially hazardous materials, and potential impacts of accidental releases are potentially significant and will be evaluated in the EIR.

b. **Would the Project create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the likely release of hazardous materials into the environment?**

Potentially Significant Impact. Two potential sources of upset or accident involving the release of hazardous materials are possible from the proposed Project. First, the demolition of existing improvements on the proposed Project site could result in the release of, or exposure to, potentially hazardous materials. At present, it is not known whether hazardous materials are contained in the existing improvements. An existing 20,000-gallon aboveground diesel storage tank and a 1,000-gallon, aboveground unleaded gasoline tank will be removed. There is the potential for soil contamination associated with these existing storage tanks. Due to the historic use of the site for industrial purposes, hazardous materials may be present at the site. In the event that any such materials are found or thought to be present, proper cleanup procedures would be identified and the materials would be removed in compliance with existing hazardous waste/materials rules and regulations. The adequacy of such cleanup procedures, to the extent any are needed, will be addressed in the EIR. The second potential source of release of hazardous materials into the environment would be an accident or upset associated with the onsite rail and truck operations. An Emergency Response Plan, together with Health and Safety Plans, are already in place for the existing operations and would be modified, as necessary, to reflect the conditions during proposed Project construction and following completion of construction. These plans would address the potential dangers associated with an upset or accident. The potential increase in hazards associated with the proposed Project is potentially significant and will be addressed in the EIR.

c. **Would the Project emit hazardous emissions or handle hazardous materials or acutely hazardous materials, substances, or waste within 0.25-mile of an existing or proposed school?**

Potential Significant Impact. The proposed Project is within one-quarter mile of several schools located in the City of Long Beach and a large residential area east of the ICTF. Schools within one-quarter mile of the ICTF include the Hudson Elementary School and Stephens Jr. High School. Hazards that are routinely handled in accordance with federal and state laws regarding hazardous materials could potentially adversely affect local schools due to its proximity to the proposed Project site. The EIR will evaluate the potential health risks of the proposed project on schools, as well as other sensitive receptors. This impact is potentially significant and will be addressed in the EIR.

d. Would the Project be located on a site that is included on a list of hazardous material sites compiled pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?

Potentially Significant Impact. The parcels associated with the proposed Project, including the ICTF site, the Watson Land Company parcel and the Desser parcel, are not included on lists ("Cortese List") compiled by the Department of Toxic Substances Control (DTSC) pursuant to Government Code Section 65962.5 (DTSC, 2008). The Watson Land Company parcel and the Desser parcel located immediately to its north, are largely underlain by a former organic refuse landfill so that construction activities on these sites could disturb landfill material. The Watson Land Company parcel is currently used for the storage and handling of cargo containers and truck chassis, to support ICTF operations. Construction at either property, as well as the ICTF site, could involve the disturbance of landfill materials or the discovery of contamination, resulting in potential hazardous conditions. This issue will be addressed in the EIR.

e. Would the Project be located within an airport land use plan or, where such a plan has not been adopted, within 2 miles of a public airport or public use airport, would the Project result in a safety hazard for people residing or working in the Project area?

No Impact. The proposed Project will be constructed within the confines of the existing ICTF and adjacent Watson Land and Desser properties. The proposed Project is not located within 2 miles of a public airstrip, or public airport, and is not within an airport land use plan area. The closest airport is Long Beach Airport, approximately 8 miles to the northeast of the proposed Project site. No impacts on public airports are expected and this issue will not be addressed in the EIR.

f. Would the Project be located within the vicinity of a private airstrip, would the Project result in a safety hazard for people residing or working in the Project area?

No Impact. See VII.e above. The proposed Project is not within the vicinity of a private airstrip. No impacts on a private airstrip are expected and this issue will not be further analyzed in the EIR.

g. Would the Project impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?

Potentially Significant Impact. The proposed Project would include its own internal emergency response plans and personnel. The proposed Project design will be reviewed to determine how it would operate in compliance with existing emergency response and evacuation plans in the area. This issue will be addressed in the EIR to assure that any new emergency response and evacuation plans are effective.

h. Would the Project expose people or structures to the risk of loss, injury, or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?

No Impact. The proposed Project will not increase the existing risk of fire hazards in areas with flammable brush, grass or trees. No substantial or native vegetation exists on or near the proposed Project area. The proposed Project site is located in an industrialized, urban environment and no wildland areas are located in the vicinity of the proposed Project. Further, industrial facilities are typically devoid of vegetation for fire safety purposes. As a result, fire hazard impacts relative to wildland fires are not expected. This issue will not be further analyzed in the EIR.

Conclusion

Potentially significant adverse hazards and hazardous materials impacts were identified for the proposed Project. Therefore, hazard and hazardous materials impacts associated with the proposed ICTF will be evaluated in the EIR.

VIII. HYDROLOGY AND WATER QUALITY Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Violate any water quality standards or waste discharge requirements?	☑			
b.	Substantially deplete groundwater supplies or interfere substantially with groundwater recharge, resulting in a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of preexisting nearby wells would drop to a level that would not support existing land uses or planned uses for which permits have been granted)?				☑

VIII. HYDROLOGY AND WATER QUALITY Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c.	Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner that would result in substantial erosion or siltation onsite or offsite?			☑	
d.	Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner that would result in flooding onsite or offsite?				☑
e.	Create or contribute runoff water that would exceed the capacity of existing or planned storm water drainage systems or provide substantial additional sources of polluted runoff?			☑	
f.	Otherwise substantially degrade water quality?			☑	
g.	Place housing within a 100-year flood hazard area, as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?				☑
h.	Place within a 100-year flood hazard area structures that would impede or redirect flood flows?				☑

VIII. HYDROLOGY AND WATER QUALITY Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
i.	Expose people or structures to a significant risk of loss, injury, or death involving flooding, including flooding as a result of the failure of a levee or dam?				☑
j.	Contribute to inundation by seiche, tsunami, or mudflow?				☑

Checklist Response Explanation

a. **Would the Project violate any water quality standards or waste discharge requirements?**

Potentially Significant Impact. Control of surface water quality and erosion at the existing ICTF is currently regulated through the General Construction Activities Storm Water Permits (GCASP) and NPDES permits. The proposed Project would be subject to these same permitting requirements, including the requirement to develop and implement a Storm Water Pollution Prevention Plan (SWPPP) and use of Best Management Practices (BMPs) during proposed Project construction to prevent pollutants from contacting storm water.

Operational activities associated with the proposed Project are not expected to generate additional wastewater, as the physical size of the facility is not expected to change and wastewater generated at the site is generally limited to sanitary wastes associated with the office buildings and stormwater runoff. Although the paved portion area of the ICTF is not expected to change, the additional trucks and locomotives will result in additional particulate emissions from the exhaust and tire wear from the trucks that will occur in and around the ICTF facility. This increase in particulate emissions that deposit on the paved areas has the potential to be contact stormwater. For these reasons, the proposed Project is may adversely affect water quality standards or waste discharge requirements. Therefore, this issue will be further analyzed in the EIR.

b. **Would the Project substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (i.e., the production rate of pre-existing nearby wells would drop to a level that would**

not support existing land uses or planned uses for which permits have been granted)?

No Impact. The proposed Project site is currently developed and most of the site already consists of impermeable surfaces. As a result, the site does not support significant surface recharge of groundwater. The proposed Project is not expected to interfere with groundwater recharge because impermeable surfaces at the site are not expected to substantially increase. Groundwater in the area has significant saltwater intrusion and is, therefore, unsuitable for use as drinking water. The proposed Project at the ICTF will continue to use local public supplies of water for proposed Project usage. As a result, the proposed Project would not deplete groundwater supplies and no significant adverse impacts on the local groundwater table are expected. This issue will not be addressed in the EIR.

c. Would the Project substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner that would result in substantial erosion or siltation onsite or offsite?

Less Than Significant Impact. ICTF will be installing new stormwater drainage infrastructure that will not affect the course of streams or rivers (see page 14). The proposed storm drainage infrastructure will include a series of sloped, cast-in-place trench drains, or catch basins and curb inlets constructed along new tracks. New catch basins and curb inlets draining the northern area will connect to the existing 36-inch reinforced concrete pipe draining into the Dominguez Channel via a large (7.5-foot by 10.5-foot) reinforced concrete storm drain box along the eastern edge of Alameda Street. New storm drainage improvements will be designed to be consistent with the Facility's existing Los Angeles County Standard Urban Stormwater Mitigation Plan (SUSUMP), as required under its existing NPDES permit.

In addition, the existing ICTF site is largely paved. The proposed Project would have a similar amount of impermeable surface as currently exists on the ICTF site. Nothing associated with the proposed Project design would alter the pattern of surface runoff in a manner that would result in substantial increased erosion or siltation onsite or offsite or increased surface water runoff. The proposed Project is located within an existing industrialized and urbanized area and new structures are not located near or adjacent to a stream or river. Some grading of the site is expected at site and adjacent properties to install new facilities; however, none of the activities associated with the proposed Project construction or operation would alter the course of a stream or river, as no stream or river exist onsite. Therefore, no significant adverse impacts on drainage patterns or streams or rivers are expected and this issue will not be further analyzed in the EIR.

d. Would the Project substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or

substantially increase the rate or amount of surface runoff in a manner that would result in flooding onsite or offsite?

No Impact. See VIIIc. The proposed Project would install new storm water drainage infrastructure which will not affect the course of streams or rivers (see page 14). The existing ICTF site is largely paved. The proposed Project would have a similar amount of impermeable surface as currently exists on the ICTF site. No actions associated with the proposed Project would substantially increase either the rate or amount of surface runoff in a manner that would result in flooding on or offsite. There are no actions associated with the proposed Project that would alter the course of a stream or river, as no stream or river exist onsite. This issue will not be further analyzed in the EIR.

e. **Would the Project create or contribute runoff water, which would exceed the capacity of existing or planned storm water drainage systems or provide substantial additional sources of polluted runoff?**

Less Than Significant Impact. The existing ICTF site is largely paved and the physical modifications associated with the proposed project are within the boundaries of the existing ICTF. The proposed Project is expected to have a similar amount of impermeable surface as currently exists on the ICTF site. The proposed storm drainage infrastructure is expected to include a series of sloped, cast-in-place trench drains, or catch basins and curb inlets constructed along new the proposed new tracks. The existing 78-inch reinforced concrete main that runs from east to west in the approximate center of the ICTF drains to the Dominguez Channel and will continue to collect storm water runoff. New catch basins and curb inlets draining the northern area are expected to be connected to the existing 36-inch reinforced concrete pipe draining into the Dominguez Channel via a 7.5-foot by 10.5-foot reinforced concrete storm drain box along the eastern edge of Alameda Street. New storm drainage improvements will be designed to be consistent with the Facility's existing Los Angeles County SUSUMP, as required under the existing NPDES permit. The proposed project is not expected to substantially increase either the rate or amount of surface runoff in a manner that would impact the capacity of stormwater drainage systems or provide substantial additional sources of polluted water runoff. As discussed in VIII a, the ICTF is currently regulated through the GCASP and NPDES permits. The proposed Project would be subject to these same permitting requirements, including the requirement to develop and implement a SWPPP and use of BMPs during proposed Project construction and operations to prevent pollutants from contacting stormwater. The proposed Project is not expected to significantly impact stormwater drainage systems or provide substantial additional sources of polluted runoff. Therefore, this issue will not be further analyzed in the EIR.

f. Would the Project otherwise substantially degrade water quality?

Less Than Significant Impact. The proposed Project would have a similar amount of impermeable surface as currently exists on the ICTF site. Nothing associated with proposed designs would substantially increase either the rate or amount of surface runoff in a manner that would degrade water quality. As discussed in VIII a, the ICTF is currently regulated through the GCASP and NPDES permits. The proposed Project would be subject to these same permitting requirements, including the requirement to develop and implement a SWPPP and use of BMPs during proposed Project construction and operations to prevent pollutants from contacting stormwater. No significant impacts to degrade water quality are anticipated; therefore, this issue will not be further analyzed in the EIR.

g. Would the Project place housing within a 100-year flood hazard area, as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?

No Impact. The proposed Project will expand and modernize the operation of an existing intermodal container facility. The proposed Project does not include placing housing in a 100-year flood hazard zone. Therefore, flood hazards are not significant and this issue will not be further analyzed in the EIR.

h. Would the Project place within a 100-year flood hazard area, structures that would impede or redirect flood flows?

No Impact. The proposed Project site is listed by the City of Los Angeles General Plan Safety Element as being located within a 100-year flood plain. New structures at the Facility would be limited to maintenance and office buildings within an industrial area. No structures would be located in an area where they would impede or redirect flood flows. No significant new flood hazard impacts are expected and this issue will not be further analyzed in the EIR.

i. Would the Project expose people or structures to a significant risk of loss, injury, or death involving flooding as a result of the failure of a levee or dam?

No Impact. The proposed Project involves construction and modification within an existing industrial facility and does not include construction of any new housing within a flood hazard area. The proposed Project would not change the risk level for flooding in the surrounding area, as no dams or levees are near the proposed Project site. According to the Federal Emergency Management Agency (FEMA) Flood Data Maps for the area, and the City of Los Angeles General Plan Safety Element (City of Los Angeles, 1995), the proposed Project is not within any potential dam inundation areas. No significant adverse impacts on flooding are expected due to the proposed project; therefore, this issue will not be further analyzed in the EIR.

j. Would the Project contribute to inundation by seiche, tsunami, or mudflow?

No Impact. The proposed Project would not contribute to inundation by seiche, tsunami, or mudflow. The ICTF is located in an upland area about 1.9 miles from the POLB. The City of Los Angeles General Plan Safety Element identifies the Project site as located within areas "potentially impacted by a tsunami" (City of Los Angeles, 1994). The open harbor system would allow seismic forces to travel out to sea rather than contain them in a closed basin subject to increasing oscillations, as is characteristic of seiche activity. The proposed Project would not alter the topography or otherwise enhance the potential for adverse affects of a tsunami, if one were to impact the Southern California coast. The Ports are protected by a series of breakwaters and the ICTF is located a sufficient distance (1.9 miles) from the ocean so that impacts from seiching or a tsunami are not expected. Finally, the topography of the proposed Project site area, which is essentially flat, lacks sufficient relief to support a mudflow. No significant impacts would occur. These issues will not be further analyzed in the EIR.

Conclusion

Although the paved portion area of the ICTF is not expected to change, the additional trucks and locomotives will result in additional particulate emissions from the exhaust and tire wear from the trucks that will occur in and around the ICTF facility. This increase in particulate emissions that deposit on the paved areas has the potential to be contact stormwater. For these reasons, the proposed Project may adversely affect water quality standards or waste discharge requirements. Therefore, this issue will be further analyzed in the EIR.

IX LAND USE AND PLANNING Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Physically divide an established community?				☑
b.	Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the Project (including, but not limited to, a general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?			☑	

IX LAND USE AND PLANNING Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c.	Conflict with any applicable habitat conservation plan or natural community conservation plan?				☑

Checklist Response Explanation

a. **Would the Project physically divide an established community?**

No Impact. The new facilities associated with the proposed Project will occur within an industrial area and largely within the confines of the existing ICTF. Additional land that may be used for ICTF operations (i.e., the Watson Land property and the Desser property) are also zoned for heavy industrial uses. Implementation of the proposed Project would not physically alter residential areas, or physically split an established residential community and no significant adverse impacts on land use are expected.

b. **Would the Project conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the Project (including, but not limited to the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?**

Less Than Significant Impact. Land use and other planning considerations are determined by local governments and no land use or planning requirements will be altered by adoption of the proposed Project. Construction activities associated with the proposed Project will occur within property that is zoned for industrial land uses and currently contain industrial land uses. The proposed Project site is regulated by two separate jurisdictions: the City of Los Angeles and the City of Carson. Each designates the existing ICTF and the proposed Project site for industrial use: "Manufacturing, Heavy" for the City of Carson and "Heavy Industrial" for the POLA. The Desser and Watson Land properties are also zoned Heavy Industrial by the City of Carson. The proposed Project is consistent with the heavy industrial land use of the existing sites and the surrounding facilities, which are also heavy industrial land uses. Therefore, present or planned land uses in the region will not be affected as a result of the proposed Project. The proposed Project site is not in the Coastal Zone and will not impact a local coastal program. No significant adverse land use impacts are expected and this issue will not be further analyzed in the EIR.

c. Would the Project conflict with any applicable habitat conservation plan or natural community conservation plan?

No Impact. The site and surrounding area are fully developed at an urban scale that mostly consists of industrial facilities and residential land uses. There are no habitat conservation or natural community conservation plans located within or adjacent to the proposed Project. This issue will not be addressed in the EIR.

Conclusion

The proposed Project impacts on land use and planning are expected to be less than significant and will not be further analyzed in the EIR.

X. MINERAL RESOURCES Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?				☑
b.	Result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan?				☑

Checklist Response Explanation

a. Would the Project result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?

No Impact. The proposed Project location has been urbanized since the early 20th century. All construction and operational activities that would occur as a result of the proposed Project will occur within the confines of existing industrial areas. The proposed Project would be consistent with the heavy industrial zoning and there are no mineral resources or operations on or near the ICTF property (California Department of Conservation, 1979). There are no provisions of the proposed Project that would result in the loss of availability of a known mineral resource of value to the region and the residents of the state such as, but not limited to, aggregate, coal, clay, shale, or of a locally-important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan. Based upon the above considerations, significant adverse mineral resources impacts are not expected from the proposed Project. This issue will not be addressed in the EIR.

b. Would the Project result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan?

No Impact. As discussed in Xa above, the proposed Project site is not in any significant mineral resource areas that have been identified by the state or by the Cities of Los Angeles or Carson. No significant adverse impacts to mineral resources would occur. This issue will not be further analyzed in the EIR.

Conclusion

No impacts on mineral resources are expected from the proposed Project and therefore will not be further analyzed in the EIR.

XI. NOISE **Would the Project:**		**Potentially Significant Impact**	**Less Than Significant with Mitigation Incorporated**	**Less Than Significant Impact**	**No Impact**
a.	Expose persons to or generate noise levels in excess of standards established in a local general plan or noise ordinance or applicable standards of other agencies?	☑			
b.	Expose persons to or generate excessive ground borne vibration or ground borne noise levels?	☑			
c.	Result in a substantial permanent increase in ambient noise levels in the Project vicinity above levels existing without the Project?	☑			
d.	Result in a substantial temporary or periodic increase in ambient noise	☑			

	XI. NOISE Would the Project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
	levels in the Project vicinity above levels existing without the Project?				
e.	Be located within an airport land use plan area, or, where such a plan has not been adopted, within 2 miles of a public airport or public use airport and expose people residing or working in the Project area to excessive noise levels?				☑
f.	Be located in the vicinity of a private airstrip and expose people residing or working in the Project area to excessive noise levels?				☑

Checklist Response Explanation

a. **Would the Project result in exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?**

Potentially Significant Impact. The existing noise environment at the ICTF is dominated by mobile sources including trucks, cranes, locomotive engines, and other heavy industrial activities. Proposed Project construction activities may generate short-term increases in noise levels in the proposed Project vicinity from such activities including, but not limited to, demolition, grading, asphalting surface areas, railroad track removal and installation, and building construction. Construction activities would be phased and would occur while the ICTF is operating, thus potentially increasing the noise levels at the Facility. The construction activities will be adjacent to other industrial areas and also near the residential areas of Long Beach. Noise from these activities could exceed local or applicable noise standards. This impact is potentially significant and will be addressed in the EIR.

The proposed Project includes eliminating several pieces of noise-generating equipment and would replace others with quieter models. In particular, the RTG cranes with diesel engines will be eliminated and replaced with electric WSG cranes, resulting in a decrease in noise sources related to diesel engines powering the cranes. In addition, the elimination of 71 of the 73 yard hostlers and their back-up safety horns are also expected to reduce the noise generated by that off-road mobile source.

The existing noise barrier that screens Long Beach residences from ICTF activities will not be affected by the proposed Project and will continue to reduce truck and train noise resulting from the proposed Project. Nonetheless, operation of the proposed Project is expected to double the truck and rail traffic in the area, which could change or increase traffic noise due to truck/rail movements and idling in the area. Operation of the proposed ICTF could also result in noise from the use of onsite heavy equipment and the movement/handling of additional containers at the site. Noise from these activities could exceed local or applicable noise standards and potentially adversely impact the adjacent residential areas in the City of Long Beach. The potential noise impacts at the Dolores Rail Yard will also be evaluated to determine if any increase in activity could result in increases in noise levels. This impact is potentially significant and will be addressed in the EIR.

b. Would the Project result in exposure of persons to or generation of excessive ground borne vibration or ground borne noise levels?

Potentially Significant Impact. Proposed Project-construction activities associated with demolition, grading, asphalting surface areas, railroad track removal and replacement and building construction could all result in significant ground borne vibration and/or noise levels. Increased rail loading and unloading activities and rail ingress and egress from operation of the ICTF could also result in significant ground-borne vibration or ground-borne noise levels. There would be increased traffic, and concomitant ground-borne vibrations and noise levels, although such traffic would not be adjacent to residences. These impacts are potentially significant and will be addressed in the EIR.

c. Would the Project result in a substantial permanent increase in ambient noise levels in the Project vicinity above levels existing without the Project?

Potentially Significant Impact. Operation of the proposed modified ICTF is expected to double the truck and rail traffic in the area, which could change or increase traffic noise due to truck/rail movements and idling in the area. Implementation of the proposed Project would potentially result in both short-term and long-term increases in noise levels due to construction and operation activities at the ICTF and any changes in operation at the Dolores Rail Yard that could affect adjacent communities. Of most concern regarding noise impacts are the residential portions of Long Beach adjacent to the eastern boundary of the ICTF. Noise impacts are potentially significant and will be addressed in the EIR.

d. Would the Project result in a substantial temporary or periodic increase in ambient noise levels in the Project vicinity above levels existing without the Project?

Potentially Significant Impact. Noise sources in the area currently include mobile and stationary sources at the ICTF facility; industrial noise from adjacent facilities; rail traffic from the San Pedro Branch line located along the eastern boundary of the ICTF and the Alameda Corridor to the west of the ICTF; traffic along the Terminal Island Freeway and other local streets (e.g., Alameda Street and Sepulveda Boulevard). Demolition of existing facilities and construction of the proposed Project could potentially result in substantial periodic increases in noise levels associated with construction activities and construction deliveries by truck and train in the proposed Project area. Further, the proposed Project is expected to double the truck and train traffic at the proposed Project site, resulting in a potential increase in periodic noise levels. These impacts are potentially significant and will be addressed in the EIR.

e. Would the Project be located within an airport land use plan or, where such a plan has not been adopted, within 2 miles of a public airport or public use airport, would the Project expose people residing or working in the Project area to excessive noise levels?

No Impact. The proposed Project will be constructed within an industrial area of the Cities of Carson/Long Beach. The proposed Project is not located within the vicinity of a public airstrip, is not within 2 miles of a public airport, and is not within an airport land use plan area. The closest airport is Long Beach Airport, approximately 8 miles to the northeast of the proposed Project site. No impacts on public airports are expected and this issue will not be further analyzed in the EIR.

f. Would the Project be located within the vicinity of a private airstrip, would the Project expose people residing or working in the Project area to excessive noise levels?

No Impact. See XIe above. The proposed Project is not within the vicinity of a private airstrip. No impacts on a private airstrip are expected and this issue will not be further analyzed in the EIR.

Conclusion

The proposed Project impacts on noise are potentially significant and will be evaluated in the EIR.

XII. POPULATION AND HOUSING Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a	Induce substantial population growth in an area, either directly (e.g., by proposing new homes and businesses) or indirectly (e.g., through extension of roads or other infrastructure)?				☑
b	Displace a substantial number of existing housing units, necessitating the construction of replacement housing elsewhere?				☑
c.	Displace a substantial number of people, necessitating the construction of replacement housing elsewhere?				☑

Checklist Response Explanation

a. **Would the Project induce substantial population growth in an area, either directly (e.g., by proposing new homes and business) or indirectly (e.g., through extension of roads or other infrastructure)?**

No Impact. The proposed Project is designed to help manage existing and projected growth in containerized cargo at the San Pedro Bay Ports by providing for increased efficiency at an existing near-dock rail loading facility. The proposed Project would not induce population growth as it is designed to handle containerized cargo. It is expected that the peak number of construction workers can be obtained from the existing labor pool. Peak construction periods will require the employment of between 100 to 150 construction workers. The proposed Project is also not expected to require an increase in the number of operational workers at the facility because of the automated nature of the new or modified equipment onsite. Substantial population growth is not expected directly or indirectly from implementation of the proposed Project and therefore will not be further analyzed in the EIR.

b. **Would the Project displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?**

b. Would the Project displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?

No Impact. The proposed Project site consists of expansion and modernization of an existing ICTF. The Facility is currently operating and located within a heavy industrial area. Since the proposed Project will generally occur within the boundaries of the existing facility, it will not displace any existing housing. The proposed Project is not expected to displace substantial numbers of existing house, and thus, will not be further analyzed in the EIR.

c. Would the Project displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?

No Impact. The proposed Project site consists of expansion and modernization of an existing ICTF. The Facility is currently operating and located within a heavy industrial area and is not expected to require additional workers. Similarly, it is expected that construction of the proposed Project would draw workers from the existing local labor pool. As a result, the proposed Project would not displace people, requiring the construction of new housing. A substantial number of people is not expected to be impacted from the proposed project and, therefore, will not be further analyzed in the EIR.

Conclusion

The proposed Project is not expected to impact on population and housing and, therefore, will not be further analyzed in the EIR.

XIII. PUBLIC SERVICES Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities or a need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, to maintain acceptable service ratios, response times, or other performance objectives for any of the following public services:				
i.	Fire protection?			☑	
ii.	Police protection?				☑
iii.	Schools?				☑

XIII. PUBLIC SERVICES Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
iv.	Parks?				☑
v.	Other public facilities?				☑

Checklist Response Explanation

a. **Would the Project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts to maintain acceptable service ratios, response times or other performance objectives for any of the public services:**

i. **Fire protection?**

Less than Significant Impact? The Los Angeles City Fire Department (LAFD) currently provides fire protection and emergency services for the existing ICTF and proposed Project area. The Facility has implemented an emergency response plan that provides procedures in the event an emergency arises. Following Project completion, the Facility's emergency response plans will need to be updated to account for the new and modified facilities (e.g., the new storage tanks and elimination of existing fuel tanks, and increased number of containers, trucks, and trains). The proposed Project would expand and modernize the ICTF but would continue to handle the same types of containerized cargo, but increase the number of containerized cargo. Hazardous materials are handled at the facility and the proposed Project may increase the amount of hazardous materials handled at the ICTF. However, releases are generally handled by the facility or the owner of the material per the requirements of the emergency response plans and generally do not require City fire services. The proposed Project is not expected to require additional fire protection services and, thus, is not expected to require new or altered fire facilities to maintain acceptable service ratios or response times. The proposed Project's impact on fire protection is expected to be less than significant and will not be further analyzed in the EIR.

ii. **Police protection?**

No Impact. The ICTF is surrounded by fences and entry is restricted to several gates. A 24-hour security force operates at the Facility. Police protection is provided by the Port Police, as well as the Cities of Los Angeles and Carson Police

Departments. Following Project completion, the facility will remain fenced, and entry restricted with a 24-hour security force. The proposed Project is not expected to require additional police services and, thus, is not expected to require new or altered police facilities to maintain acceptable service ratios or response times. The ICTF has its own onsite security and is not anticipated to significantly increase demands on local police departments. No impact on police protection is expected from the proposed Project and the issue will not be further addressed in the EIR.

iii., iv., and v. Schools? Parks? Other Public Facilities?

No Impact. Peak construction periods will require the employment of between 100 to 150 construction workers. The local labor pool (e.g., work force) from the Southern California area is expected to be adequate to fill the short-term construction positions for the proposed Project. The proposed Project is not expected to result in any additional permanent workers at the facility or increase the local population. The proposed Project would not involve any school-related activities and would not cause an increase in the number of nearby residents such that it could impact schools, parks, or other public facilities. Thus, no impacts are expected to local schools, parks, other public facilities or government services. Noise, air quality and potential health risk impacts of the proposed Project on schools and the surrounding communities will be analyzed in other portions of the EIR.

Conclusion

The proposed Project impacts on public services are expected to be less than significant and will not be further analyzed in the EIR.

XIV. RECREATION Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?				☑
b.	Include recreational facilities or require the construction or expansion of recreational facilities that might have an adverse physical effect on the environment?				☑

Checklist Response Explanation

a. **Would the Project increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?**

No Impact. No recreation impacts associated with the proposed ICTF Project were identified for the following reasons. The proposed Project does not involve the use of, or direct impacts to, any existing parks or recreational facilities. Thus, no impacts are expected to recreational facilities and the proposed Project would not result in deterioration of recreational facilities. This issue will not be further analyzed in the EIR.

b. **Does the Project include recreational facilities or require the construction or expansion of recreational facilities that might have an adverse physical effect on the environment?**

No Impact. The proposed Project will require additional construction workers. These workers are expected to come from the large labor pool in Southern California. The proposed Project is not expected to result in additional permanent workers at the facility or increase the local population. The proposed Project does not involve the use of, or direct impacts to, any existing parks or recreational facilities. Thus, no impacts are expected to recreational facilities and the proposed Project would not require the construction or expansion of recreational facilities that might have an adverse physical effect on the environment. This issue will not be further analyzed in the EIR.

Conclusion

No recreational impacts are expected, thus this issue will not be further analyzed in the EIR.

XV. TRANSPORTATION Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Cause an increase in traffic that is substantial in relation to the existing traffic load and capacity of the street system (i.e., result in a substantial increase in the number of vehicle trips, the volume-to-capacity ratio on roads, or	☑			

XV. TRANSPORTATION Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
	congestion at intersections)?				
b.	Cause, either individually or cumulatively, exceedance of a level-of-service standard established by the county congestion management agency for designated roads or highways?	☑			
c.	Result in a change in vessel traffic patterns, including either an increase in traffic levels or a change in location that results in substantial safety risks?				☑
d.	Substantially increase hazards because of a design feature (e.g., sharp curves or dangerous intersections), or incompatible uses (e.g., farm equipment)?	☑			
e.	Result in inadequate emergency access?				☑
f.	Result in inadequate parking capacity?				☑
g.	Conflict with adopted policies, plans, or programs supporting alternative transportation (e.g., bus turnouts, bicycle racks)?				☑

Checklist Response Explanation

a. **Would the Project cause an increase in traffic that is substantial in relation to the existing traffic load and capacity of the street system (i.e., result in a substantial increase in either the number of vehicle trips, the volume-to-capacity ratio on roads, or congestion at intersections)?**

Potentially Significant Impact. During the construction phase, the proposed project will increase traffic at the ICTF by an estimated 100 to 150 construction workers, plus additional trips to deliver construction materials. Construction activities are phased and will occur while the existing ICTF continues to operate. Construction activities will introduce additional vehicle and truck traffic into the surrounding streets. Large pieces of equipment that may be brought into the Facility may require special transportation needs (e.g., electric WSG cranes and permits to transport on roadways, if applicable). Therefore, construction traffic impacts associated with the proposed Project are potentially significant and will be evaluated in the EIR.

Once construction activities are complete, the proposed Project is expected to double the cargo containers that move through the ICTF. Therefore, the proposed Project would cause an increase in truck traffic on existing major traffic arteries in the proposed Project area. Increased vehicular movement on these major arteries would further occur during operation of the modified ICTF due to an estimated increase in truck traffic of about 1.1 million one-way truck trips per year (for a total of about 2.2 million trips per year) to and from the facility. The proposed Project could adversely affect volume-to-capacity ratios at local intersections; therefore, these impacts are potentially significant.

The EIR will analyze the proposed Project traffic volumes before, during and after construction in relation to road capacities. The EIR will also consider the regional effects of truck traffic on area highways, such as the Long Beach Freeway (I-710) and the Terminal Island Freeway (I-103), including any potential reduction in truck traffic due to consolidation of truck/rail trips as a result of the proposed Project. Further, the EIR will evaluate whether an alternative means of access to the ICTF would reduce identified potentially significant traffic impacts to the local community.

Development of a new ICTF gate at Alameda Street will alter traffic flow by the use of Alameda Street as a main conduit between the ICTF and the Ports. The new Alameda Street gate will serve as the truck entrance to the ICTF, while truck traffic will exit at the Sepulveda Boulevard gate. By designating Alameda Street as the required route between ICTF and the Ports, the proposed Project would limit the number of left-hand truck-turning movements onto Sepulveda Boulevard associated with trucks returning to the Ports. Subject to obtaining any necessary public agency approvals, UP will eliminate the left-turn signal light and post “no left turn” signs at the ICTF outbound Sepulveda Gate to prevent left-turns onto Sepulveda Boulevard. In addition, the need for mitigation on local streets and intersections (e.g., signal improvements or modifications) and the potential impact of mitigation measures will also be evaluated in the EIR.

The proposed Project is expected to increase the rail traffic to/from the ICTF from about 4,745 rail trips per year to 9,490 rail trips per year. The increase in rail traffic is potentially significant and will be evaluated in the EIR. Existing train routes to and from the ICTF, the Dolores Rail Yard and the Ports are not expected to change as a result of the proposed Project.

b. Would the Project exceed, either individually or cumulatively, a level-of-service standard established by the county congestion management agency for designated roads or highways?

Potentially Significant Impact. Due to increased surface street traffic on major traffic arteries, the proposed Project could result in traffic exceeding a level-of-service standard for congestion management program intersections in the Ports area. Cumulative traffic impacts of the proposed Project and other nearby Projects in the area are also potentially significant. Traffic impacts are potentially significant and will be addressed in the EIR. In addition, the EIR will evaluate whether an alternative means of access to the ICTF would reduce potentially significant traffic impacts to the local community.

c. Would the Project result in a change in vessel traffic patterns, including either an increase in traffic levels or a change in location that results in substantial safety risks?

No Impact. The proposed Project would not result in changes in vessel traffic levels or patterns that could result in substantial safety risks. The proposed Project will help to improve the handling of containerized cargo in the Port area and handle the increased growth in containerized cargo. However, the proposed Project is not expected to result in a change in vessel patterns or an increase in vessel traffic. No impacts on vessel traffic are expected and this issue will not be addressed in the EIR.

d. Would the Project substantially increase hazards to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?

Potentially Significant Impact. The proposed Project is expected to double the cargo containers that move through the ICTF and increase the truck and rail traffic in the vicinity of the ICTF. The proposed Project is expected to result in increased traffic on existing streets in the proposed Project area, which could increase hazards at pedestrian crossings. A traffic study will be prepared for the proposed Project that will address traffic hazards (including potential pedestrian impacts) as part of the ICTF access analysis. Design features that may create hazards to vehicle ingress and egress will also be addressed. In addition, the need for mitigation of significant impacts on local streets and intersections and the potential impact of mitigation measures also will be evaluated. These issues are potentially significant will be addressed in the EIR.

e. Would the Project result in inadequate emergency access?

No Impact. Emergency access to the area occurs along major thoroughfares in the proposed Project site area (e.g., Sepulveda Boulevard and Alameda Street). These thoroughfares would not be altered by the proposed Project. Emergency access to the ICTF will continue to be provided without interruption during construction and operational activities. The proposed project will result in the construction of a new entrance along Alameda Street and provide a new access to the ICTF, which could be used to provide emergency access to the ICTF facility. These issues will not be addressed in the EIR.

f. Would the Project result in inadequate parking capacity?

No Impact. Parking for construction workers is expected to be provided within the existing ICTF and sufficient onsite parking is available so no adverse impacts on parking are expected during the construction phase. The proposed Project is not expected to result in an increase in workers so that no increase in parking is required during Project operation. Parking spaces would be established onsite for employees and trucks arriving and departing the ICTF. No adverse parking impacts are expected and the issue will not be further analyzed in the EIR.

g. Would the Project conflict with adopted policies supporting alternative transportation (e.g., bus turnouts, bicycle racks)?

No Impact. The proposed Project would not conflict with adopted policies supporting alternative transportation. No barriers to pedestrian or bicycle circulation would occur. The proposed Project would comply with all policies regarding alternative transportation. This issue will not be further analyzed in the EIR.

Conclusion

The proposed Project impacts on traffic and circulation are potentially significant and will be evaluated in the EIR.

XVI. UTILITIES AND SERVICE SYSTEMS Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Exceed wastewater treatment requirements of the applicable Regional Water Quality Control Board?				☑
b.	Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the				☑

XVI. UTILITIES AND SERVICE SYSTEMS Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
	construction of which could cause significant environmental effects?				
c.	Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?				☑
d.	Have sufficient water supplies available to serve the Project from existing entitlements and resources, or would new or expanded entitlements be needed?				☑
e.	Result in a determination by the wastewater treatment provider that serves or may serve the Project that it has adequate capacity to serve the Projected demand of the Project in addition to the provider's existing commitments?				☑
f.	Be served by a landfill with sufficient permitted capacity to accommodate the solid waste disposal needs of the Project?				☑
g.	Comply with federal, state, and local statutes and regulations related to solid waste?				☑
h.	Impact on Other Utilities	☑			

Checklist Response Explanation

a. **Would the Project exceed wastewater treatment requirements of the applicable regional water quality control board?**

No Impact. Wastewater treatment services are provided to the ICTF by the LADWP. LADWP is responsible for supplying, conserving, treating, and distributing water for domestic, industrial, agricultural, and firefighting purposes within the City of Los Angeles. The expansion and modernization of the ICTF would occur at a facility that already exists and is within an area of existing industrial facilities. The proposed Project is not expected to require a substantial increase in water use or generate additional wastewater by the Facility. Wastewater from the ICTF is limited to wastewater from the administration buildings. No increase in employees or substantial increase in wastewater generation is expected. Therefore, no impacts on wastewater treatment requirements are expected and this issue will not be further analyzed in the EIR.

b. **Would the Project require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?; and**

No Impact. Please refer to the discussion in XVIa above. The proposed Project is not expected to require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities and, therefore, will not be further analyzed in the EIR.

c. **Would the Project require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?**

No Impact. The existing storm drain system will continue to convey runoff to an existing 78-inch reinforced concrete main that runs from east to west near the center of the ICTF and drains to the Dominguez Channel. New catch basins and curb inlets constructed in the northern portion of the ICTF will convey runoff to an existing reinforced concrete storm drain box along the eastern edge of Alameda Street. The flow will continue via an existing 36-inch reinforced concrete pipe and will drain into the Dominguez Channel. All new storm drainage improvements will comply with the ICTF's existing Los Angeles County SUSUMP, as required by its existing NPDES permit. The proposed Project is not expected create additional stormwater runoff, as there will be no increase in impervious surface area associated with the proposed Project. Therefore, no changes to or increases in stormwater are expected due to the proposed Project. This issue will not be further analyzed in the EIR.

d. **Would the Project have sufficient water supplies available to serve the Project from existing entitlements and resources, or are new or expanded entitlements needed?**

No Impact. Potable water is provided to the ICTF by the LADWP. LADWP is responsible for supplying, conserving, treating, and distributing water for domestic, industrial, agricultural, and firefighting purposes within the City of Los Angeles. The proposed ICTF Project will occur at a facility within an area of existing industrial facilities. Water use during construction activities associated with the proposed Project is expected to be limited to water for dust-suppression activities. No substantial increase in water demand is expected for the operation of the proposed Project, as water use is generally limited to the worker use within the administration buildings and no increase in workers is expected. LADWP will continue to provide drinking water and wastewater disposal services. Therefore, no impacts on potable water or wastewater treatment facilities are expected. This issue will not be further analyzed in the EIR.

e. Has the wastewater treatment provider, which serves or may serve the Project, determined that it has adequate capacity to serve the Projected demand of the Project in addition to the provider's existing commitments?

No Impact. Please refer to the discussion in XVIa above. The proposed Project is not expected to impact the wastewater treatment provider and therefore will not be further analyzed in the EIR.

f. Is the Project served by a landfill with sufficient permitted capacity to accommodate the solid waste disposal needs of the Project?

Less Than Significant Impact. Construction activities associated with the proposed Project are expected to generate additional waste material associated with the removal of concrete and equipment. Concrete is expected to be sent to an onsite crushing plant where it will be recycled into useable product and will not adversely impact landfill capacity. Equipment that will be removed, such as hostlers and RTG cranes, is expected to be sold or taken to another site for use or would be scrapped for their metal content. Although the specific use or fate of the equipment may not be known at this time, the equipment would not be sent to a landfill because it has monetary value as usable equipment or scrap metal and thus, will not impact landfill capacity. Solid waste in the form of construction debris and railroad ties could also be generated during the construction phase.

As of January 2006, the total remaining permitted Class III landfill capacity in Los Angeles County is about 104 million tons (see Table 2.3). Based on the 2005 approximate average disposal rate of 31,000 tons per day (tpd) (6-day week), excluding waste being imported to the County, the LACDPW anticipates that landfill capacity in the county could be exceeded in approximately 10.8 years (LACDPW, 2007).

TABLE 2.3

LOS ANGELES COUNTY LANDFILL STATUS

LOS ANGELES COUNTY	Total Waste Disposed 2005 (tons)	2005 Average Tons per Day (tpd)	Average Tons per 6 Day Week	Permitted tons/day	Remaining Permitted Capacity (million tons) (as of 1/01/06)	Estimated Life Or Year of Closure[1]
CLASS III LANDFILLS						
Antelope Valley #1	371,000	1,189	7,134	1,400	10.21	26 years
Bradley[2]	270,000	864	5,184	10,000	0.09	Closed 4/07
Burbank (Burbank use only)	42,000	133	798	240	3.00	2053
Calabasas (Calabasas Watershed use only)	553,000	1,772	10,632	3,500	8.81	15 years
Chiquita Canyon	1,549,000	4,965	29,790	6,000	13.74	8 years
Lancaster	469,000	1,503	9,018	1,700	17.66	5 years[3]
Pebbly Beach (Avalon)	3,000	10	60	49	0.10	2033
Puente Hills #6	3,913,000	12,543	73,518	13,200	32.30	7 years
Scholl Canyon (Scholl Canyon Watershed use only)	453,000	1,452	8,712	3,400	6.80	14 years
Sunshine Canyon (County)	1,411,000	4,521	27,126	6,600	1.95	1 year[4]
Sunshine Canyon (City) [5]	571,000	1,831	10,986	5,500	5.33	4 years[4]
Savage Canyon - Whittier	92,000	294	1,764	350	4.60	2025
TOTALS	**9,697,000**	**31,077**	**184,722**	**51,939**	**104.59**	
UNCLASSIFIED LANDFILLS						
Azusa Land Reclamation Co.	164,000	460	2,760	6,500	36.54[6]	2025[7]
Peck Road Gravel Pit	6,000	18	108	1,210	9.79	Closed 1/08[7]

LOS ANGELES COUNTY	Total Waste Disposed 2005 (tons)	2005 Average Tons per Day (tpd)	Average Tons per 6 Day Week	Permitted tons/day	Remaining Permitted Capacity (million tons) (as of 1/01/06)	Estimated Life Or Year of Closure(1)
TOTALS	**170,000**	**478**	**2,868**	**7,710**	**46.33**	
TRANSFORMATION FACILITIES						
Commerce Refuse to-Energy Facility	101,000	325	1,950	1,000	466.64	15 years(8)
Southeast Resource Recovery Facility	484,000	1,487	8,922	2,240	1,602.45	15 years(8)
TOTALS	**585,000**	**1,812**	**10,872**	**3,240**	**2069.09**	

Sources: CIWMB web site: www.ciwmb.cs.gov/SWIS; 2005 Annual Report, LAC Countywide Integrated Waste Management Plan, LACPDW, June 2007 (LACDPW, 2007).

Notes: (1) As January 1, 2007 as cited in LACPDW, 2007; (2)The Bradley landfill closed in April 2007; (3) Current CUP expires in August 2012; (4) On 2/6/07,the Board of Supervisors approved a new CUP establishing a 30-year life. Provided certain conditions are met, the total available capacity of the combined landfills is 74.3 million tons; (5) City of LA portion opened July 2005, currently operating at 4,400 tpd; (6) By Court order, on 10/2/96, the RWQCB ordered the Azusa Land Reclamation Landfill to stop accepting MSW. Permitted daily capacity of 6,500 tpd consists of 6,000 tpd of refuse and 500 tpd of inert waste. Facility currently accepts inert waste only; (7) per CIWMB web site: www.ciwmb.cs.gov/SWIS; (8) Assumed to remain operational during the 15-year planning period, LACPDW, 2007, Appendix E-2.1.

The total remaining permitted inert waste capacity in Los Angeles County was estimated at approximately 46 million tons. Los Angeles County is planning two new inert waste facilities in Irwindale (United Rock Pit #3 and Irwindale Rock Plant D.S.). There is expected to be adequate disposal capacity at unclassified landfills and no inert landfill crisis currently exists. There are currently two waste-to-energy facilities (i.e., incinerators) in Los Angeles County with a combined permitted daily capacity of 1,800 tons (6-day week). It is expected that these two facilities will operate at their current permitted daily capacity until the equipment life of the waste-to-energy facilities (incinerators) is exhausted (LACDPW, 2007).

The existing landfill capacity is expected to be sufficient to handle the potential increase in solid waste generated by construction activities associated with the ICTF, as waste would not be generated on a long-term basis. Once construction is complete, construction wastes would no longer be generated.

Solid waste generation from the operation of the proposed Project would not be significant, as the proposed Project's purpose is to accommodate future increased loading and unloading of containers, and significant solid waste generation activities have not been proposed nor are anticipated in connection with the proposed Project. Existing solid waste from the ICTF is transferred to local landfills and no substantial increase in the generation of hazardous or solid waste is expected. This issue will not be further analyzed in the EIR.

Hazardous Waste - Construction activities are not expected to generate significant quantities of hazardous waste. However, hazardous waste could be generated if contaminated soils were encountered or if contaminated materials required disposal (e.g., railroad ties).

There are two hazardous waste (Class I) facilities in California: the Chemical Waste Management Inc. (CWMI) Kettleman Hills facility in King's County, and the Safety-Kleen facility in Buttonwillow in Kern County. Kettleman Hills receives an average of 2,700 tpd and has an estimated 2 million cubic yard (cy) capacity. The facility is expected to continue receiving wastes for approximately 3 years without an expansion or 25 years with an expansion. The facility operators are in the process of obtaining permits for expansion that would increase the landfill's life by another 5 years. The facility operators would then seek a permit for development of a new landfill with a 15-year life (email communication, Fred Paap, Chemical Waste Management Inc.). Buttonwillow receives approximately 960 tpd of hazardous waste and has an approximate remaining capacity of 8.8 million cy. The expectant life of the Buttonwillow Landfill is approximately 40 years (Personal communication, Marianna Buoni, Clean Harbors Buttonwillow, Inc.).

Hazardous waste also can be transported to permitted facilities outside of California. The nearest out-of-state landfills are U.S. Ecology, Inc., located in Beatty, Nevada; USPCI, Inc., in Murray, Utah; and Envirosafe Services of Idaho, Inc., in Mountain Home, Idaho. Incineration is provided at the following out-of-state facilities: Aptus, located in Aragonite, Utah and Coffeyville, Kansas; Rollins Environmental Services, Inc., located in Deer Park, Texas and Baton Rouge, Louisiana; Chemical Waste Management, Inc., in Port Arthur, Texas; and Waste Research & Reclamation Co., Eau Claire, Wisconsin.

The proposed Project may generate hazardous waste from construction activities. There are sufficient hazardous waste facilities available to handle the potential waste generated during construction activities. Operation of the facility is not expected to result in an increase in hazardous waste generation. Therefore, no significant impacts to hazardous waste disposal facilities are expected due to the operation of the proposed project modifications and this issue will not be further analyzed in the EIR.

g. Would the Project comply with federal, state, and local statutes and regulations related to solid waste?

No Impact. The proposed Project would comply with all federal, state, and local regulations pertaining to the disposal of solid waste, including Chapter VI, Article 6, Garbage, Refuse Collection, of the City of Los Angeles Municipal Code; Part 13, Title 42, Public Health and Welfare, of the California Health and Safety Code; and Chapter 39, Solid Waste Disposal. The proposed Project would also comply with the California Solid Waste Management Act (AB939), which requires each city in the state to divert at least 50 percent of its solid waste from landfill disposal through source reduction, recycling, and composting. Because the proposed Project would implement and be consistent with the procedures and policies detailed in these codes, impacts associated with consistency related to laws pertaining to solid waste disposal would result in no impact. This issue will not be further analyzed in the EIR.

h. Other Impacts

Potentially Significant Impact. The ICTF receives electricity from: (1) LADWP via two separate lines supported on poles terminating south of the Facility and north of Sepulveda Boulevard; and (2) SCE via an overheard 12.5 kV distribution line terminating north of Sepulveda Boulevard on a riser pole east of the Dominguez Channel. Six substations are located throughout the ICTF serving various structure and container refrigeration requirements. The proposed ICTF is expected to require an additional 30 MW of electricity to operate the electric WSG cranes and transportation refrigeration units, as well as other facilities operations. The increase in electrical use is potentially significant and the ability of the local utilities to supply the increased electricity will be evaluated in the EIR.

Conclusion

The proposed Project impacts on utilities and service systems are expected to be less than significant for all utilities, except electricity. The potential impacts of the increased use in electricity will be evaluated in the EIR.

XVII. MANDATORY FINDINGS OF SIGNIFICANCE Would the Project:		Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a.	Does the Project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal, or eliminate important examples of the major periods of California history or prehistory?				☑
b.	Does the Project have impacts that are individually limited but cumulatively considerable? Cumulatively considerable" means that the incremental effects of a Project are considerable when viewed in connection with the effects of past Project, the effects of other current Project, and the effects of probable future Project.)	☑			
c.	Does the Project have environmental effects that will cause substantial adverse effects on human beings, either directly or indirectly?	☑			

Checklist Response Explanation

a. **Does the Project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal, or eliminate important examples of the major periods of California history or prehistory?**

Less than Significant Impact. As shown in Section IV – Biological Resources and Section V – Cultural Resources of this environmental checklist evaluation, the proposed ICTF Project is not expected to reduce or eliminate any plant or animal species or destroy prehistoric records of the past. The ICTF is an existing industrial facility that has been previously graded. No biological resources are located onsite and the proposed Project is not expected to extend into biologically sensitive areas. Past disturbance of the site to build the existing ICTF did not uncover any evidence of cultural resources. As a result, it is expected that the proposed Project will not uncover cultural resources or extend into culturally sensitive areas. The proposed Project would not otherwise degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal, or eliminate important examples of the major periods of California history because these are not currently located at the ICTF site. The proposed Project is not expected to eliminate important periods of prehistory, so that no significant adverse impacts are expected.

b. Does the Project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a Project are considerable when viewed in connection with the effects of past Project, the effects of other current Project, and the effects of probable future Project.)

Potentially Significant Impact. The proposed Project may result in cumulatively considerable impacts in the areas of aesthetics, air quality, hazardous and hazardous materials, noise, transportation/traffic, and electric utilities. Several other development projects are currently under construction, including another planned ICTF proposed by BNSF south of the ICTF and refinery-related projects, are planned, or have recently been completed in the vicinity of the proposed Project. For example, the combined air quality impacts from the construction and operation of these other facilities may be cumulatively significant on humans. Similarly, localized traffic impacts in the proposed Project area could also combine with existing traffic and noise in the area to create potentially significant cumulative impacts. Cumulative impacts will be addressed in the EIR.

c. Does the Project have environmental effects that would cause substantial adverse effects on human beings, either directly or indirectly?

Potentially Significant Impact. The proposed Project may cause substantial adverse effects on human beings associated with Project-related noise, traffic, hazardous materials and air quality. Incorporation of mitigation measures that may be identified in the EIR would minimize potential adverse effects on human beings to the maximum extent feasible. Several other development Projects are currently under construction, including another planned intermodal container facility proposed by BNSF south of the ICTF and refinery-related projects, are planned, or have recently been completed in the vicinity of the proposed Project. Similarly, localized traffic impacts in the proposed Project area could also combine with existing traffic and noise in the area to create potentially significant cumulative impacts. The potential effects of the proposed Project on human beings will be evaluated in the EIR.

Chapter Three

References, Acronyms, and Glossary

3.0 References

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3.1 Acronyms

ABBREVIATION	DESCRIPTION
AQMP	Air Quality Management Plan
BMPs	Best Management Practices
BNSF	Burlington Northern Santa Fe
CAAP	Clean Air Action Plan
CARB	California Air Resources Board
CEQA	California Environmental Quality Act
CHE	Cargo Handling Equipment
CY	Cubic Yards
EIR	Environmental Impact Report
GCASP	General Construction Activities Storm Water Permits
GHGs	greenhouse gas emissions
HCP	Habitat Conservation Plan
HDVs	Heavy-Duty Vehicles
ICTF	Intermodal Container Transfer Facility
JPA	Joint Powers Authority
LADWP	Los Angeles Department of Water and Power
LAFD	Los Angeles City Fire Department
LNG	liquefied natural gas
MW	Megawatt
MY	model year
NCCP	Natural Communities Conservation Plan
NPDES	National Pollutant Discharge Elimination System

NOP	Notice of Preparation
NOx	nitrogen oxide
OASIS	Optimization Alternatives Strategic Intermodal Scheduler
POLA	Port of Los Angeles
POLB	Port of Long Beach
PM2.5	particulate matter less than 2.5 microns in diameter
PM10	particulate matter less than 10 microns in diameter
Project	ICTF Expansion and Modernization Project
ROG	reactive organic gases
RTG	Rubber Tired Gantry
SCAB	South Coast Air Basin
SCE	Southern California Edison
SCAQMD	South Coast Air Quality Management District
SCIG	Southern California International Gateway Project
SUSUMP	Standard Urban Stormwater Mitigation Plan
TOS	Terminal Operating System
ULSD	ultra low sulfur diesel
UP	Union Pacific Railroad Company
U.S.EPA	United States Environmental Protection Agency
VOC	volatile organic compounds
WSG	Wide-Span Gantry

3.2 Glossary

TERM DEFINITION

TERM	DEFINITION
Alameda Corridor	A 20-mile long cargo expressway that opened in 2002 for cargo carrying train traffic moving between the Ports and the transcontinental rail network based near downtown Los Angeles.
Ambient Noise	The background sound of an environment in relation to which all additional sounds are heard.
dBA	The decibel (dDB) is one tenth of a bel where one bel represents a difference in noise level between two intensities I1, I0 where one is ten times greater than the other. (A) indicates the measurement is weighted to the human ear.
Drayage	Transportation of containerized cargo by trucks between ports and inland locations in intermodal freight transport.
hostlers	At ICTF, hostlers are diesel-powered off-road equipment that transports containers from storage areas to loading areas (similar to container trucks) and vice versa.
ICTF	Near-dock railyard located approximately 5 miles from the Ports for handling marine cargo containers between the Ports and major railyards near downtown Los Angeles.
Ladder	This is a series of sidings parallel to each other with a set of linked switches for access.
Lead Track (Yard Lead)	The portion of track before the yard ladder used to assemble the train.
Paleontological	Prehistoric life.
Peak Hour	This typically refers to the hour during the morning (typically 7 AM to 9 AM) or the evening (typically 4 PM to 6 PM) in

TERM	DEFINITION
	which the greatest number of vehicles trips are generated by a given land use or are traveling on a given roadway.
Reefer	Refrigerated containers.
Seiches	A vibration of the surface of a lake or landlocked sea that varies in period from a few minutes to several hours and which may change in intensity.
Switching	Trains being guided from one railway track to another at a railway junction.
Top Pick	Crane-type equipment used to pick up and move containers.
Turnout	Areas in the track that permit a train to cross from one line to another.
Unit Train	Train with a single cart type and a single destination.

APPENDIX A

List of Addresses for Property Owners in the Primary Project Area and Potential Operations Areas for Affected Property Owners/Lessees

Vopak	2000 West Loop South, Ste. 2200 Houston, TX 77027
Praxair	39 Old Ridgebury Road Danbury, CT 06810
Fast Lane Transportation	2400 E. Pacific Coast Highway Wilmington, CA 90744
California Carbon	2825 E. Grant St. Wilmington, CA 90744
Alameda Corridor Maint. Facility	445 S. Figueroa St., 31st Fl. Los Angeles, CA 90071-1602
California Sulphur	2250 E. Pacific Coast Highway Wilmington, CA 90744
K&R Transportation, Inc.	3545 Long Beach Blvd., 5th Floor Long Beach, CA 90807
Three Rivers Trucking, Inc.	2300 W. Willow Street Long Beach, CA 90810
L.A. Harbor Grain Terminal	2422 E. Sepulveda Blvd. Long Beach, CA 90810
San Pedro Forklift	1861 N. Gaffey St., Ste. E San Pedro, CA 90731
California Multimodal Inc.	2875 Temple Avenue Signal Hill, CA 90755
Total Intermodal Services	2396 E. Sepulveda Blvd. Long Beach, CA 90810
Flexi-Van	251 Monroe Avenue Kenilworth, NJ 07033
Genobia Turner	1428 E. Gladwick St. Carson, CA 90746-3804
Global Oil Production LLC	2209 E. I St. Wilmington, CA 90744-4037
Gonzalo & Ramiro Venegas	1046 N. Banning Blvd. Wilmington, CA 90744-4604
Harbor Oil Co., Inc.	342 Madison Avenue New York, NY 10173-0002
John C. Taylor	P.O. Box 15271 Long Beach, CA 90815-0271
LA City	400 S. Main St., 8th Floor Los Angeles, CA 90013-1314

LA City Harbor Depart	425 S. Palos Verdes Street San Pedro, CA 90733-0151
LA Co. Flood Control Dist.	500 W. Temple St., Ste. 754 Los Angeles, CA 90012-2700
Livingston Graham, Inc.	16080 Arrow Hwy Irwindale, CA 91706-6601
City of Long Beach	P.O. Box 570 Long Beach, CA 90801-0570
Marcus Mo	2545 Loma Vista Drive Alhambra, CA 91803-4336
Moises Rugerio	914 Farragut Avenue Wilmington, CA 90744-4076
Pamela Andrisani	8701 Remick Avenue Sun Valley, CA 91352-2935
Southern California Edison Co	P.O. Box 800 Rosemead, CA 91770
Watson Land Co	22010 Wilmington Ave., Suite 400 Carson, CA 90745-4372
California Cartage Corporation	3545 Long Beach Blvd., 5th Floor Long Beach, CA 90807
Mortimer & Wallace, Inc.	2422 E. Sepulveda Blvd. Long Beach, CA 90810
City of Long Beach	333 West Ocean Boulevard Long Beach, CA 90802
Alameda Corridor Trans. Authority	One Civic Plaza, 3rd Floor Carson, CA 90745
Balfour Beatty	1017 Foote Avenue Wilmington, CA 90744
Berg & Associates	1017 Foote Avenue Wilmington, CA 90744
B & H Fabricators, Inc.	830 Sampson Avenue Wilmington, CA 90744
Italian Home Marble & Granite	824 Schley Avenue Wilmington, CA 90744-4058
Corpus Truck Repair	906 Schley Avenue Wilmington, CA 90744-4060

Lupes Auto Sales	918 Schley Avenue Wilmington, CA 90744-4060
AJC Sandblasting, Inc.	932 Schley Avenue Wilmington, CA 90744-4060
Ricardos Auto Dismantling	815 MacDonough Avenue Wilmington, CA 90744-4047
El Cid Auto Sales	819 MacDonough Avenue Wilmington, CA 90744-4047
Silva Auto Sales & Wrecking	818 MacDonough Avenue Wilmington, CA 90744-4048
Lovos Auto Dismantler	818 MacDonough Avenue Wilmington, CA 90744-4048
Olmedo Auto Service	828 MacDonough Avenue Wilmington, CA 90744-4048
Wilmington Marine Salv & Whl	822 Cushing Avenue Wilmington, CA 90744-4014
D & R	1040 Cushing Avenue Wilmington, CA 90744-4018
Berg & Associates. Inc.	1017 Foote Avenue Wilmington, CA 90744-4004
Marta Track Constructor	1017 Foote Avenue Wilmington, CA 90744-4004
LG Auto Dismantling	1001 Foote Avenue Wilmington, CA 90744-4004
Chicos Auto Wrecking	905 Farragut Avenue Wilmington, CA 90744-4075
G&G Auto Dismantling	905 Farragut Avenue Wilmington, CA 90744-4075
Delmy U Auto SLS & Dismantling	930 Farragut Avenue Wilmington, CA 90744-4076
Sibrian Trucking	1008 Farragut Avenue Wilmington, CA 90744-4074
H.J. Baker	1001 Schley Avenue Wilmington, CA 90744-4077
Occupant	814 Sampson Avenue Wilmington, CA 90744-4056
Occupant	940 Schley Avenue Wilmington, CA 90744-4060

Occupant	825 Schley Avenue Wilmington, CA 90744-4057
Occupant	815 Schley Avenue Wilmington, CA 90744-4057
Occupant	829 MacDonough Avenue Wilmington, CA 90744-4047
Occupant	831 MacDonough Avenue Wilmington, CA 90744-4047
Occupant	820 MacDonough Avenue Wilmington, CA 90744-4048
Occupant	814 MacDonough Avenue Wilmington, CA 90744-4048
Occupant	903 MacDonough Avenue Wilmington, CA 90744-4049
Occupant	915 MacDonough Avenue Wilmington, CA 90744-4049
Occupant	902 Foote Avenue Wilmington, CA 90744-4008
Occupant	815 Foote Avenue Wilmington, CA 90744-4002

Intermodal Container Transfer Facility (ICTF)
Joint Powers Authority (JPA)
Board Meeting

Scheduled board meeting will include discussion of proposed Modernization and Expansion Project

LONG BEACH, Calif. – The governing board of the Intermodal Container Transfer Facility (ICTF) Joint Powers Authority (JPA) will meet at 6:00 p.m., Tuesday, November 29 at Silverado Park Social Hall located at 1545 West 31st Street, Long Beach. The proposed agenda will include administrative items and an update on preparation of an EIR for the ICTF Modernization and Expansion Project. The agenda will be published on the JPA's website (www.ICTF-JPA.org) once it is finalized. The meeting is open to the public and attendees are welcome to address the JPA Board.

The ICTF serves to enhance the efficient flow of intermodal (truck and rail) cargo through the Port of Los Angeles (POLA) and the Port Long Beach (POLB). The 148 acre facility is located approximately 5 miles north of POLA and POLB, at the northern terminus of State Highway 103 and is operated by Union Pacific.

The ICTF JPA is a public entity created in 1983 to oversee the development and operation of the ICTF. This JPA is administered by a governing board that operates separately and apart from the Cities of Long Beach and Los Angeles.

Union Pacific Railroad has proposed an ICTF Modernization and Expansion Project that would more than double the throughput capacity of the ICTF from 725,000 to 1.5 million containers per year. The proposed Project would incorporate a number of environmental improvements including the use of electric overhead cranes, cleaner yard tractors, and ultra-low emission locomotives. The ICTF JPA has released the Notice of Preparation/Initial Study (NOP/IS) for the proposed Project. The NOP/IS describes the proposed Project and discusses the likely environmental impacts of the Project. These impacts will be fully analyzed and discussed in the Draft Environmental Impact Report (EIR) that is currently being written. Copies of the NOP/IS and previous JPA meeting minutes are available at the JPA website.

* * * * *

For more information, please visit the JPA's website at: www.ICTF-JPA.org or contact Greg Alexander at 562-740-1069.

925 Harbor Plaza, Long Beach, CA 90802
Tel: (562) 590-4133 | Fax: (562) 901-1727
Mailing Address:
P.O. Box 570, Long Beach, CA 90801-0570

425 S. Palos Verdes Street, San Pedro, CA 90731
Tel: (310) 732-3750 | Fax: (310) 831-9778
Mailing Address:
P.O. Box 151, San Pedro, CA 90733-0151

THE PORT
OF LOS ANGELES

Port of Los Angeles

America's Port ™

STRATEGIC PLAN 2006 - 2011

Antonio R. Villaraigosa
Mayor, City of Los Angeles

Janice Hahn
Councilwoman, 15th District

Board of Harbor Commissioners

S. David Freeman
President

Jerilyn López-Mendoza
Vice President

Kaylynn L. Kim
Commissioner

Douglas P. Krause
Commissioner

Joseph R. Radisich
Commissioner

Senior Management

Geraldine Knatz, Ph.D.
Executive Director

Michael Christensen
Deputy Exectuive Director Development

Molly Campbell
Deputy Exectuive Director
Finance and Administration

Captain John M. Holmes
Deputy Executive Director Operations

Kathryn McDermott
Deputy Executive Director
Business Development

Arley Baker
Director
Public Relations and Legislative Affairs

Thomas A. Russell
General Counsel

PORT OF LOS ANGELES

The Port of Los Angeles is among the world's premier ports and is a critical hub for global trade. This prominence brings with it responsibilities and expectations for the highest possible standards for efficiency, safety and security, and environmental leadership.

Booming Asian trade has made Los Angeles the nation's busiest container port – and part of the world's fifth busiest port complex, handling 8.4 million twenty-foot equivalent units (TEUs) in 2007. The six-county metropolitan area surrounding the Los Angeles Harbor is home to 21.2 million residents, 485,000 businesses and – with more than 930,000 workers – is one of the largest U.S. manufacturing centers. The Port is the optimal gateway for Pacific Rim cargo moving to Sunbelt and Southeastern United States factories and distribution centers.

San Pedro Bay, which includes both the ports of Los Angeles and Long Beach, receives more than 42% of total U.S. waterborne containerized imports, with some 70% of such imports coming from Asia. Container cargo moving across Port of Los Angeles docks has doubled since 1999, and tripled since 1995. The Port's 7,500 acres, 43 miles of waterfront, 270 berths and 26 cargo terminals represent a critical segment of the U.S. trade infrastructure and the global supply chain.

In addition to containerized cargo, the Port's diverse maritime operations handle bulk products, scrap metal, steel, and cruise passengers. But it is container traffic, with its double-digit annual growth over much of the past decade that poses the greatest challenge for all U.S. ports, especially those on the West Coast. Regularly scheduled vessel calls, and the increasing need for more terminal acreage and more efficient operations, contribute to this challenge. Port staff is also focused on transforming the Port into a model environmental-friendly gateway through the implementation of the San Pedro Bay Ports Clean Air Action Plan, which promotes a "grow green" philosophy.

THE PORT OF LOS ANGELES

PORT OF LOS ANGELES - **STRATEGIC PLAN**

DEFINITION: *A strategic plan is a management tool used to improve the performance of an organization and outlines the organization's direction and priorities.*

OBJECTIVES: *This summary identifies the twelve (12) strategic objectives for the next five years. Each of the objectives identifies a series of initiatives/action items that the Port will undertake to accomplish that objective.*

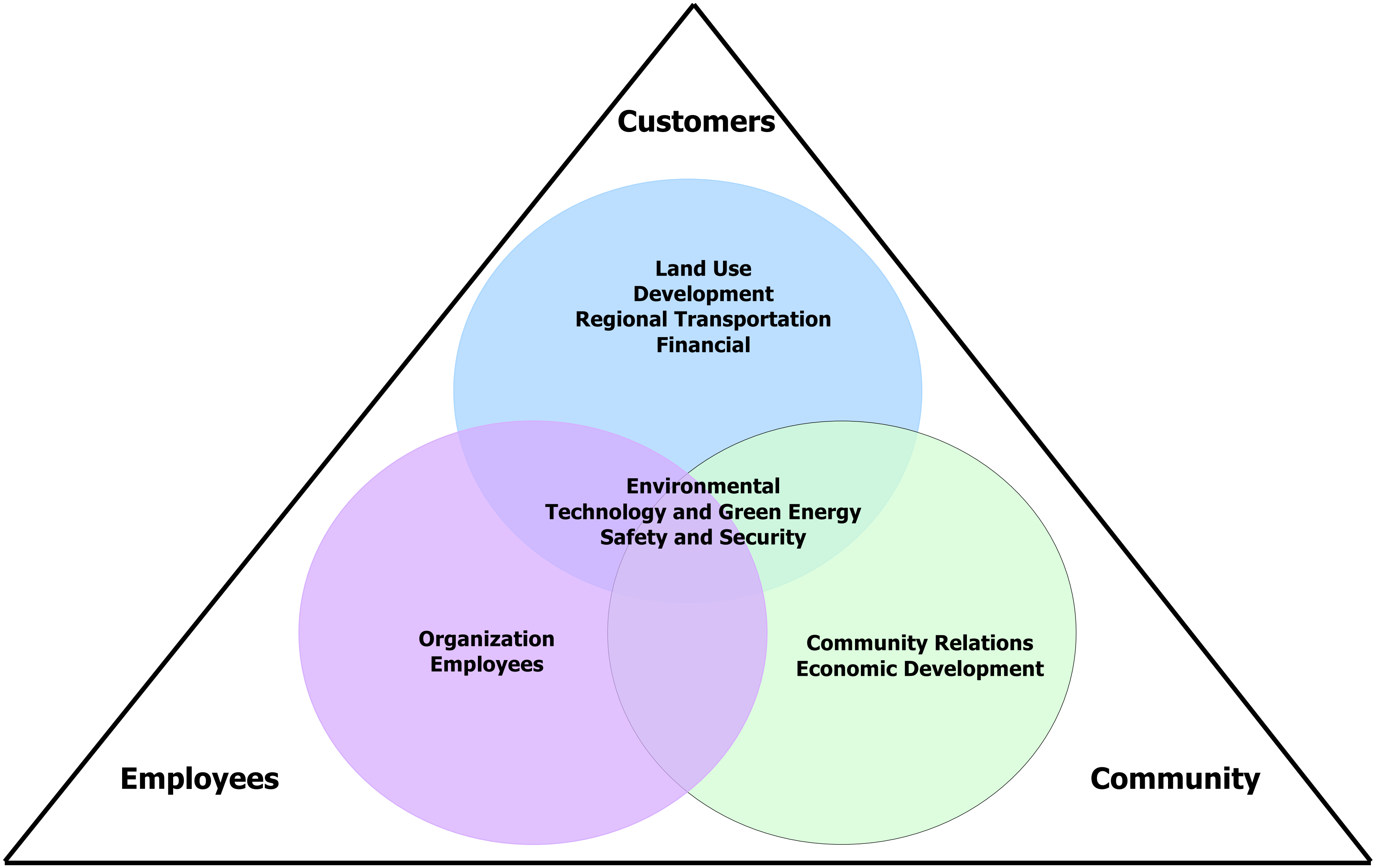
Initiatives are shaded by color, see below:

- **BLUE:** **Denotes consistency with Mayor Villaraigosa's four-year strategic plan**
- **RED:** **Targeted for Fiscal Year 2008/09**
- **GREEN:** **Completed in Fiscal Year 2007/08**
- **BLACK:** **Will be identified during the budget preparation process for each subsequent year of this plan**

Any and all projects would be subject to CEQA review

PORT OF LOS ANGELES – **OUR MISSION**

To be the world's premier port in planning, design, construction, maintenance and security, and to promote a "grow green" philosophy, while embracing evolving technology and meeting our fiduciary responsibilities while promoting global trade.


Customers
Land Use
Development
Regional Transportation
Financial
Environmental
Technology and Green Energy
Safety and Security
Organization
Employees
Community Relations
Economic Development
Employees
Community

LAND USE

Strategic Objective: **Ensure the Port maintains and efficiently manages a diversity of cargo and land uses; maximize land use compatibility and minimize land use conflicts**

Initiatives/Action Items:

Marketing Plan

- Develop and maintain an annual strategic marketing plan that highlights improvements to customer service and builds relationships with beneficial cargo owners, shipping lines, and terminal operators
- Continuously identify and communicate customer-focused messages that support the Business Development Plan's goals and objectives, while promoting the Port of Los Angeles brand

Land Use Planning

- Develop a conceptual facilities plan for a maritime research complex at City Dock No. 1 that will accommodate academic and governmental marine research labs, a research and development park and business incubator for emerging marine environmental companies and educational support facilities.
- Develop an Ancillary Uses plan that addresses the land and water needs of a variety of harbor support services (tugboats, barges, water taxis, pilots, sportfishing and harbor tour vessels) as well as public safety facilities, consistent with the comprehensive port land use plan
- Develop a specific plan for the long term use of Knoll Hill after the relocation of the temporary use by Eastview Little League
- Maximize water-dependent uses at all waterfront facilities

Made it Happen in 2007/08

- Updated cargo forecast examining potential long-range influence of Mexican and Canadian ports and the Panama Canal expansion
- Developed a comprehensive land use plan that recognizes the needs of commerce and recreation; establish land areas that consolidate liquid bulk storage facilities; retain economically viable breakbulk operations; promote the expansion of water-dependent institutional/research facilities and develop appropriate recreational facilities
- Consolidated and modernized proposed commercial fishing facilities that meet fishing industry forecasts and local fishing industry needs

DEVELOPMENT

Strategic Objective:	**Maximize the efficiency and the capacity of current and future facilities**
Initiatives/Action Items:	**Customer Needs** o Identify existing customers' expansion plans along with growth opportunities and pursue development that meets their needs **Facility Development and Maintenance** o Implement the San Pedro and Wilmington Waterfront infrastructure elements within five years o Develop and implement an affordable multi-year capital improvement program to modernize facilities and improve security and safety o Modernize recreational boating facilities in Wilmington and in the San Pedro West Channel **Aesthetics** o Create a physical presence, particularly at the port/community interface, that is distinctive, recognizable, and well maintained throughout the Port o Implement the Mayor's Million Trees L.A. Planting Program within the Port area

REGIONAL TRANSPORTATION

Strategic Objective:	**Define and address infrastructure requirements needed to support safe, environmentally friendly, and efficient goods movement throughout the region**
Initiatives/Action Items:	**Transportation Studies/Plans/Projects** o Update transportation and trip generation models for use in upcoming EIRs and the I-710 Corridor EIS/EIR o Analyze Port rail needs, including on-dock and off-dock (SCIG, ICTF, APL, and other POLA projects) o I-110 Connectors: Caltrans Project Report traffic studies; needed for environmental documentation, PS&E, and CTC final allocation of Prop 1B funds o Electric Container Mover System (ECMS): Working with ACTA and POLB, evaluate possible Ports area project in conjunction with I-710 effort o I-710: As funding/management partner with METRO, oversee project, including evaluation of ECMS working with ACTA and POLB **Funding Mechanisms** o Prop 1B TCIF: Secure Prop 1B TCIF and Air Quality funds (support role): On-going advocacy o Implement Infrastructure Cargo Fee; revenue collection scheduled to begin January 1, 2009 o Advocate for funded "freight program" in re-authorization of federal surface transportation program (SAFETEA-LU); seek fair share of funds for Southern California and ports area projects

FINANCIAL

Strategic Objective: **Maintain financial self-sufficiency and generate sufficient funds to implement strategic and policy priorities**

Initiatives/Action Items:

Compensation Strategies

- Develop an equitable compensation strategy for Port leases while promoting business objectives of the customer and the Port

Budget Accountability

- Establish accountability of the budget process within each division

Insurance & Risk Management

- Review and improve Port insurance requirements
- Develop a wellness program that benefits all Port employees
- Provide a health fair for all employees that is as successful as last year's
- Reduce Injury on Duty and the associated costs from FY 2008 levels
- Increase safety training, particularly in those divisions with a high frequency of claims

Enhance Ability to Set Priorities for the Port's Financial Resources

- Increase usefulness of the operating budget as a management planning tool for near-term resource allocation

Increase Financial Transparency and Monitoring

- Refine financial management reporting to support decision making
- Focus internal audits to increase operational efficiency
- Modernize the Port's accounting systems

Protect Port's Financial Assets

- Streamline contracts and purchasing processes, while maintaining appropriate safeguards

Made it Happen in 2007/08

- Developed comprehensive capital plan to assist management with long-term priority setting
- Implemented new budget system
- Completed audits of the Engineering and Construction & Maintenance divisions

ENVIRONMENTAL

Strategic Objective: **Transform the Port of Los Angeles into the greenest port in the world by raising environmental standards and enhancing public health**

Initiatives/Action Items:

Clean Air Action Plan (CAAP)

- Implement the Clean Air Action Plan
- Promote adoption of Clean Air Action Plan measures internationally

Sustainability Ethic

- Incorporate sustainability ethic into all Port activities and communicate to employees, customers, and the community

CEQA/Mitigation

- Conduct timely, user friendly CEQA evaluations of waterfront projects and terminal improvements, and utilize mitigation as an implementation strategy for environmental action plans toward "growing green"

Clean Water/Habitat Plans

- Create and implement water resources action plan (WRAP) and habitat management plan, including pursuing additional habitat mitigation projects

Clean Soil & Groundwater

- Create and implement clean soil and groundwater action
- Complete remedial action planning in support of key port waterfront and terminal projects and properties

Compliance Measures

- Provide an environmental compliance program for Port and customer construction and operations in support of the environmental directive of the Port's Leasing Policy

Made it Happen in 2007/08

- Adopted Green Building Policy and Sustainable Construction Guidelines
- Completed Phase 1 Cabrillo Beach Sand Replacement Project

TECHNOLOGY AND GREEN ENERGY

Strategic Objective: **Be the leading port for new, emerging and environmentally-friendly cargo movement technology and energy sources**

Initiatives/Action Items:

Alternative Cargo handling and Transportation Equipment

- Develop prototype Electric Rubber-Tired Gantry Crane (ERTG)
- Explore emerging alternative container transport technology that can be used within and beyond Port boundaries
- Continue development of electric-powered heavy-duty truck for short haul drayage and terminal operations
- Facilitate conversion of terminal operating systems to electrical power
- Advance technological programs that will achieve the long-term goal of an emissions-free port

AMP Power Rates

- Develop power rate structures with Los Angeles Department of Water and Power (LADWP) to enhance customer receptivity to Alternative Maritime Power (AMP)/Cold-ironing

Green Power Investments

- Pursue investment in green power production with LADWP to ensure power rate stability for Port customers
- Install the first 1MW of solar power at the Port
- Working with LADWP, implement a Power Purchase agreement as a basis for the remaining 9MW of solar power at the Port
- Encourage Port tenants to implement solar power projects

Made it Happen in 2007/08

- Executed MOU with Attorney General for solar production within the Port

SAFETY AND SECURITY

Strategic Objective: **Transform the Port into a world-class model for crime prevention, counter-terrorism detection, and emergency incident response and mitigation**

Initiatives/Action Items:

Public Safety – Enhance the safety of the Port and the community by:

- Expanding the Port Police personnel, facilities, and operations
- Establishing a police substation in Wilmington and increase marine and land patrol
- Establishing 24-hour waterborne patrol
- Expanding Port Police communication capabilities
- Enhancing vehicle and cargo inspection capabilities
- Developing Port-wide and City-wide emergency operations contingencies
- Continuing the "Responsible Marina" program

Homeland Security/Emergency Preparedness – Improve the capability of the Port to prevent or detect an event, to respond to an incident, mitigate its effects on the Port and the community and resume critical operations by:

- Installing of a Port-wide emergency public notification system
- Updating emergency procedure and Port recovery plans
- Conducting a real-time evacuation exercise that involves the Port and the community
- Continuing security upgrades at all critical locations
- Working with Transportation Security Administration (TSA) to initiate implementation of the TWIC security credentialing program
- Promoting increased scanning of cargo prior to loading at overseas ports
- Developing a security awareness training program for Port, terminal, and dock workers
- Enhancing outreach to terminals, labor, and educational institutions

OPERATIONS, CONSTRUCTION AND MAINTENANCE

Strategic Objective:	**Transform the Port into a world-class model for safe and efficient operations and outstanding customer service**
Initiatives/Action Items:	**Port Operations and Maintenance – Enhance operational efficiency and service to our customers by:** o Improving internal communications in the Operations Bureau o Automating pilot and dockage invoicing o Streamlining access to truck gate, rail gate, and ACTA data for improved revenue verification o Implementing internet-based pilot order system o Implementing an electronic customer feedback system o Implementing the operational aspects of the Clean Truck Program o Implementing the Construction and Maintenance Division (C&M) Audit Recommendations **Made it Happen in 2007/08** o Implemented a "Responsible Marina" program

COMMUNITY OUTREACH

Strategic Objective:

Strengthen relations with local community members through meaningful interaction and community focused programs

Initiatives/Action Items:

City Planning/Community Redevelopment Agency (CRA) Partnerships

- Develop a partnership with the City Planning Department and the Community Redevelopment Agency (CRA) to effectively plan physical and economic linkages between the Port and the community

Port Community Advisory Committee (PCAC)

- Assess PCAC's role and mission and implement adjustments that benefit the Port and the community

Community Support

- Expand the Port's network of supportive Harbor Area businesses and residents

Education

- Expand our region-wide outreach programs through the new POLA mobile exhibit, a multi-tier Speakers Bureau program, a re-launched "CommunityConnect" program and a more automated booking process for POLA's successful school boat tour and field trip programs

Made it Happen in 2007/08

- Executed loan to CRA
- Utilized the Port's year-long Centennial Celebration as a milestone opportunity to educate Southern Californians and out-of-area visitors about the Port

ECONOMIC DEVELOPMENT

Strategic Objective:	**Realize the potential of the diversity of L.A.'s population by expanding opportunity and inclusion. Develop more and higher quality jobs**
Initiatives/Action Items:	**Jobs/Economic Impacts** o Promote economic development in San Pedro and Wilmington o Include the Port in the redevelopment districts **Small Business Enterprise** o Develop a mentoring program **Workforce Development Program** o Facilitate entry into workforce for all residents by creation of a workforce development program **CDD/CRA Partnerships** o Develop a partnership with the Community Development Department (CDD) and Community Redevelopment Agency (CRA) to promote economic and career development in the surrounding communities **Outreach** o Conduct outreach programs in various Los Angeles City neighborhoods that focus on trade and business opportunities with the Port **Made it Happen in 2007/08** o Identified the jobs and economic impacts the Port provides to the local communities o Initiated visioning process for maritime research facilities at City Dock No. 1 o Developed a Small Business Enterprise (SBE) program o Selected Director of Economic Development

ORGANIZATION

Strategic Objective: **Ensure Port leadership, staff and facilities are in place to meet current and future workforce needs**

Initiatives/Action Items:

Leadership Development

- Develop the leaders of the organization to meet current and future needs

Training

- Enhance and develop staff skills and capabilities by working with each Bureau head to explore and assess staff needs

Information Technology

- Upgrade our information technology systems

Workplace Environment

- Create a safe, healthy and comfortable working environment for employees that encourages collaboration and team building

Workers' Compensation

- Strive for continued positive trends in workers' compensation claims, Injury on Duty hours, and light duty through safety training and communication

Made it Happen in 2007/08

- Initiated five year IT strategic plan development
- Enhanced labor relations through the use of a newly created specialized position
- Reviewed the role of Construction and Maintenance Division and ensured the proper amount of equipment and staff are in place to meet future needs

EMPLOYEES

Strategic Objective: **Make the Port a Great Place to Work**

Initiatives/Action Items:

Morale

- Review, assess, and implement actions that improve employee morale
- Increase laughter by 30%
- Work with the A-Team to make recommendations to senior management on action items needed to address the areas needing improvement as described by our 2007 Employee Opinion Survey

Communications

- Improve communication and information sharing with employees by emphasizing the five 2008/09 Budget Priorities frequently so that all employees can use them as a guide in prioritizing their daily work

Recruitment and Retention

- Seek ways to become competitive to attract and retain quality employees

Office Space

- Develop short-term and long-term plan to provide adequate facilities for employees, including a gathering space within the existing facility for employee informal collaboration

Empowerment

- Create a culture that supports strategic thinking at all levels and quality internal customer service
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ENVIRON

Date: September 2, 2009

MEMORANDUM

To: Mark Stehly

From: Rob Scofield and Linda Hall

Subject: **Draft Environmental Assessment for the BNSF Intermodal Facility Proposed by BNSF Railway Company near Gardner, in Johnson County, Kansas**

This memorandum addresses two broad issues either raised in or implicit to the comments on the **Draft Environmental Assessment for the BNSF Intermodal Facility Proposed by BNSF Railway Company near Gardner, in Johnson County, Kansas** (EA) submitted by Andrea Hricko (University of Southern California) and by the Natural Resources Defense Council (NRDC) specifically:

1. The reasons that health risks calculated for railyards in California are not directly applicable to the Gardner, Kansas facility; and
2. The reasons USEPA cited for their conclusion that the approach adopted by California for quantifying cancer risk is not valid.

In the following discussion, we address each of these issues in turn.

1. **The reasons that health risks calculated for railyards in California are not directly applicable to the Gardner, Kansas facility;**

    Expanding on the comments by Harold Holmes of California's Air Resources Board (CARB) (Kansas City Star, 2007) on this topic, we note that the physical features of any air emission source have an important influence on the estimated air concentrations and health risks. In particular, the proximity of houses to specific rail yard operations will have substantial influence on the risks estimated for the Maximally Exposed Individual (MEI); and when discussing estimated risks for rail yards the estimated risk at the MEI is the value most commonly cited. Estimated risks are also dependent on specific assumptions for emissions, dispersion, exposure and toxicity of chemicals. For any particular evaluation, the selection of these assumptions is guided by local regulatory authorities. California has specific assumptions that must be used for emission factors, dispersion modeling, exposure frequency, and toxicity of chemicals (e.g. diesel exhaust). Some of the assumptions required for use in California differ substantially from the USEPA guidelines used for the Gardner evaluation. Accordingly, estimated health risks for identical facilities in California and Kansas would be quite different because of the distinct set of guidelines used in each analysis. Simple ratios between the number of lifts and estimated health risks, such as are discussed in comments on the EA, are not valid.

    Among the more important specific factors rendering invalid the use of ratios between measures of throughput (e.g., numbers of lifts) and estimated health risks are the fact that each railyard is distinct with respect to the local meteorological conditions, the type of equipment used, the activity patterns of the equipment, and the location and number of people who work or live in the vicinity or each yard Additionally, California calculates cancer risk from DPM based on an approach that has been rejected by the USEPA. These differences are discussed below.

Meteorology. The local meteorologic conditions in the vicinity of a railyard, such as predominant wind speed and direction, temperature, barometric pressure, and cloud cover (as well as the variability in each of these factors), are key determinants of any potential health effects associated with the yard. These factors are important in that the local meteorology governs the direction that emissions might be carried and the extent of their dispersal. Because of the significance of these parameters to health effects estimation, the USEPA has strict meteorologic data requirements for modeling emissions. These requirements are for one-year or five years of representative data on each of the aforementioned parameters, depending on whether the data were obtained on-site or off-site, respectively (USEPA, 2005). Meteorological data cannot be extrapolated between railyards (or between any other facility) unless they are in direct proximity to each other. Consequently, it is clear that extrapolation of such data between California and Kansas - states with dramatically different climate and meteorological regimens - is not supported (USEPA, 2004a,b; 2005). The statement that,"[s]ince the wind at the Gardner IMF proposed location apparently blows toward the town of Gardner, including toward a subdivision and two schools within a mile of the proposed IMF, there is every reason to believe that there will be elevated cancer risks as a result of the Gardner IMG (sic)", has no technical merit, cannot be substantiated, and is contradicted by the emission estimation, dispersion modeling, and health evaluation that was completed and included in the EA.

Equipment Usage and Activity. Commensurate with their individual design and geographic location, each BNSF railyard is used to conduct either different activities or a different combination of activities, and each uses a unique mix of equipment as a consequence. These differences have a substantial impact on the emissions from a railyard, making direct comparisons between yards invalid. For example, compared to BNSF's San Bernardino facility, the Argentine intermodal facility has approximately one-third fewer lifts, and compared with BNSF's Hobart yard about 70% fewer lifts. The Argentine intermodal facility has less classification and train building activity compared to other intermodal facilities, so the switching engines have fewer hours of activity relative to the number of lifts. Additionally, the majority of the arriving and departing trains at the Argentine facility are of the "setout" type, which only stop to cut off rail cars before moving on. This reduces the line-haul locomotive activity, especially idling, compared to San Bernardino or Hobart. Also, there are very few refrigerated containers with auxiliary diesel engines operating at Argentine. Lastly, while Argentine activity levels have been used to project future lift levels at the proposed new intermodal facility, the new facility will have several design features that will minimize emissions compared to even Argentine. These include electric overhead cranes, automated gate technology for truck arrivals and departures, and long tracks to accommodate whole trains, thus minimizing switch locomotive usage.

Impacted Communities. Any calculated impacts from a railyard are also a function of the proximity and number of individuals in the vicinity – factors that are unique to each railyard, and which preclude direct comparisons of health effects between yards. For example, Harold Holmes of the CARB has noted (Kansas City Star, 2007) that the CARB estimated relatively high cancer risks from the BNSF San Bernardino yard because individuals lived in the immediate vicinity of concentrated emissions. However, higher emissions at the BNSF Barstow yard did not have comparable risks because emissions were dispersed prior to reaching the local community.

Furthermore, many of the health studies cited by Ms. Hricko and the NRDC as evidence of railyard-related health impacts are studies of populations exposed to multiple sources of industrial and transportation-related emissions (e.g., freeways) and photochemical smog in southern California, and the implication that the health effects observed in these studies can be attributed to emissions from one or more intermodal railyards in southern California is misleading. To further imply that such health effects could be expected from a single intermodal railyard in Kansas, or anywhere else, is even more misleading.

To address the noncancer health effects of diesel exhaust, the USEPA has developed a Reference Concentration. As shown in the EA, the exposure to diesel exhaust from the Gardner facility would be less than the USEPA exposure limit designed to prevent noncancer health effects (i.e. the Reference Concentration).

Calculation of Cancer Risks. For reasons explained in more detail below, the approach required in California for estimating cancer risks from diesel emissions was explicitly rejected by the USEPA as a valid way to evaluate cancer risks from diesel emissions. Because California's approach to estimating cancer risk is not accepted outside of California, any comparison of cancer risks from California rail yards to the Gardner facility is not applicable.

2. The reasons USEPA cited for their conclusion that the approach adopted by California for quantifying cancer risk is not valid.

Diesel exhaust is a complex mixture of hydrocarbons, particulates, gases, water, and other compounds (the precise composition of the mixture depends on many factors, including the fuel source, engine type, engine age, and operating condition). For both the USEPA and California, the general approach to estimating cancer risk from exposure to mixtures - such as combustion exhaust - is to select a subset of so-called indicator chemicals (e.g., the principal components of the exhaust), multiply the estimated concentration of each by a chemical-specific cancer slope factor (CSF), and then add the risks estimated for each indicator chemical. That is, the sum of the health risks from each individual chemical is used as an estimate of the risk posed by the mixture as a whole. Under current USEPA risk assessment practice this approach is used, for example, when estimating health risks from combustion of fuels such as gasoline, fuel oil, wood, natural gas, etc. While California also generally relies on this indicator chemical approach for quantifying cancer risks from mixtures, they have developed an alternative approach for quantifying cancer risks from diesel exhaust. In contrast to the approach used for other mixtures, California developed a CSF to represent the carcinogenicity of the entire mixture of chemicals in diesel exhaust, using diesel particulate matter (DPM) as a surrogate for that mixture (Office of Environmental Health Hazard Assessment [OEHHA], 1998). Both California and the USEPA have adopted a concentration limit of 5 ug/m^3 for diesel exhaust particulate matter (DPM) as a way to evaluate the noncarcinogenic health effects of diesel exhaust.

California's CSF was developed from epidemiology studies on rail road workers in which quantitative correlations were drawn between exposure to diesel exhaust and the incidence of lung cancer. Whether these epidemiology studies are adequate to support development of a CSF for diesel exhaust, using DPM as a surrogate, is the central issue in the different approaches used to quantify diesel exhaust-attributable risk by California and the USEPA.

One of the studies central to California's analysis was that of Garshick et al. (1988). The Garshick et al. (1988) study represents a retrospective analysis of 55,407 white male railroad workers from across the U.S. The lung tumor incidence for these railroad workers was reported in Garshick *et al.* (1987, 1988) and the estimated exposures were reported in Woskie *et al.* (1988a,b).

The USEPA (2002) identified a number of limitations in the Garshick et al. (1988) data, including:

- inadequate information on exposure to diesel exhaust (i.e., assigning who was exposed and who was not exposed),
- lack of knowledge of when workers first began working with diesel equipment, and
- lack of information on smoking and other lifestyle correlates of lung cancer risk.

Of particular concern to the USEPA, to Dr. K. Crump (1991, 1999, 2001) and to the members of an expert panel[1] was the fact that lung cancer risks among the exposed workers decreased with increasing length of exposure – the opposite biological effect from what is expected for a carcinogen. Additionally, one of the categories of workers potentially exposed to high levels of DPM (shop workers), had no elevated cancer risk. Because of these findings, the USEPA has not adopted a CSF (or unit risk factor) for diesel exhaust emissions, stating that, "the available data are too uncertain at this time" (USEPA 2002).

We note that Garshick subsequently published the results of a longer follow-up study of the same workers and found the same trend (Garshick et al., 2004) - suggesting that the original observation of a negative correlation between exposure and lung cancer risk was not an artifact attributable to a truncated follow-up period. Despite the passage of seven years since the original analysis, the USEPA has not revised its position on the adequacy of available data on DPM, has not developed a CSF (USEPA, 2009), and has not adopted California's CSF for DPM.

While the USEPA approach to estimating health risks for mixtures is as discussed above, the USEPA and several states have elected to address the carcinogenicity of diesel exhaust by promoting emission reducing technologies without quantifying cancer risks.

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[1] The Diesel Epidemiology Expert Panel was formed by the Health Effects Institute (HEI), a not-for-profit research organization jointly funded by the USEPA and the automobile and trucking industries.

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UNITED STATES DISTRICT COURT

CENTRAL DISTRICT OF CALIFORNIA, WESTERN DIVISION

ASSOCIATION OF AMERICAN RAILROADS, BNSF RAILWAY COMPANY, AND UNION PACIFIC RAILROAD COMPANY, Plaintiffs, vs. SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT; THE GOVERNING BOARD OF SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT, Defendants.	Case No. CV06-1416 JFW (PLAx) ASSOCIATION OF AMERICAN RAILROADS, BNSF RAILWAY COMPANY, AND UNION PACIFIC RAILROAD COMPANY'S POINTS AND AUTHORITIES IN SUPPORT OF MOTION FOR AN ORDER TO SHOW CAUSE WHY SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT AND ITS EMPLOYEES SHOULD NOT BE HELD IN CIVIL CONTEMPT OR, IN THE ALTERNATIVE, AN ORDER OF CONTEMPT Date: January 9, 2012 Time: 1:30 PM Place: Courtroom of the Honorable John F. Walter, Unites States District Judge

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I. INTRODUCTION.

The South Coast Air Quality Management District ("SCAQMD" or "District"), and employees of the District have violated and continue to violate this Court's May 18, 2007 Judgment and Permanent Injunction ("Final Injunction") by taking steps to implement and enforce enjoined District Rules 3501 and 3502. After a full trial on the merits, this Court ruled that District Rules 3501, 3502 and 3503, as adopted by the Governing Board of the District, are preempted in their entirety by the Interstate Commerce Commission Termination Act of 1995 ("ICCTA"), 49 U.S.C. § 10101 *et seq.* Ct. Doc. 193 at 1:15-18.[1] Additionally, this Court held that the District lacked authority under state law to promulgate the District Rules. As a result, this Court adjudged and decreed that:

> [T]he District, its Governing Board, and their board members, officers, agents, employees, attorneys and all others acting in concert or participation with them, are hereby *permanently enjoined from implementing or enforcing* any provision of Rules 3501, 3502 or 3503.

Id. at 1:19-23 (emphasis added). This Court's ruling was upheld and affirmed without modification by the Ninth Circuit Court of Appeals on September 15, 2010. Ct. Doc 224 (Ninth Circuit Mandate entered the judgment of the District Court on October 12, 2010); *Ass'n. of Am. R.Rs. v. S. Coast Air Quality Mgt. Dist.*, 622 F.3d 1094 (9th Cir. 2010).

In violation of the express terms of the Final Injunction, the District, through various employees, including Executive Officer Barry Wallerstein, Deputy Executive Officer for Planning, Rule Development & Area Sources

[1] Unless otherwise noted, all referenced Court Documents are from Case No. CVO6-1416 JFW (PLAx).

Elaine Chang, and District Counsel Barbara Baird, formally submitted Rules 3501 and 3502 to the California Air Resources Board ("CARB") on November 2, 2011 and requested that upon CARB's review and concurrence the District Rules "be provided to U.S. EPA for its review and inclusion in" California's State Implementation Plan ("SIP").[2] Declaration of Mark E. Elliott ("Elliott Decl."), Ex. 1. Dr. Chang sent the District's submission to CARB. It includes two legal memoranda authored by Ms. Baird: one which entirely ignores the trial and appeal of this case, the other which misconstrues them. Both memoranda patently ignore the existence of the Final Injunction as well as the Findings of Fact and Conclusions of Law entered by the Court on April 30, 2007 ("Findings"). *Ibid.* According to correspondence from the District, Dr. Chang and Ms. Baird, as employees of the District, acted at the direction of Dr. Wallerstein in authoring the November 2, 2011 SIP submittal. Elliott Decl., Ex. 5. The District, Dr. Wallerstein, Dr. Chang and Ms. Baird are referred to collectively as the "Contempt Defendants."

The District submitted Rules 3501 and 3502 to CARB for the express purpose of incorporating them in the State Implementation Plan so that they

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[2] This Court issued the following findings regarding the SIP process:

> The United States Environmental Protection Agency (the "EPA") is the federal agency responsible for setting National Ambient Air Quality Standards ("NAAQS") for air pollutants identified by the EPA which may reasonably be anticipated to endanger public health or welfare. …
>
> The CAA also requires each state to adopt 'state implementation plans' which contain enforceable measures to attain the NAAQS. *See* 42 U.S.C. § 7410. Pursuant to California Health & Safety Code ("CHSC") § 39602, CARB 'is designated as the state agency responsible for the preparation of the state implementation plan required by the [CAA], and to this end, shall coordinate the activities of all districts necessary to comply with that act." CHSC § 39602.

Ct. Doc. 191 at 12:7-11, 12:20-28.

If a state's SIP meets the Clean Air Act's requirements, EPA will approve it, at which point it becomes enforceable under federal law. 42 U.S.C. § 7410.

would then become enforceable by EPA, the District and the State of California. This act violates the Court's order that Defendants are "permanently enjoined from implementing or enforcing any provision of Rule 3501, [or] 3502." Ct. Doc. 193 at 1:19-23. Plaintiffs accordingly seek an order of civil contempt imposing sanctions against the Contempt Defendants to remedy the contempt, including the recovery of all costs that Plaintiffs have incurred to bring this action.

II. STATEMENT OF JURISDICTION.

This Court retains jurisdiction over the District and the other enjoined parties to enforce the Final Injunction. When persons already are subject to the jurisdiction of the court, no new process is required to subject them to contempt charges. *Leman v. Krentler-Arnold Hinge Last Co.*, 284 U.S. 448, 452-53 (1932). Parties of record to a decree, upon appropriate notice of the contempt proceeding, may be held in contempt for noncompliance with the decree because the contempt charges are a continuation of the original proceedings over which the Court retains jurisdiction. *Id.* at 454-55.

III. STATEMENT OF FACTS.

A. Adoption of the Rules and Procedural History.

On October 7, 2005, the District's Governing Board adopted Rule 3503 and on February 3, 2006, it adopted Rules 3501 and 3502 as rules of the District.[3] On March 7, 2006, Plaintiffs filed a Complaint for Declaratory and Injunctive Relief ("Complaint") against the Governing Board and District seeking a ruling that Rules 3501, 3502 and 3503 are invalid and to enjoin implementation and enforcement of the District Rules. Ct. Doc. 1. Plaintiffs' Complaint included a total of seven claims for declaratory and injunctive

[3] This Court struck down all three rules The District has not sought to implement Rule 3503 through its submission to CARB and it is therefore not at issue in this contempt action.

relief, alleging that Rules 3501, 3502 and 3503 were preempted by the ICCTA, 49 U.S.C. §§ 10101, *et seq*.; violated the Clean Air Act ("CAA"), 42 U.S.C. §§ 7401, *et seq*.; exceeded SCAQMD's authority under the California Health & Safety Code ("CHSC"), §§ 40702, *et seq.* and violated other provisions of federal and California law. Ct. Doc. 1 at 1:5-17.

On April 30, 2007, following a full trial on the merits, this Court adopted its written Findings and concurred with Plaintiffs:

> The Court concludes that the Rules are preempted in their entirety by the ICCTA as alleged in Plaintiffs' First Claim for Relief. Accordingly, the Court also concludes that the Plaintiffs are entitled to a permanent injunction against enforcement of the Rules by Defendants.

Ct. Doc. 191 at 20:8-12. The Court also issued a Finding concluding that the District lacked authority to adopt the District Rules under California law:

> Based upon the express limitations on the District's authority set forth in CHSC § 40702, the provision of CHSC § 43013 regarding CARB's authority to adopt standards regulating locomotives to the extent permitted by federal law, and the efforts made by CARB in negotiating the 1998 and 2005 MOUs, the Court finds that the District *does not have the authority under the CHSC to regulate air contaminants from locomotives*, and therefore was not acting under the CAA when it adopted the Rules.

Id. at 14:20-27, 15:1 (emphasis added). In accord with the Court's Findings, on May 18, 2007, the Court entered the Judgment and Permanent Injunction, which "ordered, adjudged and decreed" the following:

> 1. District Rules 3501 and 3502, adopted by the Governing Board on February 3, 2006, are preempted in their entirety by the Interstate Commerce Commission Termination Act of 1995 ("ICCTA"), 49 U.S.C. § 10101 et seq.
>
> 2. Under Plaintiffs' First Cause of Action, the District, the Governing Board, and their board members, officers, agents, employees, attorneys and all others acting in concert of participation with them, are hereby permanently enjoined from implementing or enforcing any provision of Rules 3501, 3502 or 3503.

Ct. Doc. 193 at 1:15-23.

On May 30, 2007, Defendants appealed. Ct. Doc. 194. On September 15, 2010, the Ninth Circuit denied the appeal and issued an opinion affirming the Judgment and Final Injunction without modification. *Ass'n. of Am. R.Rs.*, 622 F.3d at 1098. The Ninth Circuit found that the District Rules do not have the force and effect of federal law and are preempted by ICCTA:

> The rules apply exclusively and directly to railroad activity, requiring the railroads to reduce emissions and to provide, under threat of penalties, specific reports on their emissions and inventory. Because ICCTA 'preempts all state laws that may reasonably be said to have the effect of managing or governing rail transportation,' . . . ICCTA preempts the District's rules here.

Id.

On October 12, 2010, pursuant to Rule 41(a) of the Federal Rules of Appellate Procedure, the Ninth Circuit issued its Mandate entering the judgment of the U.S. District Court for the Central District of California, Los

Angeles ("the Mandate") without modification. Ct. Doc. 224. There was no subsequent appeal.

B. <u>The District Is Violating the Final Injunction</u>.

On November 2, 2011, the District through the acts of its employees, officers and attorneys, took purposeful steps to violate the Final Injunction. Elaine Chang, the District's Deputy Executive Officer for Planning, Rule Development & Area Sources, sent a letter to CARB on behalf of the District, submitting District Rules 3501 and 3502 as well as information about the rulemaking process undertaken by the District in adopting the District Rules in 2006. In that letter, Dr. Chang specifically requested that CARB provide the Rules "to U.S. EPA for its review and inclusion in the SIP." Elliott Decl., Ex. 1 at p. 1. Dr. Chang further stated:

> Attached you will find information pertaining to *Rule 3501 and 3502* which were adopted by the South Coast Air Quality Management District (AQMD) Governing Board on February 3, 2006. Please note that the submittal includes two memoranda providing assurances that this portion of the implementation plan is authorized under State law and is not prohibited by any provision of Federal law, namely the Interstate Commerce Commission Termination Act, as required by CAA § 110(a)(2)(E).
>
> *We are requesting that upon your review and concurrence the attached information be provided to U.S. EPA for its review and inclusion in the [California] SIP.*

Id. (emphasis added). This SIP submittal was sent to a lengthy list of copy recipients including Deborah Jordan and Andrew Steckel of EPA, as well as Ellen M. Peter, Lynn Terry and Cynthia Marvin of CARB. *Id.* Also copied were Laki Tisopulos, Susan Nakamura, and Mary Leonard of SCAQMD.[4] *Ibid.*

Noticeably lacking from the SIP submittal were copies of the Final Injunction, the Court's Findings, and the Ninth Circuit's 2010 opinion and Mandate. The District's submittal to CARB specifically asserts that submission of the District Rules for inclusion in the SIP is "authorized under State law and is not prohibited by any provision of Federal law, namely the Interstate Commerce Commission Termination Act…." However, the submittal does not make a single reference to the existence of the Findings and Final Injunction which specifically found to the contrary.

The clear purpose for the submission of Rules 3501 and 3502 to CARB for inclusion in the State Implementation Plan is to implement and render enforceable the District Rules. The District did not even attempt to disguise this purpose – it submitted to CARB for SIP inclusion the identical rules passed by the District in 2005/2006 and enjoined by this Court in 2007. The District's intentional attempt to evade the prohibition on implementation and enforcement of the District Rules is in direct violation of both the letter and the spirit of the permanent Final Injunction imposed by this Court and constitutes sanctionable civil contempt.

C. <u>Meet and Confer Efforts.</u>

In compliance with Local Rule 7-3, on November 22, 2011 Plaintiffs contacted the District in writing and requested that it immediately withdraw its submission of the District Rules to CARB. Elliott Decl., Ex. 2. Plaintiffs noted that if such withdrawal was not forthcoming, they would be forced to seek relief from the Court in the form of this contempt action. *Id.* In a

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4 Ms. Nakamura testified in the 2006 trial on behalf of the District and Governing Board. Elliott Decl. ¶ 4.

response dated November 23, 2011, the District failed to address Plaintiffs' request that it withdraw its submission of the Rules. Elliott Decl., Ex. 3. On November 29, 2011, Plaintiffs again contacted the District regarding the withdrawal of the District Rule submission. Elliott Decl., Ex. 4. On December 2, 2011, representatives for the District and Plaintiffs spoke telephonically and the District confirmed its refusal to withdraw the SIP submittal. Elliott Decl., ¶ 6.

During the December 2nd conference, District General Counsel Kurt Wiese stated that Dr. Wallerstein had directed Ms. Baird's and Dr. Chang's submission of the Rules to CARB. On that basis, Mr. Weise requested that Plaintiffs substitute Dr. Wallerstein for Ms. Baird and Dr. Chang as a Contempt Defendant. Mr. Weise confirmed his oral statements in a letter to Plaintiffs' counsel dated December 3, 2011. Elliott Decl., Ex. 5.

IV. <u>LEGAL STANDARD FOR CIVIL CONTEMPT.</u>

Courts have broad power to punish disobedience through the power of civil contempt and, where appropriate, criminal contempt. *International Union, United Mine Workers of America, et al. v. Bagwell,* 512 U.S. 821, 831 (1993). This Court has inherent authority to enforce compliance with its orders through civil contempt sanctions. *Stone v. City & County of San Francisco,* 968 F.32 850, 856 (9th Cir. 1992)(citing *Spallone v. United States,* 493 U.S. 265, 276 (1990)). *See also, Gifford v. Heckler*, 741 F.2d 263, 266 (9th Cir. 1984)(the district court "has wide latitude in determining whether there has been contemptuous defiance of its order…").

To establish liability for civil contempt, the plaintiff needs to show by clear and convincing evidence merely that the party has violated a specific and definite order of the court. *FTC v. Affordable Media, LLC*, 179 F.3d 1228, 1239 (9th Cir. 1999). Here there is overwhelming evidence that the Contempt

Defendants did just that. The Contempt Defendants are bound by, had notice of, and indisputably violated the unambiguous terms of the Final Injunction, which permanently prohibits the implementation and enforcement of the District Rules.

Once a contempt plaintiff has met its initial burden, the burden then shifts to the contemnors to demonstrate why they were unable to comply with the injunction. *Nat'l Labor Relations Bd. v. Trans Ocean Export Packing, Inc.*, 473 F.2d 612, 616 (9th Cir. 1973). It is no defense to contempt to "disobey a court order and later argue that there were 'exceptional circumstances' for doing so." *In re Crystal Palace Gambling Hall, Inc.*, 817 F.2d 1361, 1365 (9th Cir. 1987). Here, Plaintiffs easily meet their burden and Contempt Defendants cannot excuse their purposeful violation of the Final Injunction.

V. A FINDING OF CIVIL CONTEMPT IS WARRANTED.

A. There Is Clear and Convincing Evidence that the Contempt Defendants Violated the Final Injunction By Taking Actions to Implement and Enforce the District Rules.

Civil contempt is appropriate when a party fails to comply with a specific and definite court order. *Gifford v. Heckler*, 741 F.2d 263, 265 (9th Cir. 1984). Failure to comply consists of not taking "all the reasonable steps within [one's] power to insure compliance with the order…." *Sekaquaptewa v. MacDonald*, 544 F.2d 396, 406 (9th Cir. 1976). Here, the Final Injunction expressly states that "the District, the Governing Board, and their board members, officers, agents, employees, attorneys and all others acting in concert or participation with them, are hereby permanently enjoined from implementing or enforcing any provision of Rules 3501 [or] 3502." Not only did the Contempt Defendants fail to take reasonable actions to ensure compliance with the order,[5] the District and District employees Dr. Chang and Ms. Baird, at the direction of Dr. Wallerstein, actively took steps to implement and/or enforce the barred District Rules.

In common usage the term "implement" means to carry out, accomplish, or to give practical effect to and ensure actual fulfillment by concrete measures. Merriam-Webster Online Dictionary, <http://www.merriam-webster.com/dictionary/implement?show =1&t=1321904924>, (last visited November 21, 2011). By submitting the District Rules to CARB, the Contempt Defendants are attempting to circumvent the Final Injunction by having CARB submit the rules to EPA for inclusion in the SIP. The submission of the Rules to CARB with a request that CARB pass them to EPA plainly constitutes implementation – the entire purpose of these acts is to give the enjoined District Rules practical effect by incorporating them into the State Implementation Plan.[6]

Moreover, any act to enforce the District Rules is itself prohibited by the Final Injunction. The submission to CARB of the District Rules, which included the District's legal memoranda attempting to justify such submission, was a concrete measure designed to attempt to enforce the rules under the

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[5] For example, despite the fact that the Rules were enjoined in early 2007, as of the filing of this brief, the District's online Rule Book still contains Rules 3501, 3502 and 3503, and lists them as "adopted" on their original adoption dates in 2005 and 2006. The District website makes no reference to the fact that this Court enjoined the District's Rules and that the Ninth Circuit upheld that decision. Elliott Decl., ¶ 7, Exs. 6-7; *See also,* << http://aqmd.gov/rules/rulesreg.html >> and <<http://aqmd.gov/rules/reg/reg35_tofc.html>>.

[6] The California SIP now contains hundreds of local district rules, including more than 150 adopted by the District and approved by EPA. *See* <http://yosemite.epa.gov/R9/r9sips.nsf/Agency?ReadForm&count=500&state=California&cat=South+Coast+Air+Quality+Management+District-Agency-Wide+Provisions >, (last visited November 16, 2011).

Clean Air Act if the District Rules are approved by EPA as part of the SIP. *See, e.g., Safe Air for Everyone v. EPA*, 488 F. 3d 1088, 1091 (9th Cir. 2007).

Further, the District may not enlist CARB and EPA as instruments to aid and abet a violation of the Final Injunction. A party may not nullify an injunction by carrying out prohibited acts through non-parties. *Independent Fed'n of Flight Attendants v. Cooper*, 134 F. 3d 917, 920 (9th Cir. 1998). In fact, Federal Rule of Civil Procedure 65(d) prevents exactly this type of evasion by extending the scope of an injunction to persons acting "in concert with" a party. "In essence, it is that defendants may not nullify a decree by carrying out prohibited acts through aiders and abettors, although they were not parties to the original proceedings." *Regal Knitwear Co. v. National Labor Relations Board*, 324 U.S. 9, 14 (1945) (in considering whether successors and assigns were bound to the terms of an injunction, the Court focused on whether they were being used as instruments by the defendant to evade an injunction).

The Contempt Defendants have intentionally breached the Final Injunction by submitting Rules 3501 and 3502 to CARB and EPA for inclusion in California's SIP. The materials submitted by the District to CARB plainly demonstrate the District's intent and action to give effect to – i.e., to implement – the Rules and make them enforceable against Plaintiffs. Three documents are especially revealing in this regard: (1) the November 2, 2011 submission cover letter authored by Elaine Chang, (2) District Counsel Barbara Baird's memorandum entitled "ICCTA Does Not Preempt South Coast AQMD Rules 3501 and 3502" (hereafter, "ICCTA Legal Memo"), and (3) Ms. Baird's memorandum regarding "State Law Authority" ("State Law Memo"). These documents provide clear and convincing evidence of the contemptuous behavior of the Contempt Defendants.

1. Dr. Chang's Cover Letter To CARB Evidences The District's Intention to Give Effect to the District Rules.

The cover letter from Dr. Chang to CARB is clear and convincing evidence of the District's contempt. In that letter, which includes the submission of Rules 3501 and 3502 as well as their supporting Staff Reports (dated 2006) developed as part of the Governing Board's original rule development and approval process, Dr. Chang, in her official capacity as the Deputy Executive Officer of the District, asked CARB to "review" and concur with the "attached information" and provide the information to EPA for "its review and inclusion in the SIP." Elliott Decl., Ex. 1. Moreover, this letter concludes that the Rules are authorized under state law and not preempted by ICCTA, but fails to mention that this Court found the opposite. By making this request, the District expressly seeks to give effect to the District Rules and therefore to implement and enforce them in direct violation and blatant disregard of the Final Injunction.

2. Ms. Baird's ICCTA Legal Memo Demonstrates the District's Intention to Implement and Render the District Rules Enforceable.

Perhaps more objectionable is the ICCTA Legal Memo which evidences the District's intention to make the District Rules enforceable against Plaintiffs. The ICCTA Legal Memo ignores the Court's Findings, and re-argues the legal merits of issues already fully tried and adjudicated by this Court, including the "issue of whether the federal … ICCTA[] preempts the two rules proposed for inclusion on the SIP, and thereby would prohibit their implementation." Elliott Decl., Ex. 1 at 31.

Extraordinarily, the ICCTA Legal Memo suggests that the Ninth Circuit set out a "procedural roadmap" for the District, which the District argues allows it to avoid the Final Injunction. The District asserts that as "authorized" by the Ninth Circuit, the enjoined District Rules can gain the authority of federal law, at which point they will no longer be preempted by ICCTA and instead must be harmonized with ICCTA. Ms. Baird states that according to the Ninth Circuit's "harmonization test: the rules must first be approved by EPA into the SIP. Accordingly, the SCAQMD is submitting the two rules for inclusion in the state implementation plan." Elliott Decl., Ex. 1 at 32. It is only by misreading the decision from the Ninth Circuit and ignoring this Court's Findings and the Final Injunction, that Ms. Baird's ICCTA Legal Memo is able to conclude that the District Rules are enforceable.

Ms. Baird rationalizes the District's efforts to implement the enjoined Rules with the circular logic that, "ICCTA does not preempt the rules from the point of view of a court looking at the situation as it exists *once the rules are approved by EPA*." Elliott Decl., Ex. 1 at 32 (emphasis added). She argues that it would be "absurd" to preempt the District Rules because EPA had not yet had the opportunity to act on them and give the Rules the effect of federal law, at which point they would not be preempted. The only thing "absurd" about the situation is Ms. Baird's conclusion that EPA can approve rules that (1) contravene the Final Injunction and (2) are beyond the District's authority to implement and enforce under California law. Mr. Weise reiterated this unfounded position in his December 3rd letter, which evidences the District's continued failure to respect this Court's Final Injunction as well as the Ninth Circuit's decision affirming it. Elliott Decl., Ex. 5.

Not only is the District's argument circular, it mischaracterizes the Ninth Circuit's opinion. The Ninth Circuit in no way authorized the District to breach the Final Injunction. Rather, it merely noted – solely in response to the

District's pretextual argument at trial that it intended at some point in the future to submit the rules for inclusion in the SIP and therefore it was acting under the authority of the CAA when it adopted the Rules[7] – that if the court were facing a situation where the District Rules already had been incorporated into the SIP and therefore had the effect of federal law, the court would then potentially have to harmonize the rules with ICCTA. But because the District Rules before the court had only the effect of local law, the Ninth Circuit rejected this hypothetical future argument, finding them preempted without the need to harmonize with the CAA and ICCTA:

> Here, the District's rules do not have the force and effect of federal law. The District alleges that it *will* submit the rules to the state agency, CARB, for its approval and that *if* CARB approves, CARB *will* submit the rules to the federal EPA as part of California's state implementation plan. Once approved by EPA, state implementation plans have "the force and effect of federal law." [citation omitted]. The corollary to that rule is that, *until approved by the EPA*, state implementation plans do *not* have the force and effect of federal law. For that reason, it is irrelevant that the Clean Air Act reserves certain regulatory authority to the states and localities. Because the District's rules have not become a part of California's EPA-approved state implementation plan, they do not have the force and effect of federal law, even if they might in the future. Accordingly, there

[7] This Court found that the argument was pretextual: "[B]ased on the fact that the CAA was never mentioned as part of the District proceedings which led to the adoption of the Rules, it appears that the decision to invoke the CAA was 'pretextual' – a litigation decision made after Plaintiffs filed suit against the District [citation omitted]." Ct. Doc. 191 at 15, n. 6.

is no authority for the courts to harmonize the District's rules with ICCTA.

Ass'n. of Am. R.Rs. v. S. Coast Air Quality Mgt. Dist., 622 F.3d at 1098 (emphasis in original). The District incorrectly casts these dicta statements as providing a controlling test, while ignoring the Court's holding which *affirmed the lower Court's ruling without modification* and upheld the Final Injunction. *Id.*

More importantly, the District ignores the fact that no matter how the Ninth Circuit opinion is interpreted, the District lacks the authority under state law to promulgate the Rules, which means they cannot become part of the SIP.[8] *See* section 3, *supra.* Ignoring this Court's Findings, the District falsely makes assurances to CARB of the District's authority to issue the Rules.[9] Elliott Decl., Ex. 1 at 1. As confirmed by Mr. Wiese in his December 3rd letter, the District believes it has a *right* to have its rules gain the force and effect of federal law, despite this Court's finding that the District has no authority to promulgate the Rules at all. Elliott Decl., Ex. 5.

Perhaps most egregiously, Ms. Baird's ICCTA Legal Memo not only ignores the facts of this case, it incorrectly represents that no Findings of Fact

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[8] CAA section 110(a) requires that implementation plans and revisions provide "necessary assurances that the State…will have…authority under State…law to carry out" the plan, "including authority to: … enforce applicable laws, regulations, and standards…." 42 U.S.C. § 7410(a)(2)(E); 40 C.F.R. § 51.230. The legal authority to carry out and enforce the SIP or SIP revision must be "available to the State *at the time of submission of the plan.*" 40 C.F.R. § 51.231 (emphasis added).

[9] District Resolution 06-6 states that the District Rules are "in harmony with and not in conflict with or contradictory to, existing federal or state statutes, *court decisions*, or regulations." Although written before trial, this statement now is patently false given the Final Injunction, and the District's submission of it to CARB without any reference to the Final Injunction is improper.

were ever made by this Court. In a statement targeting EPA (as a recipient of the memorandum), Ms. Baird erroneously states:

> As EPA is aware, the railroads and SCAQMD have participated in a thorough and lengthy factual discovery process and have participated in a trial at which the railroads presented all of their evidence. However, the trial court *never made any factual findings*,[10] since it concluded that SCAQMD was not authorized to regulate locomotives under state law (a conclusion which we demonstrate is plainly incorrect in an accompanying memorandum.) If EPA believes a factual submission is needed, SCAQMD offers to submit to EPA the factual materials presented to the trial court by both sides, together with an analysis why the facts presented do not support preemption.

Elliott Decl., Ex. 1 at 37 (emphasis and footnote added). In this concluding statement, Ms. Baird, on behalf of the District, steps over the line from consciously disregarding the Findings and Final Injunction to actively misrepresenting and omitting material facts. This is sanctionable contempt.

3. The State Law Memo Ignores the Court's Finding that the District Lacks State Law Authority For the District Rules.

The ICCTA Legal Memo is not the end of the evidence of the District's impermissible efforts to implement and enforce the District Rules. Ms. Baird, in her capacity as District Counsel, also authored and presented to CARB and EPA a second "State Law Memo," which attempts to identify the District's authority to promulgate the District Rules. Ms. Baird undertakes this analysis even though this Court considered this question and found that the District lacked the requisite authority under state law: "The Court finds that the

[10] The Court's Findings are located in Ct. Doc. 191.

District does not have authority under the CHSC to regulate air contaminants from locomotives and therefore was not acting under the CAA when it adopted the Rules." Ct. Doc. 191 at 14:25-15:1.

Despite this express finding, which was not disturbed on appeal, Ms. Baird largely restates the District's arguments on state law authority from Defendants' Supplemental Trial Brief in Response to Plaintiffs' Memorandum of Contentions of Fact and Law. *See* Ct. Doc. 75. After repeating the previously rejected arguments made at trial, Ms. Baird's State Law Memo inexplicably ignores the Court's ruling and finds to the contrary:

> Taken as a whole, these provisions of the Health & Safety Code are interpreted to mean that the Legislature granted the districts authority over all sources – including locomotives – except motor vehicles and expressly allowed districts to adopt stricter rules than those adopted by CARB. Health & Safety Code §§ 39002, 40000. Therefore, the District has authority under state law to adopt the rules [i.e., Rules 3501 and 3502].

Elliott Decl., Ex. 1 at 30.

The issue of state law authority was raised by the District in its appeal to the Ninth Circuit. While the Ninth Circuit concluded that it need not address the question of the District's state law authority, it did not overturn the Court's conclusion that the District *lacked* such authority. It stated: "The district court also held, in the alternative, that the District's rules were not within the scope of the District's state-law regulatory authority. The Railroads reiterate that view on appeal. We need not, and do not, decide that issue of state law." *Ass'n. of Am. R.Rs.*, 622 F.3d at n. 1. The District did not appeal from the Ninth Circuit's decision on this or any other issue. With its rights of appeal exhausted, the District is bound by this Court's finding of law that it lacks authority under State law to promulgate the District Rules.

In sum, the District's November 2, 2011 rule submission to the CARB, with the request that the District Rules be incorporated in California's SIP, contains intentional misrepresentations of facts and law and purposefully disregards the controlling and binding factual and legal decisions of this Court and the Ninth Circuit, as well as the Final Injunction, all in an undisguised attempt to implement the Rules and enforce them. This is clear and convincing evidence of an intentional breach of the Final Injunction by the District, Ms. Baird and Dr. Chang, as well as by Dr. Wallerstein who admittedly directed their behavior.

B. The Final Injunction Is Sufficiently Detailed.

Federal Rule of Civil Procedure 65(d)(1) requires that an order granting an injunction state (1) the reasons why it was issued, (2) the specific terms of the injunction and (3) describe in reasonable detail the acts restrained. The purpose of these requirements is to allow a party to know what is required of it in order to comply with the injunction. Here, the Final Injunction is sufficiently detailed to allow compliance and to justify a contempt sanction.

The Final Injunction specifically states why it was issued – the Rules violate ICCTA:

> The action having been tried and the Court having issued its Findings of Fact and Conclusions of Law on May 1, 2007, IT IS HEREBY ORDERED, ADJUDGED AND DECREED THAT:
>
> 1. District Rule 3503, adopted by the Governing Board on October 7, 2005, and District Rules 3501 and 3502, adopted by the Governing Board on February 3, 2006, are preempted in their

entirety by the Interstate Commerce Commission Termination

Act of 1995 ("ICCTA"), 49 U.S.C. § 10101 *et seq.*

Ct. Doc. 193 at 1:1-11.

The Final Injunction likewise sufficiently details its terms and, in particular, the actions it permanently prohibits, and by whom: "the District, the Governing Board, and their board members, officers, agents, employees, attorneys and all others acting in concert or participation with them, are hereby permanently enjoined from implementing or enforcing any provision of Rules 3501 [or] 3502." Ct. Doc. 193 at 1:19-23.

Thus, the Final Injunction (1) identifies the parties against whom the injunction applies ("*the District, the Governing Board, and their board members, officers, agents, employees, attorneys and all others acting in concert or participation with them*"), (2) specifically states the terms of the injunction (i.e., "*are permanently enjoined*") and (3) provides reasonable detail of the restrained acts (i.e., "*are permanently enjoined from implementing or enforcing any provision of Rules 3510, 3502 or 3503.*"). Accordingly, the Final Injunction is sufficiently detailed to allow the Contempt Defendants to understand and comply with its terms, and to warrant issuance of a contempt order for their failure to do so.

C. <u>The District, and Its Employees, Officers and Attorneys are Bound by the Final Injunction</u>.

Federal Rule of Civil Procedure 65(d)(2) explains that injunctions bind the parties to the action, their officers, agents, servants, employees, and attorneys, as well as those persons in active concert or participation with a party. The language of the Final Injunction mirrors Rule 65 regarding the parties bound by its terms. Ct. Doc. 193 at 1:19-23. The District, and its officers, employees, and attorneys, including Dr. Wallerstein, Dr. Chang and

Ms. Baird, received constructive or actual notice of the Final Injunction and are bound to comply with it.

As stated on the face of the Final Injunction, the entry of personal service of the Judgment by the Court "Constitutes Notice of Entry as Required by FRCP, Rule 77(d)." Ct. Doc. 193. Copies of the Final Injunction were served by U.S. Mail on counsel for the District at their respective addresses of record on May 18, 2007, as noted on the Proof of Service page. *Id.* The Court Docket identifies the following counsel for the District and Governing Board: Barbara B. Baird, Kirk A. Dublin, Kurt R. Wiese, Michael Ray Harris, Brian J. O'Neill, Brian A. Sun, Daniel P. Selmi, Philip A. Leider, and Reed T. Aljian. *Id.* More to the point, neither the District nor its Governing Board can dispute receipt or actual notice of the Final Injunction as evidenced by the District's Notice of Appeal filed on May 30, 2007. Ct. Doc. 194.

Dr. Wallerstein and Dr. Chang may attempt to argue that unlike the District and Ms. Baird, they did not receive actual notice of the Final Injunction. But even if true, this argument has no consequence for this contempt proceeding. Under Rule 65(d), actual notice via personal service is not required to bind an employee of a party to the terms of an injunction. Fed. R. Civ. P. 65(d). Rather, employees commonly are bound by the terms of an injunction issued to their employers because "[t]he threat of potential contempt liability will provide … sufficient incentive to give the required notice, thereby easing [the enjoined employer's] task of securing their compliance and eliminating any problem of impossibility." *Coca-Cola Co. v. Overland, Inc.*, 692 F.2d 1250, 1255-56 (9th Cir. 1982)(enjoining individual employees who failed to comply with terms of injunction). Similarly, the Seventh Circuit reasoned that "[w]hile certainly some type of notice of an injunction is required by contemporary notions of due process…, we are not convinced that rule 65(d) requires [a party employee] to have … actual notice of the … judgment. … only 'persons in active concert or participation with' parties, their officers, agents, servants, employees, and attorneys [are required] to have possessed actual notice of an injunction before they can be bound by it." *Shakman v. Democratic Org. of Cook County*, 533 F.2d 344, 352 (7th Cir. 1976)(finding that no evidence of actual notice was necessary to find an employee of an enjoined party in civil contempt).

Dr. Chang is the Deputy Executive Officer of Planning, Rule Development & Area Sources for the District and has been since at least 2006 when the District Rules were promulgated. Elliott Decl., ¶ 5. In fact, she is the direct supervisor of Susan Nakamura who testified at the 2006 trial. *Id*. Dr. Wallerstein is the District's Executive Officer and Dr. Chang's direct supervisor. *Id.* Dr. Wallerstein also testified at the 2006 trial. *Id.* Given these facts, it is unreasonable for Dr. Wallerstein and Dr. Chang to suggest they did not have actual notice of the Final Injunction. However, actual notice to them is not required to bind them to the terms of the Final Injunction. By virtue of their employment by a party to the Final Injunction, they – and any other violating employees – can be held personally in contempt for actions in violation of the Final Injunction. As explained in detail above, Dr. Chang signed the cover letter for the entire submission to CARB, in particular requesting that CARB pass the package to EPA for inclusion in the SIP. And as the District has admitted in writing, Dr. Wallerstein directed the contemptuous actions of Dr. Chang and Ms. Baird. These actions directly violate the terms of the Final Injunction.

The District, Barry Wallerstein, Barbara Baird, and Elaine Chang are bound by and should be held in contempt of the Final Injunction.

VI. THE COURT SHOULD IMPOSE CIVIL CONTEMPT SANCTIONS TO REMEDY THE DISTRICT'S NON-COMPLIANCE.

Once a party is found in contempt, the Court has wide discretion to determine appropriate sanctions. *United States v. United Mine Workers of America*, 330 U.S. 258, 303-304 (1947). Sanctions for civil contempt serve two purposes: (1) to coerce a defendant into compliance with the court's order; and (2) to compensate the plaintiff for losses sustained as a result of the contumacious behavior. *Id*. at 303-304. To the extent that a contempt sanction is coercive, the court has broad discretion to design a remedy that will bring about compliance. *Falstaff Brewing Corp. v. Miller Brewing Co.*, 702 F.2d 770, 786 (9th Cir. 1983). A close analogy to coercive imprisonment is a per diem fine imposed for each day a contemnor fails to comply with an affirmative court order. *United Mine Workers of America*, 512 U.S. at 829. Per diem fines exert a constant coercive pressure, and once the commands of the injunction are obeyed, daily fines may be purged. See also, *FTC v. Productive Mktg Inc*., 136 F.Supp.2d 1096, 1112-1113 (C.D. Cal. 2001).

Here, the appropriate remedy is an order mandating that the District formally take all necessary actions to cease implementation or enforcement of the District Rules, including requiring the District to provide formal notice to CARB and EPA. Such notice should include the following: (1) a statement that the November 2, 2011 submission of Rules 3501 and 3502 to CARB was in violation of this Court's Injunction; (2) an immediate and complete withdrawal of the November 2, 2011 submission by the District to CARB; (3) the specific rescission of the District's request that CARB pass Rules 3501 and 3502 to EPA for inclusion in the SIP; and (4) the formal acknowledgment that the District shall immediately rescind Rules 3501, 3502 and 3503 from the Rules of the South Coast Air Quality Management District (including deleting them from, or noting they are invalid, in any website or other public references).

In light of the District's complete disregard for the Final Injunction, it is further appropriate to impose a daily coercive sanction on the District – a per diem fine for each day of noncompliance if the District does not come into full compliance within 10 days, until the District has formally withdrawn the submittal to CARB and EPA. This fine is intended to coerce the District to comply and is not intended as a punitive sanction.

Further, Plaintiffs are entitled to recover the costs and fees they incur to bring the contempt action. As the Ninth Circuit explained:

> [T]he trial court should have the discretion to analyze each contempt case individually and decide whether an award of fees and expenses is appropriate as a remedial measure. ... 'It matters not whether the disobedience is willful[;] the cost of bringing the violation to the attention of the court is part of the damages suffered by the prevailing party and those costs would reduce any benefits gained by the prevailing party from the court's violated order.'

Perry v. O'Donnell, 759 F.2d 702, 705 (9th Cir. 1985)(quoting *Cook v. Ochsner Foundation Hospital*, 559 F.2d 270, 272 (5th Cir.1977)).

VII. CONCLUSION.

For the foregoing reasons, Plaintiffs seek an order to show cause why Contempt Defendants should not be held in civil contempt or, in the alternative, issuance of a civil contempt order.

Dated: December 7, 2011

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Attachments from Comment Letter 114

GREEN FREIGHT TRANSPORT: FROM CONCEPT TO PRACTICE

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Executive Summary

Ports and the associated freight transport network are fundamental to the supply chain of goods. Ports however are major source of pollution while trucks serving the ports and intermodal facilities have a detrimental effect on traffic congestion which is also another source of pollution. The cost of congestion and pollution is enormous both financially as well as health wise.

With the expected increase of population in urban areas and the rising volume in international trade, congestion will worsen and pollution will increase unless drastic measures are taken.

The small steps usually taken such as adding more capacity on the road network, improving diesel engine combustion to be cleaner etc. are unlikely to catch up with the impact the increase in volume of freight will have. The most optimistic result with small changes is for pollution and congestion increasing at possibly lower rates than without these changes. While these smaller steps may ease political pressure for a cleaner environment in the near term, in the long term the situation will get worse. What is really needed is a new approach that puts efficiency and the environment as top priority.

The purpose of this study is to assess the feasibility of a new concept referred to as Green Rail Intelligent Development (GRID) and the GRID SuperDock. In this concept, containers are loaded/unloaded by a very efficient facility referred to as SuperDock which interfaces directly

with the ships and also serves as temporary container storage. The containers are then transported underground via specially made water pipe like tunnels to intermodal hubs to be served by trucks by using electrified rail. GRID will eliminate thousands of truck trips to the port and will cut down truck travel miles considerably. The number of trucks on the road network will be highly reduced alleviating congestion and cutting down on pollution. The GRID concept is designed to work by taking into account all mechanical and energy issues associated with loading/unloading containers. The next step is to perform an extensive evaluation of the performance of the system, its cost in terms of capital to build and maintain, and environmental impact in comparison with the existing multimodal system. To achieve this elaborate task we propose to build a microscopic simulation model of the GRID system including the SuperDock and associated freight transportation network as well as a cost model. The microscopic simulator will simulate all parts of the system in great detail in order to assess the performance of the system under different demand levels, under normal and emergency situations where certain parts of the system may break down as well as its interface with intermodal hubs, ships, ordinary rail and trucks. The cost model will take into account all relevant construction cost, maintenance, power, labor etc. in order to assess the cost of moving containers through the port using the SuperDock and compare with the cost of current equivalent operations. A vehicle emissions model will be used to assess the impact of GRID on the environment by calculating the reduction in fuel consumption and pollution due to the reduction of truck trips. This simulation study will demonstrate the size of the benefits that are expected from the GRID under all possible operating conditions. A constructability study will focus on pipeline specifications and constructability in relation to all topographical and sub-terrain conditions along potential pipeline routes.

For the region of Southern California the GRID concept is of significant importance. It offers an opportunity to bring a project of a national significance to the region. It will greatly improve surface traffic congestion and safety on southern section of 710 freeway and have a great impact on the environment. In addition it offers a strong potential for private financing and investments in the region that will lead to many jobs and a revived local economy.

The Center for Advanced Transportation Technologies (CATT) have worked on similar advanced technology concepts and automation and developed expertise and the appropriate simulation, optimization, performance and cost evaluation tools for intelligent transportation systems such as the GRID. CATT can provide an unbiased evaluation of systems such as GRID by using its experience with similar systems. For these reasons CATT researchers are ready to partner with transportation authorities and regional stakeholders to perform an unbiased evaluation of GRID by first developing an elaborate microscopic simulation of the GRID system and SuperDock and then exercise the model using if scenarios and different operating conditions.

1. Introduction

Globalization and rapid economic growth have vastly increased the volume of commodity flows in all transport modes. It is anticipated that the growth in containerized trade will continue as more and more cargo is transferred from break-bulk to containers. Every major port in the US is expected to double its container traffic by 2020 even though the recent economic recession modified some of these estimates. The largest container ships operating today have a capacity of about 11,000 TEUs. 18,000 TEU-range vessels will be coming on line within the next few years. The rapid escalation in vessel size is ahead of schedule. Larger capacity ships have influenced shipping patterns, concentrating volumes at those locations with sufficiently deep channels and terminal capacity to serve large ships.

Container terminals in most metropolitan areas and areas where land is very scarce have to make significant changes in order to keep pace with increasing demand under environmental, road network congestion, labor force, land costs and other constraints. The choices are limited and include the following:

Expand port land where possible and cost effective. A traditional way of adding capacity but not always feasible due to scarcity and/or cost of land and political opposition

Move cargo from trucks to rail. This is a trend that is expected to continue even though trains are reaching their capacity too.

Automated Container Terminals (ACT): Automated container terminals are one way of improving productivity and increasing capacity while cutting labor cost, without the use of additional land. While a few automated container terminals have been operating overseas for some years, the concept is not spreading rapidly. Furthermore how an ACT will interact with the rest of the supply chain has not been adequately addressed. A highly efficient ACT has to be served efficiently too otherwise a bottle neck will be created that will reduce the benefits of automation.

Inland Ports: Inland ports, intermodal hubs, logistic centers, dry ports etc. are some of the names used to identify facilities away from marine terminals that process cargo in order to reduce congestion at the ports. Inland ports serve as an opportunity for direct links with seaports using zero emissions container transport systems bypassing the use of the roadway network.

Environmental-related technologies: The environment is on the agenda of most government departments, ports, local communities and many non-profit organizations. While most immediate efforts focus on cleaner trucks and equipment and ways to reduce ship pollution at the terminals, several more revolutionary concepts developed by different innovators over the recent years are still alive even though none of them has been implemented yet. These concepts are mostly based on fixed guideway systems using magnetic field to hover containers over air gaps and linear motors or electricity to move them along the guideway. The gate appointment system is also viewed as a way to reduce pollution by having trucks avoid peak hours and reduce idling by waiting at the gates. The performance of several zero emission container transport systems have not been analyzed when used in the supply chain under different volume demands. Some of them assume a high container volume to justify their cost and effectiveness.

Los Angeles/Long Beach Port Environment

As the fifth largest container port complex on Earth, the San Pedro Bay combined ports of Los Angeles and Long Beach exert a certain influence on ports and related logistics sectors throughout the continent. The amount of trade-related activity LA and Long Beach draw to the West Coast provides a critical mass of actors who help to shape the development and adoption of technologies for the port sector.

LA/LB exhibits scale economies in international shipping, has a large local consumer market, offers good connections to the US national market as well as an extensive network of supporting industries. Its role as a gateway has been further defined as a result of the tremendous growth in trade from Asia. Because of its proximity to Asian production centers, California in general, and the Los Angeles region in particular, has accommodated a large share of this growth. This growth has created a demand for technologies that improve system capacity and make supply chain operations more efficient.

The rapid growth in trade has come with an increasing awareness on the part of local communities of the negative environmental impacts of that growth. This has also created a demand for technology-based responses. Elected officials, particularly at the State level, have responded on their part with a series of legislative measures designed to bring about changes in the way the supply chain in general, and ports in particular, operate. Environmental lawsuits were pursued with the same outcome in mind.

The success of policy measures and court action – and sometimes merely the threat of the same – has played a critical role in encouraging the port and logistics sector to become environmental innovators. In addition, the presence of a vibrant research community provides a test bed for many port-driven innovations.

The LA/LB port complex is a natural place for innovation as this is where some of the most serious problems associated with multimodal freight transport are located. Due to political pressures to reduce emissions and traffic congestion in and around the twin Ports of Long Beach and Los Angeles, the Ports and the Alameda Corridor Transportation Authority (ACTA) have been seeking new, non-polluting technologies to move containers between the marine terminals and an intermodal rail yard next to West Long Beach. As a result a Request for Concepts and Solutions (RFCS) for a Zero Emission Container Mover System (ZECMS) was issued in June of 2009 with a deadline for response October 23, 2009. Seven concepts have been proposed and came from the following corporations:

- American Maglev Technology of Florida Inc.
- Bombardier
- Flight Rail Corp.
- Freight Shuttle Partners
- Innovative Transportation Systems Corp.
- Magna Force Inc.
- Tetra Tech Inc.

The ports, ACTA and independent experts including the University of Southern California (USC) Keston Institute for Public Finance and Infrastructure Policy evaluated the proposals in 2010.

Some of the key requirements for the proposed systems indicated in the RFCS were:

- The proposed system is not intended to either diminish or replace on-dock rail loadings.
- The system would still need to compete financially with drayage i.e. the Ports will not ban the use of trucks to the near-dock rail-yards
- Respondents should assume the responsibility for the costs of all non-port, private right-of-way (including terminal leaseholds).
- Respondents should assume that this would be a stand-alone project i.e. one that would be financed without contribution or subsidy by the Ports or ACTA.

The above requirements put a lot of pressure on the proposers as most if not all of the automated container transport concepts are based on high container volume demand to justify the cost. If they have to compete with existing facilities, that means the demand would be shared increasing the uncertainty for success. The requirements also make it clear that the financing of the system will not be the responsibility of the Ports or ACTA and there is no indication anywhere that the local government will finance any of the projects either. For these reasons the proposers have to assume that the financing will be done solely by the private sector. The conclusions of the review were the following:

- Even though a ZECMS appears to be technologically feasible none of the systems proposed are sufficiently mature to commit to a full-scale operational deployment at this time; additional testing that simulates port environment is needed;
- A full understanding of port duty cycles was absent from all responses none of the submissions adequately address the risks of insufficient market demand.
- Technology and financial risk cannot be fully evaluated until the robustness and reliability of the systems have been demonstrated.
- Given best case assumptions regarding growth in container volume, market share, capital costs, and system availability, absent other drivers (e.g., environmental regulations and/or a subsidy provided by Ports or others), ZECMS will have difficulty competing economically with conventional truck drayage
- Great variation in submissions for assumptions regarding construction, terminal right-of-way, and other costs.

- None of the respondents have shown that they can deliver a reliable and financially sustainable ZECMS at no cost to the Ports.

The above conclusions indicate that a ZECMS operating in a Port environment is at its infancy. From the technical point of view more work is required to demonstrate the reliability and robustness of the system in a port environment.

The purpose of this project is to study the feasibility of a new ZECMS by not only looking at the system itself and its cost but also how it operates and performs in a Port environment and more important as part of the supply chain in a multimodal transportation system.

2. GRID Concept

GRID ("Green Rail, Intelligent Development") and the GRID SuperDock [1]: At the 2007 METRANS Conference in Long Beach, California, David Alba and Jack Hogue of SkyStorage Systems Inc. presented a container terminal designed primarily to store empty containers to consolidate storage at ports. Four years later, this system has been further developed into a total logistic solution for the transfer of containers (loaded or unloaded) from ships to trains to trucks, that completely redesigns and reconfigures the forty year old logistics model still in use today . The concept involves the development of a Super Dock for ship to rail operations at the ports and an *underground pipeline* for fully automated electric cargo trains that will transport cargo inland to various mini inland ports for further processing and transport to nearby destinations by trucks. The concept is developed for application to the Ports of LA/LB.

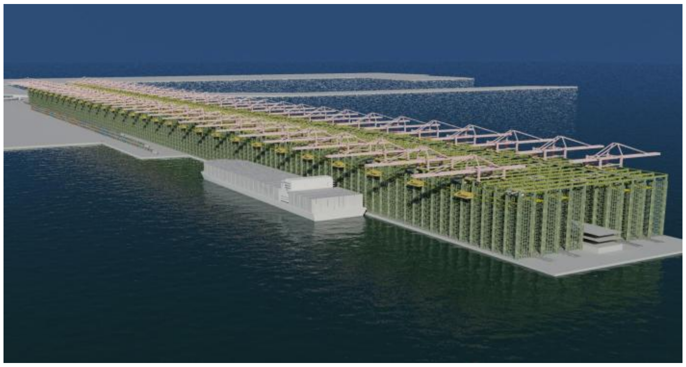

Figure 1 Grid SuperDock

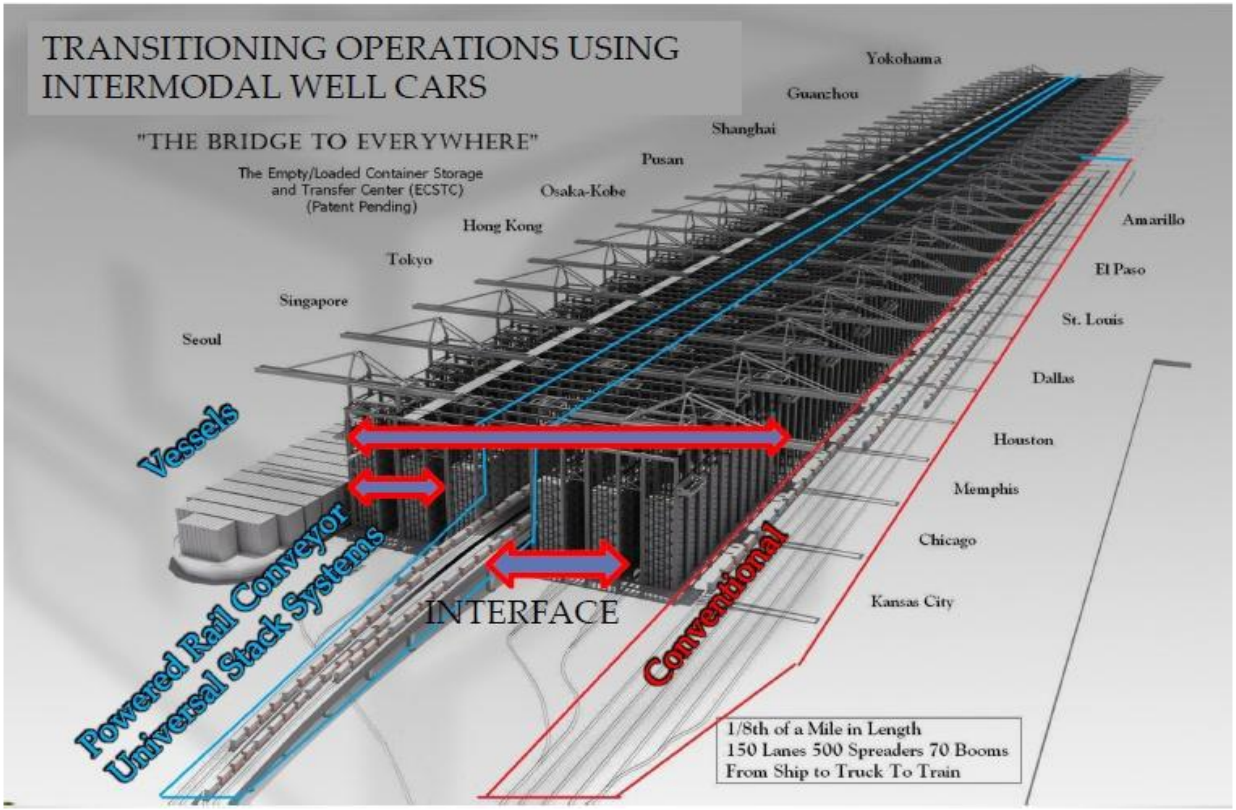

Figure 2 Interface of SuperDock with rail

The SuperDock converts the space under shipping cranes into a computerized storage facility for empty and loaded containers as shown in Figure 1. Containers are moved to and from ships directly into the SuperDock. Full-length trains drive under or adjacent to the facility to be loaded or unloaded within the Port, (see Figure 2) so there is no intermediate shuffling of containers to off-site container transfer facilities to assemble trains for transport beyond Southern California. According to the designers of the system unloading and reloading time for cross-country trains can be reduced from 36 to less than 4 hours, at a lower total cost than today's port facilities. An underground powered rail "container conveyor" freight pipeline is proposed to run from the SuperDock to inland rail hubs connected to existing warehousing and trans-loading areas of the Inland Empire, central California and beyond (see Figure3). This pipeline would move containers using clean electricity, drastically reducing diesel fume emissions and congestion due to reduction of truck traffic in the roadway network. Portions of the lower I-710 freeway, Los Angeles, Rio Hondo, and San Gabriel River beds were identified by the designers as the ideal right-of way locations for an unobstructed “container conveyor” freight pipeline. The proximity to power lines which can also go underground avoiding the urban blight of high-voltage transmission towers, offers another opportunity to free thousands of acres currently occupied by power line rights-of-way. By going underground issues such as right of way, noise and impact to neighborhoods are avoided. Another opportunity the designers see is that the approval of GRID will obviate the need for each railroad’s independent new container transfer facilities, planned Ports upgrades, the widening of I-710, and could serve as an alternate version of the recently proposed East/West Freight Corridor. Ultimately if GRID were adopted, savings from the $15B to $23B estimated cost for those projects can be applied as funding for some form of public-private partnership. However, according to GRID designers and their conversations/impressions from business leaders, they believe project costs could largely come from private sector interests leading to significant savings in public financing. According to the designers the total cost for GRID is as economically feasible as existing proposals that expand and exacerbate the problems they attempt to resolve. The underground pipeline is expected to be cost effective and already a construction company specializing in large underground water pipes and crane manufacturing is ready to take up the project provided clarity on project demand coming from the region’s key leadership and decision making apparatus at local, state, and federal levels emerge to become strongly evident. In addition, the Sierra Club endorsed the system as environmentally friendly.

Figure 3 Proposed pipeline (in blue) and Super Dock in relation to existing infrastructure

While some of the benefits are obvious to the inventors of the concept, proceeding to implementation is not an easy decision without considerable in depth evaluation of the system itself but also its interactions with the rest of the supply chain. Technical feasibility of operation, performance under different operating conditions and container volume demand during normal and emergency situations, cost of development and operation, environmental benefits etc are some of the major issues that need to be addressed. Computer simulations offer a powerful low cost tool to evaluate and transportation concept without disturbing current operations and consider many if scenarios.

3. Proposed Investigations

Task 1: Microscopic Simulation Evaluation

A microscopic simulation model of the SuperDock and associated transport network will be developed. The simulator will simulate the movement and dynamics of each piece of equipment, such as loading/unloading equipment shuttles, in time and space and their interactions with ships, intermodal hubs etc. The simulator will be used to examine the following:

- Performance under different container volume demands
- Identify possible bottle necks
- Evaluate impact of equipment break out or maintenance cycles
- Evaluate impact of interactions due to delays, randomness
- Use the simulator and optimization tools to optimize operations
- Compare performance of the proposed system with current operations
- Run any if scenarios any user may come up with associated with the system

Task 2: Cost Evaluation Model

Costs associated with container handling and storage operations within a terminal can be classified into the following three categories:

- Cost of activities: that is the costs of locations where activities (operations) take place i.e. buildings and facilities such as gates, customs, etc.

- Cost of land: the capital investment for land in different areas, e.g. berth area, storage area, etc.

- Cost of equipment, the cost of yard equipment e.g. yard cranes, quay cranes, AGVs, etc.

- **Labor costs.**

Currently a cost model for container terminals has been used to evaluate several terminal concepts. This model written in C++ will be modified to apply to the SuprDock facility in order to generate various cost estimates that will also include an average cost to move a container through the facility. Since cost is related to the volume of containers handled the cost model will be integrated with the microscopic simulator which will be generating the volume of containers handled under different operating scenarios.

Task 3: Impact on Congestion and Environment

The GRID system is expected to reduce the number of trucks on the road network. Under this task we plan to use a microscopic traffic simulator that simulates traffic on a large network adjacent to the complex port of LA/LB together with a vehicle emission model to assess the benefits with respect to traffic congestion and environment the GRID system will bring. The traffic simulator and vehicle emission model are already built and available to use to evaluate different traffic scenarios that will result from the use of the GRID system

Task 4: Freight Pipeline Constructability

Another goal of the study is to analyze the constructability of the freight pipeline. Aspects to be reviewed include but are not limited to installation process for the pipe wall, (i.e., segmented tunnel liners, jacked pipe, or cut-and-cover pipe), joint requirements, seismic and fault crossing design, and review of stabilization of native soils for repeated loadings from drone trains, plus installation procedures for track and linear electric motors.

Estimated Budget

The estimated budget for performing Tasks 1-3 is about $700,000 and is calculated as follows

Task 1 Estimated Cost $400K

Task 2. Estimated Cost $100K

Task 3. Estimated Cost $100K

Task 4. Estimated Cost $100K

Curriculum Vitae – Petros A. Ioannou

Professional Preparation

- University of London, London, England; Mechanical Engineering; B.Sc. First Class Honors, 1978
- University of Illinois, Urbana, Illinois; Mechanical Engineering; MS, 1980
- University of Illinois, Urbana, Illinois; Electrical Engineering; Ph.D., 1983

Appointments

- 1982 to present University of Southern California (USC), Professor of Electrical Engineering Systems and Aerospace and Mechanical Engineering
- 2011 to present Joint Appointment with Industrial Engineering and Systems Department
- 1992 to present Director for the Center for Advanced Transportation Technologies at USC
- 2006 to present Associate Director for Research of the University Transportation Center METRANS,
- 2010 to present Adjunct Professor University of Cyprus,
- 2008-present Director of the Masters Program in Financial Engineering at USC
- 1995-1996 Dean of the School of Pure and Applied Science at the University of Cyprus

Ten Most Relevant Publications

1. P.A. Ioannou Intelligent Freight Transportation, CRC Press, 2008
2. P. A. Ioannou and A. Pitsillides, Modelling and Control of Complex Systems, CRC Press, 2007
3. J. Zhang and P.A. Ioannou, "Longitudinal Control of Heavy Trucks in Mixed Traffic: Environmental and Fuel Economy Considerations," IEEE Transactions on Intelligent Transportation Systems, vol. 7, no. 1, pp. 92-104, 2006

4. H. Jula, M. Dessouky, and P. Ioannou, "Truck route planning in non-stationary stochastic networks with Time Windows at Customer Locations," IEEE Transactions on Intelligent Transportation Systems, Vol. 7, No. 1, pp. 51-62, March 2006.
5. H. Jula, M. Dessouky, P. Ioannou, and A. Chassiakos, "Container movement by trucks in metropolitan networks: modeling and optimization," Transportation Research – Part E, 41, 235-259, 2005.
6. C. I. Liu, H. Jula, and P.A. Ioannou, "Design, simulation, and evaluation of automated container terminals," IEEE Transactions on Intelligent Transportation Systems, vol. 3, no. 1, March 2002 pp.12-27.
7. I. Liu, H. Jula, P.A. Ioannou, ' Automated Guided Vehicle System for Two Container Yard Layouts' Transportation Research Part C: Emerging Technologies, no.12, pp.349-368, 2004.
8. Hwan Chang, Hossein Jula, Anastasios Chassiakos and Petros Ioannou, "A heuristic solution for the empty container substitution problem," Transportation Research Part E, Vol. 44, no. 2, March 2008, pp. 203-216.
9. A. Bose and P. Ioannou, "Issues and Analysis of Mixed Semi-Automated/Manual Traffic", SAE Technical Paper #981943, *SAE Transactions-Journal of Passenger Cars*, 1998.
10. H. Jula, E. Kosmatopoulos and P. Ioannou, " Collision Avoidance Analysis for Lane Changing and Merging", IEEE Transactions on Vehicular Technology, Vol. 49, No.6, November 2000 pp 2295-2308

Synergistic Activities and Awards

- **2008** ***IEEE ITSS Outstanding ITS Application Award***, June 2009
- **2009** ***IET Heaviside Medal for Achievement in Control***, November 2009
- ***Fellow of the Institution of Engineering and Technology (IET), since 2009***
- ***Fellow of the Institute of Electrical and Electronic Engineers (IEEE) since 1992***
- ***Fellow of the International Federation of Automatic Control (IFAC) since 2006***
- ***Presidential Young Investigator Award*** **in 1985**
- ***Best Research Paper Award*** **by the IEEE Control System Society in 1984.**

- Established the Center for Advanced Transportation Technologies at the University of Southern California in 1992 and directed the center from 1992 to today
- Author of 8 books and more than 200 papers in the area of Control Systems, Dynamics and Transportation
- Rated as the 2nd most productive author and the 6th most cited author in the IEEE Transactions on ITS (see study in, L. Li et.al. IEEE Trans. on ITS vol.11, no.2, June 2010 pp 251-255)
- Supervised and graduated 29 Ph.D. (4 from underrepresented groups) students, Supervised 6 Postdoctoral Students (2 from underrepresented groups). Four of the former PhD students are Fellows of IEEE and 11 are Professors.
- Served as Associate Editor of IEEE Trans. on Automatic Control, Automatica, International Journal of Control and IEEE Transactions on Intelligent Transportation Systems (ITS) and Associate Editor at Large of the IEEE Trans. on Automatic Control.
- Organizer and National Organizing Committee Chair 12th IFAC Symposium on Transportation Systems, September 2-4, 2009
- Organizer and General Chair of the 2008 International Trade and Freight Transportation Conference, September 1-3, 2008, Ayia Napa, Cyprus
- Technical Program Chair of the 2007 IEEE Intelligent Vehicles Symposium, June 13-15, 2007, Istanbul, Turkey
- Organizer and Program Chair of the International Conference on Intelligent Systems And Computing: Theory And Applications (ISYC), July 6-7, 2006, Ayia Napa, Cyprus
- Technical Program Chair of the 2nd Annual National Urban Freight Conference, Dec. 5-7, 2007
- Chairman of the IFAC Technical Committee on Transportation Systems, 2005 to 2008

Funding Agencies

Dr Ioannou’s transportation research has been funded over the years by:

- National Science Foundation
- California Department of Transportation

- Department of Transportation
- Federal Highway Administration
- Federal Transit Administration
- Maritime and USTRASCOM via CCDoTT
- Ford Motor Company
- General Motors
- AUDI

Attachments from Comment Letter 116

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James J. J. Clark, Ph.D.

Principal Toxicologist

Toxicology/Exposure Assessment Modeling

Risk Assessment/Analysis/Dispersion Modeling

Education:

Ph.D., Environmental Health Science, University of California, 1995

M.S., Environmental Health Science, University of California, 1993

B.S., Biophysical and Biochemical Sciences, University of Houston, 1987

Professional Experience:

Dr. Clark is a well recognized toxicologist, air modeler, and health scientist. He has 20 years of experience in researching the effects of environmental contaminants on human health including environmental fate and transport modeling (SCREEN3, AEROMOD, ISCST3, Johnson-Ettinger Vapor Intrusion Modeling); exposure assessment modeling (partitioning of contaminants in the environment as well as PBPK modeling); conducting and managing human health risk assessments for regulatory compliance and risk-based clean-up levels; and toxicological and medical literature research.

Significant projects performed by Dr. Clark include the following:

LITIGATION SUPPORT

Case: Rose Roper V. Nissan North America, et al. Superior Court of the State Of California for the County Of Los Angeles – Central Civil West. Civil Action. NC041739

Client: Rose, Klein, Marias, LLP, Long Beach, California

Dr. Clark performed a toxicological assessment of an individual occupationally exposed to multiple chemicals, including benzene, who later developed a respiratory distress. A review of the individual's medical and occupational history was performed to prepare an exposure assessment. The exposure assessment was evaluated against the known outcomes in published literature to exposure to respiratory irritants. The results of the assessment and literature have been provided in a declaration to the court.

Case Result: Settlement in favor of plaintiff.

Case: O'Neil V. Sherwin Williams, et al. United States District Court Central District of California

Client: Rose, Klein, Marias, LLP, Long Beach, California

Dr. Clark performed a toxicological assessment of an individual occupationally exposed to petroleum distillates who later developed a bladder cancer. A review of the individual's medical and occupational history was performed to prepare a quantitative exposure assessment. The results of the assessment and literature have been provided in a declaration to the court.

Case Result: Summary judgment for defendants.

Case: Moore V., Shell Oil Company, et al. Superior Court of the State Of California for the County Of Los Angeles

Client: Rose, Klein, Marias, LLP, Long Beach, California

Dr. Clark performed a toxicological assessment of an individual occupationally exposed to chemicals while benzene who later developed a leukogenic disease. A review of the individual's medical and occupational history was performed to prepare a quantitative exposure assessment. The exposure assessment was evaluated against the known outcomes in published literature to exposure to refined petroleum hydrocarbons. The results of the assessment and literature have been provided in a declaration to the court.

Case Result: Settlement in favor of plaintiff.

Case: Raymond Saltonstall V. Fuller O'Brien, KILZ, and Zinsser, et al. United States District Court Central District of California

Client: Rose, Klein, Marias, LLP, Long Beach, California

Dr. Clark performed a toxicological assessment of an individual occupationally exposed to benzene who later developed a leukogenic disease. A review of the individual's medical and occupational history was performed to prepare a quantitative exposure assessment. The exposure assessment was evaluated against the known outcomes in published literature to exposure to refined petroleum hydrocarbons. The results of the assessment and literature have been provided in a declaration to the court.

Case Result: Settlement in favor of plaintiff.

Case: Richard Boyer and Elizabeth Boyer, husband and wife, V. DESCO Corporation, et al. Circuit Court of Brooke County, West Virginia. Civil Action Number 04-C-7G.

Client: Frankovitch, Anetakis, Colantonio & Simon, Morgantown, West Virginia.

Dr. Clark performed a toxicological assessment of a family exposed to chlorinated solvents released from the defendant's facility into local drinking water supplies. A review of the individual's medical and occupational history was performed to prepare a qualitative exposure assessment. The exposure assessment was evaluated against the known outcomes in published literature to exposure to chlorinated solvents. The results of the assessment and literature have been provided in a declaration to the court.

Case Result: Settlement in favor of plaintiff.

Case: JoAnne R. Cook, V. DESCO Corporation, et al. Circuit Court of Brooke County, West Virginia. Civil Action Number 04-C-9R

Client: Frankovitch, Anetakis, Colantonio & Simon, Morgantown, West Virginia.

Dr. Clark performed a toxicological assessment of an individual exposed to chlorinated solvents released from the defendant's facility into local drinking water supplies. A review of the individual's medical and occupational history was performed to prepare a qualitative exposure assessment. The exposure assessment was evaluated against the known outcomes in published literature to exposure to chlorinated solvents. The results of the assessment and literature have been provided in a declaration to the court.

Case Result: Settlement in favor of plaintiff.

Case: Patrick Allen And Susan Allen, husband and wife, and Andrew Allen, a minor, V. DESCO Corporation, et al. Circuit Court of Brooke County, West Virginia. Civil Action Number 04-C-W

Client: Frankovitch, Anetakis, Colantonio & Simon, Morgantown, West Virginia.

Dr. Clark performed a toxicological assessment of a family exposed to chlorinated solvents released from the defendant's facility into local drinking water supplies. A review of the individual's medical and occupational history was performed to prepare a qualitative exposure assessment. The exposure assessment was evaluated against the known outcomes in published literature to exposure to chlorinated solvents. The results of the assessment and literature have been provided in a declaration to the court.

Case Result: Settlement in favor of plaintiff.

Case: Michael Fahey, Susan Fahey V. Atlantic Richfield Company, et al. United States District Court Central District of California Civil Action Number CV-06 7109 JCL.

Client: Rose, Klein, Marias, LLP, Long Beach, California

Dr. Clark performed a toxicological assessment of an individual occupationally exposed to refined petroleum hydrocarbons who later developed a leukogenic disease. A review of the individual's medical and occupational history was performed to prepare a qualitative exposure assessment. The exposure assessment was evaluated against the known outcomes in published literature to exposure to refined petroleum hydrocarbons. The results of the assessment and literature have been provided in a declaration to the court.

Case Result: Settlement in favor of plaintiff.

Case: Tanya Drummond V. E.I. Dupont De Nemours and Company, Meadowbrook Corporation, Mattheissen & Hegler Zinc Company Inc, Nuzum Trucking Company, T.L. Diamond & Company, Inc., and Joseph Paushel, Circuit Court of Harrison County, West Virginia. Civil Action Number 04-C-296-2.

Client: Cochran, Cherry, Givens, Smith, Lane & Taylor, P.C., Dothan, Alabama

Dr. Clark performed a comprehensive exposure assessment of a plaintiff exposed to toxic metals from a former zinc smelting facility. The site has undergone a CERCLA mandated removal action/remediation for the presence of the toxic metals. Intensive modeling results (from physical and numerical models) were used to determine a daily dose of metals in the plaintiff over a life time of exposure along with a causal analysis to determine the contribution of the toxic metals to the renal carcinomas the plaintiff died from.

Case Result: Settlement in favor of plaintiff.

Case: City of Stockton v. BNSF Railway Co., et al. Eastern District of California, Case No. 2:05-CV-02087

Dr. Clark offered opinions regarding the potential health risks from exposure to chemicals present in and emanating from the soil and into the air at a site formerly operated by the defendant using the regulatory guidance framework from USEPA and DTSC. The evaluation was designed to establish cleanup goals based upon the current and future land uses of the Site. A second objective was to evaluate whether current conditions at the Site put patrons and staff of the Children's Museum at an elevated potential health risk from exposure to chemicals present in and emanating from the soil and into the air at the Site.

Case Result: Judgment in favor of plaintiff.

Case: Constance Acevedo, et al., V. California Spray-Chemical Company, et al., Superior Court of the State Of California, County Of Santa Cruz. Case No. CV 146344

Dr. Clark performed a comprehensive exposure assessment of community members exposed to toxic metals from a former lead arsenate manufacturing facility. The former manufacturing site had undergone a DTSC mandated removal action/remediation for the presence of the toxic metals at the site. Opinions were presented regarding the elevated levels of arsenic and lead (in attic dust and soils) found throughout the community and the potential for harm to the plaintiffs in question.

Case Result: Settlement in favor of defendant.

Case: Lori Lynn Moss and Rand Moss, et al. V. Venoco, Inc. et al. Superior Court of the State of California, County of Los Angeles, Central Civil West. Case Number BC 297083

Client: Baron & Budd, PC. Dallas, TX.

Dr. Clark performed a comprehensive exposure assessment of plaintiffs (former students at a school adjacent to the plant) to dioxin-like compounds from a large urban electrical utility generator and from multiple oil and gas production facilities adjacent to an active school. Modeling of emissions has confirmed that emissions from the facilities have impacted the school, resulting in significant exposure to carcinogens and neurotoxins. Intensive modeling results (from physical and numerical models) were used to determine a daily dose of contaminants from multiple sites over decades of exposure.

Case Result: Under Appeal.

Case: Michael Nawrocki V. The Coastal Corporation, Kurk Fuel Company, Pautler Oil Service, State of New York Supreme Court, County of Erie, Index Number I2001-11247

Client: Richard G. Berger Attorney At Law, Buffalo, New York

Dr. Clark performed a toxicological assessment of an individual occupationally exposed to refined petroleum hydrocarbons who later developed a leukogenic disease. A review of the individual's medical and occupational history was performed to prepare a qualitative exposure assessment. The exposure assessment was evaluated against the known outcomes in published literature to exposure to refined petroleum hydrocarbons. The results of the assessment and literature have been provided in a declaration to the court.

Case Result: Judgement in favor of defendant.

Case: RFI et al., V. City of Santa Clarita, Superior Court of the State of California, County of Los Angeles

Client: City of Santa Clarita, Santa Clarita, California

Dr. Clark provided testimony regarding the characterization, remediation and development activities of a former 1,000 acre munitions manufacturing facility. The site is impacted with a number of contaminants including perchlorate, unexploded ordinance, and volatile organic compounds (VOCs). The site is currently under a number of regulatory consent orders, including an Immanent and Substantial Endangerment Order. Dr. Clark provided depositional testimony and trial testimony on the extent of contamination in the subsurface and groundwater, the migration of contaminants offsite, and cost estimates for remediating the contamination.

Case Result: Under Appeal.

Case: Costco Wholesale Corporation, etc, V. San Francisco Bay Area Rapid Transit District, etc., et. al., Superior Court of the State of California For the County of San Mateo

Dr. Clark evaluated analytical laboratory results to determine whether remediation efforts by the plaintiff were necessary based on the proposed site land use. Deposition testimony was offered on the composition of petroleum hydrocarbons in the subsurface at the site, clean-up standards, and the necessity of remediation.

Case Result: Settlement in favor of defendant.

SELECTED AIR MODELING RESEARCH/PROJECTS

Client – Confidential

Dr. Clark performed a comprehensive evaluation of criteria pollutants, air toxins, and particulate matter emissions from a carbon black production facility to determine the impacts on the surrounding communities. The results of the dispersion model will be used to estimate acute and chronic exposure concentrations to multiple contaminants and will be incorporated into a comprehensive risk evaluation.

Client – Confidential

Dr. Clark performed a comprehensive evaluation of air toxins and particulate matter emissions from a railroad tie manufacturing facility to determine the impacts on the surrounding communities. The results of the dispersion model have been used to estimate acute and chronic exposure concentrations to multiple contaminants and have been incorporated into a comprehensive risk evaluation.

Client – Los Angeles Alliance for a New Economy (LAANE), Los Angeles, California

Dr. Clark is advising the LAANE on air quality issues related to current flight operations at the Los Angeles International Airport (LAX) operated by the Los Angeles World Airport (LAWA) Authority. He is working with the LAANE and LAX staff to develop a comprehensive strategy for meeting local community concerns over emissions from flight operations and to engage federal agencies on the issue of local impacts of community airports.

Client – City of Santa Monica, Santa Monica, California

Dr. Clark is advising the City of Santa Monica on air quality issues related to current flight operations at the facility. He is working with the City staff to develop a comprehensive strategy for meeting local community concerns over emissions from flight operations and to engage federal agencies on the issue of local impacts of community airports.

Client: Omnitrans, San Bernardino, California

Dr. Clark managed a public health survey of three communities near transit fueling facilities in San Bernardino and Montclair California in compliance with California Senate Bill 1927. The survey included an epidemiological survey of the effected communities, emission surveys of local businesses, dispersion modeling to determine potential emission concentrations within the communities, and a comprehensive risk assessment of each community. The results of the study were presented to the Governor as mandated by Senate Bill 1927.

Client: Confidential, San Francisco, California

Summarized cancer types associated with exposure to metals and smoking. Researched the specific types of cancers associated with exposure to metals and smoking. Provided causation analysis of the association between cancer types and exposure for use by non-public health professionals.

Client: Confidential, Minneapolis, Minnesota

Prepared human health risk assessment of workers exposed to VOCs from neighboring petroleum storage/transport facility. Reviewed the systems in place for distribution of petroleum hydrocarbons to identify chemicals of concern (COCs), prepared comprehensive toxicological summaries of COCs, and quantified potential risks from carcinogens and non-carcinogens to receptors at or adjacent to site. This evaluation was used in the support of litigation.

Client – United Kingdom Environmental Agency

Dr. Clark is part of team that performed comprehensive evaluation of soil vapor intrusion of VOCs from former landfill adjacent residences for the United Kingdom’s Environment Agency. The evaluation included collection of liquid and soil vapor samples at site, modeling of vapor migration using the Johnson Ettinger Vapor Intrusion model, and calculation of site-specific health based vapor thresholds for chlorinated solvents, aromatic hydrocarbons, and semi-volatile organic compounds. The evaluation also included a detailed evaluation of the use, chemical characteristics, fate and transport, and toxicology of chemicals of concern (COC). The results of the evaluation have been used as a briefing tool for public health professionals.

EMERGING/PERSISTENT CONTAMINANT RESEARCH/PROJECTS

Client: Ameren Services, St. Louis, Missouri

Managed the preparation of a comprehensive human health risk assessment of workers and residents at or near an NPL site in Missouri. The former operations at the Property included the servicing and repair of electrical transformers, which resulted in soils and groundwater beneath the Property and adjacent land becoming impacted with PCB and chlorinated solvent compounds. The results were submitted to U.S. EPA for evaluation and will be used in the final ROD.

Client: City of Santa Clarita, Santa Clarita, California

Dr. Clark is managing the oversight of the characterization, remediation and development activities of a former 1,000 acre munitions manufacturing facility for the City of Santa Clarita. The site is impacted with a number of contaminants including perchlorate, unexploded ordinance, and volatile organic compounds (VOCs). The site is currently under a number of regulatory consent orders, including an Immanent and Substantial Endangerment Order. Dr. Clark is assisting the impacted municipality with the development of remediation strategies, interaction with the responsible parties and stakeholders, as well as interfacing with the regulatory agency responsible for oversight of the site cleanup.

Client: Confidential, Los Angeles, California

Prepared comprehensive evaluation of perchlorate in environment. Dr. Clark evaluated the production, use, chemical characteristics, fate and transport, toxicology, and remediation of perchlorate. Perchlorates form the basis of solid rocket fuels and have recently been detected in water supplies in the United States. The results of this research were presented to the USEPA, National GroundWater, and ultimately published in a recent book entitled *Perchlorate in the Environment*.

Client – Confidential, Los Angeles, California

Dr. Clark is performing a comprehensive review of the potential for pharmaceuticals and their by-products to impact groundwater and surface water supplies. This evaluation will include a review if available data on the history of pharmaceutical production in the United States; the chemical characteristics of various pharmaceuticals; environmental fate and transport; uptake by xenobiotics; the potential effects of pharmaceuticals on water treatment systems; and the potential threat to public health. The results of the evaluation may be used as a briefing tool for non-public health professionals.

PUBLIC HEALTH/TOXICOLOGY

Client: Brayton Purcell, Novato, California

Dr. Clark performed a toxicological assessment of residents exposed to methyl-tertiary butyl ether (MTBE) from leaking underground storage tanks (LUSTs) adjacent to the subject property. The symptomology of residents and guests of the subject property were evaluated against the known outcomes in published literature to exposure to MTBE. The study found that residents had been exposed to MTBE in their drinking water; that concentrations of MTBE detected at the site were above regulatory guidelines; and, that the symptoms and outcomes expressed by residents and guests were consistent with symptoms and outcomes documented in published literature.

Client: Confidential, San Francisco, California

Identified and analyzed fifty years of epidemiological literature on workplace exposures to heavy metals. This research resulted in a summary of the types of cancer and non-cancer diseases associated with occupational exposure to chromium as well as the mortality and morbidity rates.

Client: Confidential, San Francisco, California

Summarized major public health research in United States. Identified major public health research efforts within United States over last twenty years. Results were used as a briefing tool for non-public health professionals.

Client: Confidential, San Francisco, California

Quantified the potential multi-pathway dose received by humans from a pesticide applied indoors. Part of team that developed exposure model and evaluated exposure concentrations in a comprehensive report on the plausible range of doses received by a specific person. This evaluation was used in the support of litigation.

Client: Covanta Energy, Westwood, California

Evaluated health risk from metals in biosolids applied as soil amendment on agricultural lands. The biosolids were created at a forest waste cogeneration facility using 96% whole tree wood chips and 4 percent green waste. Mass loading calculations were used to estimate Cr(VI) concentrations in agricultural soils based on a maximum loading rate of 40 tons of biomass per acre of agricultural soil. The results of the study were used by the Regulatory agency to determine that the application of biosolids did not constitute a health risk to workers applying the biosolids or to residences near the agricultural lands.

Client – United Kingdom Environmental Agency

Oversaw a comprehensive toxicological evaluation of methyl-*tertiary* butyl ether (M*t*BE) for the United Kingdom's Environment Agency. The evaluation included available data on the production, use, chemical characteristics, fate and transport, toxicology, and remediation of M*t*BE. The results of the evaluation have been used as a briefing tool for public health professionals.

Client – Confidential, Los Angeles, California

Prepared comprehensive evaluation of *tertiary* butyl alcohol (TBA) in municipal drinking water system. TBA is the primary breakdown product of M*t*BE, and is suspected to be the primary cause of M*t*BE toxicity. This evaluation will include available information on the production, use, chemical characteristics, fate and transport in the environment, absorption, distribution, routes of detoxification, metabolites, carcinogenic potential, and remediation of TBA. The results of the evaluation were used as a briefing tool for non-public health professionals.

Client – Confidential, Los Angeles, California

Prepared comprehensive evaluation of methyl *tertiary* butyl ether (MTBE) in municipal drinking water system. MTBE is a chemical added to gasoline to increase the octane rating and to meet Federally mandated emission criteria. The evaluation included available data on the production, use, chemical characteristics, fate and transport, toxicology, and remediation of MTBE. The results of the evaluation have been were used as a briefing tool for non-public health professionals.

Client – Ministry of Environment, Lands & Parks, British Columbia

Dr. Clark assisted in the development of water quality guidelines for methyl tertiary-butyl ether (MTBE) to protect water uses in British Columbia (BC). The water uses to be considered includes freshwater and marine life, wildlife, industrial, and agricultural (e.g., irrigation and livestock watering) water uses. Guidelines from other jurisdictions for the protection of drinking water, recreation and aesthetics were to be identified.

Client: Confidential, Los Angeles, California

Prepared physiologically based pharmacokinetic (PBPK) assessment of lead risk of receptors at middle school built over former industrial facility. This evaluation is being used to determine cleanup goals and will be basis for regulatory closure of site.

Client: Kaiser Venture Incorporated, Fontana, California

Prepared PBPK assessment of lead risk of receptors at a 1,100-acre former steel mill. This evaluation was used as the basis for granting closure of the site by lead regulatory agency.

RISK ASSESSMENTS/REMEDIAL INVESTIGATIONS

Client: Confidential, Atlanta, Georgia

Researched potential exposure and health risks to community members potentially exposed to creosote, polycyclic aromatic hydrocarbons, pentachlorophenol, and dioxin compounds used at a former wood treatment facility. Prepared a comprehensive toxicological summary of the chemicals of concern, including the chemical characteristics, absorption, distribution, and carcinogenic potential. Prepared risk characterization of the carcinogenic and non-carcinogenic chemicals based on the exposure assessment to quantify the potential risk to members of the surrounding community. This evaluation was used to help settle class-action tort.

Client: Confidential, Escondido, California

Prepared comprehensive Preliminary Endangerment Assessment (PEA) of dense non-aqueous liquid phase hydrocarbon (chlorinated solvents) contamination at a former printed circuit board manufacturing facility. This evaluation was used for litigation support and may be used as the basis for reaching closure of the site with the lead regulatory agency.

Client: Confidential, San Francisco, California

Summarized epidemiological evidence for connective tissue and autoimmune diseases for product liability litigation. Identified epidemiological research efforts on the health effects of medical prostheses. This research was used in a meta-analysis of the health effects and as a briefing tool for non-public health professionals.

Client: Confidential, Bogotá, Columbia

Prepared comprehensive evaluation of the potential health risks associated with the redevelopment of a 13.7 hectares plastic manufacturing facility in Bogotá, Colombia The risk assessment was used as the basis for the remedial goals and closure of the site.

Client: Confidential, Los Angeles, California

Prepared comprehensive human health risk assessment of students, staff, and residents potentially exposed to heavy metals (principally cadmium) and VOCs from soil and soil vapor at 12-acre former crude oilfield and municipal landfill. The site is currently used as a middle school housing approximately 3,000 children. The evaluation determined that the site was safe for the current and future uses and was used as the basis for regulatory closure of site.

Client: Confidential, Los Angeles, California

Managed remedial investigation (RI) of heavy metals and volatile organic chemicals (VOCs) for a 15-acre former manufacturing facility. The RI investigation of the site included over 800 different sampling locations and the collection of soil, soil gas, and groundwater samples. The site is currently used as a year round school housing approximately 3,000 children. The Remedial Investigation was performed in a manner that did not interrupt school activities and met the time restrictions placed on the project by the overseeing regulatory agency. The RI Report identified the off-site source of metals that impacted groundwater beneath the site and the sources of VOCs in soil gas and groundwater. The RI included a numerical model of vapor intrusion into the buildings at the site from the vadose zone to determine exposure concentrations and an air dispersion model of VOCs from the proposed soil vapor treatment system. The Feasibility Study for the Site is currently being drafted and may be used as the basis for granting closure of the site by DTSC.

Client: Confidential, Los Angeles, California

Prepared comprehensive human health risk assessment of students, staff, and residents potentially exposed to heavy metals (principally lead), VOCs, SVOCs, and PCBs from soil, soil vapor, and groundwater at 15-acre former manufacturing facility. The site is currently used as a year round school housing approximately 3,000 children. The evaluation determined that the site was safe for the current and future uses and will be basis for regulatory closure of site.

Client: Confidential, Los Angeles, California

Prepared comprehensive evaluation of VOC vapor intrusion into classrooms of middle school that was former 15-acre industrial facility. Using the Johnson-Ettinger Vapor Intrusion model, the evaluation determined acceptable soil gas concentrations at the site that did not pose health threat to students, staff, and residents. This evaluation is being used to determine cleanup goals and will be basis for regulatory closure of site.

Client –Dominguez Energy, Carson, California

Prepared comprehensive evaluation of the potential health risks associated with the redevelopment of 6-acre portion of a 500-acre oil and natural gas production facility in Carson, California. The risk assessment was used as the basis for closure of the site.

Kaiser Ventures Incorporated, Fontana, California

Prepared health risk assessment of semi-volatile organic chemicals and metals for a fifty-year old wastewater treatment facility used at a 1,100-acre former steel mill. This evaluation was used as the basis for granting closure of the site by lead regulatory agency.

ANR Freight - Los Angeles, California

Prepared a comprehensive Preliminary Endangerment Assessment (PEA) of petroleum hydrocarbon and metal contamination of a former freight depot. This evaluation was as the basis for reaching closure of the site with lead regulatory agency.

Kaiser Ventures Incorporated, Fontana, California

Prepared comprehensive health risk assessment of semi-volatile organic chemicals and metals for 23-acre parcel of a 1,100-acre former steel mill. The health risk assessment was used to determine clean up goals and as the basis for granting closure of the site by lead regulatory agency. Air dispersion modeling using ISCST3 was performed to determine downwind exposure point concentrations at sensitive receptors within a 1 kilometer radius of the site. The results of the health risk assessment were presented at a public meeting sponsored by the Department of Toxic Substances Control (DTSC) in the community potentially affected by the site.

Unocal Corporation - Los Angeles, California

Prepared comprehensive assessment of petroleum hydrocarbons and metals for a former petroleum service station located next to sensitive population center (elementary school). The assessment used a probabilistic approach to estimate risks to the community and was used as the basis for granting closure of the site by lead regulatory agency.

Client: Confidential, Los Angeles, California

Managed oversight of remedial investigation most contaminated heavy metal site in California. Lead concentrations in soil excess of 68,000,000 parts per billion (ppb) have been measured at the site. This State Superfund Site was a former hard chrome plating operation that operated for approximately 40-years.

Client: Confidential, San Francisco, California

Coordinator of regional monitoring program to determine background concentrations of metals in air. Acted as liaison with SCAQMD and CARB to perform co-location sampling and comparison of accepted regulatory method with ASTM methodology.

Client: Confidential, San Francisco, California

Analyzed historical air monitoring data for South Coast Air Basin in Southern California and potential health risks related to ambient concentrations of carcinogenic metals and volatile organic compounds. Identified and reviewed the available literature and calculated risks from toxins in South Coast Air Basin.

IT Corporation, North Carolina

Prepared comprehensive evaluation of potential exposure of workers to air-borne VOCs at hazardous waste storage facility under SUPERFUND cleanup decree. Assessment used in developing health based clean-up levels.

Professional Associations

American Public Health Association (APHA)

Association for Environmental Health and Sciences (AEHS)

American Chemical Society (ACS)

California Redevelopment Association (CRA)

International Society of Environmental Forensics (ISEF)

Society of Environmental Toxicology and Chemistry (SETAC)

Publications and Presentations:

Books and Book Chapters

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Tam L. K.., Wu C. D., Clark J. J. and **Rosenfeld, P.E.** (2008) Methods For Collect Samples For Assessing Dioxins And Other Environmental Contaminants In Attic Dust: A Review. Organohalogen Compounds, Volume 70 (2008) page 000527

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APPENDIX C:

Health Impact Studies

APPENDIX C: Health Impact Studies

Appendix C-1: Respiratory and Children's Health Study

Barck, C., J. Lundahl, et al. (2005). "Brief exposures to NO2 augment the allergic inflammation in asthmatics." Environ Res 97(1): 58-66.

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Appendix C-2: Traffic proximity

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Appendix C-4: Cardiovascular and Neurologic

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Appendix C-6: Cancer

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Attachments from Comment Letter 126

ATTACHMENT C

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November 30, 2011

via electronic-mail and U.S. Mail

Mr. Christopher Cannon
Director of Environmental Management
Port of Los Angeles
425 South Palos Verdes Street
San Pedro, CA 90731

Re: Draft Environmental Impact Report: Southern California International Gateway

Dear Mr. Cannon:

INTRODUCTION

The South Coast Air Quality Management District (SCAQMD) staff appreciates the opportunity to comment on the Draft Environmental Impact Report (DEIR) for the Southern California International Gateway railyard project. This comment letter focuses on the issue of the proper baseline under the California Environmental Quality Act (CEQA) for the air quality analysis of the proposed project. SCAQMD staff believes that the Port of Los Angeles (Port) needs to use a baseline that will accurately quantify and identify the impacts of the project. The current approach, which uses year 2005 emissions in the impacted area as the baseline, fails to meet these goals, at least for some analysis areas. SCAQMD staff will also be providing additional comments.

First, the DEIR contains a misleading discussion regarding the baseline for the health risk assessment. The DEIR states that "The air quality analysis and the health risk assessment (HRA) of toxic air contaminant emissions associated with construction and operation of the proposed Project reported in Chapter 3.2 were conducted in accordance with a project-specific protocol prepared by the Port and reviewed and approved by SCAQMD. ..." Section ES 8.1, p. ES-85. This sentence implies that SCAQMD has approved the Port's approach to the baseline issue, which is described in the immediately following sentence. SCAQMD has not agreed to the Port's approach to the baseline issue for the HRA, and requests that this be clarified in the final EIR.

Mr. Christopher Cannon
November 30, 2011
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THE ANALYSIS IN THE DEIR

The SCAQMD staff believes that the CEQA baseline selected by the Port obscures the actual impacts of the project. The DEIR states that the Notice of Preparation (NOP) for this EIR was released in September 2005, and that therefore, "the baseline conditions for the proposed Project are, in general, the operational activities that occurred, and conditions as they existed, in 2005." Section ES 2.3, p. ES-3. Furthermore, the DEIR states that "Pursuant to CEQA Guidelines Section 15125(a) and the *Sunnyvale West Neighborhood Association v. City of Sunnyvale* (2010) 190 Cal. App. 4^{th} 1351 *(Sunnyvale)* case, the impacts were analyzed compared to the existing setting, which, for this project is the time of the Notice of Preparation (NOP) or 2005." Section ES 8.1, p. ES-85. The results of this analysis are presented in Appendix C-3.

As explained in the Appendix, "For the determination of significance from a CEQA standpoint, this HRA determined the incremental increase in health effects values due to the proposed Project by estimating the net change in impacts between the proposed Project and Baseline conditions." App. C-3, section 6.0, p. C3-34. This method of analysis resulted in a determination that the project impacts ("CEQA Increment") were negative 160 in a million cancer risk, which is to say that the project results in an actual reduction in cancer risk of 160 in a million compared to existing conditions. Table C3-7-1, p. C3-34.[1] However, this method of analysis improperly takes advantage of reductions in cancer risk that are the result of unrelated regulatory requirements and fleet turnover of mobile sources that are not the result of the project and would occur anyway if the project did not occur, as the existing tenants would be using cleaner equipment in the future than they are today.

THE DEIR ANALYSIS IS UNREALISTIC

A simplified example will illustrate the problem with the DEIR's approach.

Assume there is an existing facility that has emissions of 1000 lbs/day in the selected baseline year of 2005. In the future, if nothing else changes, the emissions will be reduced by the year 2020 to 500 lbs/day as a result of already-adopted and enforceable regulations and the impact of normal fleet turnover to newer vehicles (which are legally required to be cleaner than today's vehicles). The facility proposes a modification to increase operations so that its emissions in the year 2020 will be 750 lbs/day. If these emissions of 750 lbs/day are compared to year 2005 emissions of 1000 lbs/day, it appears that there is a reduction in emissions and no significant impact, even though in reality the modification added 250 lbs/day of emissions. As a result, there will be no alternatives and no mitigation measures designed to reduce that 250 lb/day increase. In our view, this approach does not comply with CEQA.

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[1] Due to site specific calculations, the " CEQA Increment" does not equate to the maximum impact under the CEQA Baseline minus the Proposed Project as illustrated in the Table. It would be very helpful to have an explanation of how the 160 in a million was derived.

Mr. Christopher Cannon
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The analysis of the health impacts suffers from the same defect identified above. The Appendix admits that the analysis takes advantage of emission reductions that are already required by existing rules, which in our view wrongly credits the project with unrelated emission reductions that would occur anyway, and would be even greater without the project. Thus, the Appendix states that factored into the impacts of the project were the following: "Reductions in emissions due to (a) the incidental phase-in of cleaner vehicles or equipment due to normal fleet turnover; (b) the future phase-in of cleaner fuels as required by existing regulations or agreements; and (c) the future phase-in of cleaner engines as required by existing regulations or agreements." Section 2.2, App. C-3, p. C3-4. Therefore, the project is given credit for emission reductions that would occur anyway, and would be even greater if the project did not occur. It defies common sense and logic to conclude—as the DEIR has—that a project largely designed to increase locomotive capacity will reduce cancer risk.

The purpose of CEQA is to "give the public and government agencies the information needed to make informed decisions, thus protecting 'not only the environment but also informed self-government.'" *In re Bay-Delta, etc.* (2008) 43 Cal. 4th 1143, 1162. CEQA also requires the lead agency to avoid or mitigate any significant adverse impacts to the extent feasible. Thus, CEQA contains a "substantive mandate" that public agencies not approve projects with significant environmental impacts if "there are feasible alternatives or mitigation measures" that can substantially lessen or avoid those effects. *Mountain Lion Foundation v. Fish and Game Commission* (1997) 16 Cal. 4th 105, 134 (emphasis in original). In our view, the use of year 2005 emissions as the baseline compared to future project emissions erroneously obscures the project's true impacts. Indeed, the approach taken in the DEIR would mean that projects in an urbanized area will frequently be identified to have no significant air quality operational impacts, because already-adopted air quality rules will so dramatically reduce emissions from existing equipment in the future that future emission—even with an expansion project—will be less than emissions at the time of the NOP. This approach is not consistent with CEQA because it fails to identify the significant adverse impacts *of the project*. CEQA Guidelines §15064 specifically requires the EIR to analyze the impacts of the project and determine "whether a project may have a significant effect..." and §15064(d) says "In evaluating the significance of the environmental effect of a project, the Lead Agency shall consider direct physical changes in the environment which may be caused by the project..." (emphasis added). The analysis in the DEIR violates this Guideline by not focusing on changes caused by the project and improperly taking credit for other changes that are not related to the project.

**THE DEIR ALTERNATIVE ANALYSIS
ILLUSTRATES A MORE REALISTIC APPROACH**

The weakness in the DEIR approach is amply demonstrated by the alternative approach analysis which compares project impacts with what is called a "floating baseline." This means that baseline emissions "were estimated by fixing activity levels at the time the NOP was released and allowing for future changes in emission factors due to adopted rules and regulations." Section ES 8.1, p. ES-85. In other words, this alternative attempts to avoid the flaws of the EIR's primary approach it does not credit to the project the emission reductions due to adopted rules that would occur anyway. Instead, such reductions are included in the alternative baseline. In our view, a baseline such as this alternative analysis that does not credit the project with reductions that would occur anyway due to adopted rules, is a more realistic baseline. However, the DEIR describes this analysis as one "not required by CEQA." *Id.* We believe that an analysis which realistically evaluates the impacts of the actual project, rather than crediting the project with unrelated future emission reductions, is in fact required by CEQA.

The "floating baseline" analysis, according to the Port's own calculations, results in a CEQA increment of 17 in a million cancer risk increase. Appendix C3 Section 7.4, table C3-7-10, p. C3-68. This risk level exceeds 10 in a million, which is the level identified by the Port as a significant increase. Appendix C3, Section 6.0, p. C3-33, and Table C3-7-1, p. C3-34.[2] Yet the DEIR as a whole concludes that the "CEQA Increment" using the 2005 baseline is a negative 160 in a million (i.e., a reduction in risk of 160 in a million), which is below the CEQA significance threshold of 10 in a million, so the impact is not significant. Appendix C3, Section 7.1, p. C3-34. Thus, the DEIR admits that the project increases cancer risk beyond what would occur without the project by 17 in a million, yet concludes there is no significant impact. This is an untenable result. It means that the DEIR fails to examine feasible mitigation measures or alternatives that could avoid or substantially lessen that significant cancer risk.

SUNNYVALE DECISION DOES NOT PRECLUDE A REALISTIC ANALYSIS

The DEIR takes the position that its approach is required by *Sunnyvale West Neighborhood Association v. City of Sunnyvale* (2010) 190 Cal. App. 4th 1351 *("Sunnyvale").* Section ES 8.1, p. ES-85. We disagree. In that case, the court reasoned: "The statute requires the impact of any proposed project to be evaluated against a baseline of existing environmental conditions…which is the *only way to identify the environmental effects specific to the project alone."* *Id* at 1380 (emphasis added). Therefore, the court concluded that the CEQA document improperly evaluated only the "incremental change in these conditions due to the project against the *already worse* traffic environment of the future." *Id.* at 1387 (emphasis added). In contrast, in this case the environment is expected to improve in the future, not get worse, so the rationale of *Sunnyvale* does not apply.

A leading treatise discusses the CEQA Guidelines' conclusion that the baseline is "normally" present conditions, stating that "by using the word 'normally' the Resources Agency has implicitly recognized that at least in some circumstances a 'past' or 'future' baseline might be appropriate." Michael H. Remy, et al. "Guide to CEQA (California Environmental Quality Act)" (11th Ed. 2007) p. 199. Later, that treatise states "where a proposed policy change would require the agency or the public to forego a substantial environmental benefit that otherwise would occur, the action should be treated as causing a significant effect." Id. p. 209. In this case, the alternative baseline approach makes it clear that the project results in foregoing an

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[2] SCAQMD staff does not have sufficient information to determine whether it concurs that the 17 in a million result is the correct result, but at minimum it illustrates that using a more realistic baseline demonstrates significant cancer risk impacts.

Mr. Christopher Cannon
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Page 5

incremental benefit, estimated by the part as 17 in a million cancer risk, which exceeds significant thresholds and thus should be considered significant. To the extent that the *Sunnyvale* court used language implying that a future or realistic baseline could never be appropriate, that language is dicta. The court was simply not confronted with the situation where future conditions without the project will be better than present conditions rather than worse. In such a case, looking *only* at a comparison of year 2005 emissions to future emissions with the project artificially makes it appear that the project actually provides an emissions benefit, which is not correct. This approach fails to identify "the environmental effects specific to the project alone," which is the objective of the *Sunnyvale* court. It would be perverse indeed to conclude that *Sunnyvale* precludes the lead agency from determining that impacts are significant when the project concededly has a cancer impact of 17 in a million more than conditions without the project. The *Sunnyvale* court was concerned with a case where the lead agency used a baseline other than existing conditions in order to minimize project impacts. The opposite result occurs in this case. The "existing conditions" baseline actually minimizes impacts – in fact erroneously concludes that the project reduces risk. Were a court confronted with the facts of this case, we believe it would conclude that an alternative which looks at a realistic baseline is not only appropriate but required under CEQA.

If the Port continues to believe that *Sunnyvale* always requires a comparison of future impacts with the existing (2005) environmental conditions, one way to satisfy this concern is to do both analyses, but consider the impacts significant *if they are significant under either analysis.* That way, the Port has complied with its view of *Sunnyvale*, yet has also provided a realistic analysis and will require all feasible mitigation measures and consideration of a range of reasonable alternatives.

Accordingly, CEQA requires the Port to analyze health impacts and emissions impacts using a realistic baseline, and to evaluate alternatives and mitigation measures to address significant impacts identified under this approach.

Should you have any questions or wish to discuss this issue, please contact me at (909) 396-2302 or bbaird@aqmd.gov.

Sincerely,

Barbara Baird

Barbara Baird
District Counsel

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cc: Barry R. Wallerstein, D.Env., Executive Officer

ATTACHMENT D

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January 19, 2012

via electronic-mail and U.S. Mail

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Port of Los Angeles
425 South Palos Verdes Street
San Pedro, CA 90731

Re: Draft Environmental Impact Report: Southern California International Gateway

Dear Mr. Cannon:

On November 30, 2011, this office filed comments on the Draft EIR for the Southern California International Gateway, specifically addressing our concern that the document fails to adequately identify significant adverse environmental impacts of the project because it does not use a realistic baseline for analysis. As explained in the DEIR, the Port apparently believes it is foreclosed from using a realistic baseline against which to measure adverse impacts by the court decision in *Sunnyvale West Neighborhood Association v. City of Sunnyvale* (2010) 190 Cal. App. 4th 1351 (*"Sunnyvale West"*). See Section ES 8.1, p. ES-85.[1] We wish to bring to your attention a subsequent case which makes clear the fact that the *Sunnyvale West* case should not be interpreted as preventing the Port from analyzing the significant impacts of the project using a realistic baseline.

As a reminder, we had pointed out that the DEIR includes an "alternative" analysis in the health impact section which conceded that the project increases cancer risk beyond what would occur without the project by 17 in a million, yet concludes this impact is not significant, even though the Port's significance threshold is 10 in a million. The rationale was that CEQA only allows a significant impact to be measured against a baseline of conditions in the year the NOP was issued (2005 in this case). Compared to conditions in 2005, the risk imposed by the project when it is fully operational will be smaller - but it would be even smaller without the project. Thus the DEIR obscures the significant impact of the project, which is an increase in risk of 17 in a million.

[1] Our previous letter referred to this case as *"Sunnyvale"* but in view of the potential for confusion resulting from the need to discuss a later case also involving the City of Sunnyvale, we now refer to this case as *"Sunnyvale West."*

Mr. Christopher Cannon
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A recent case decided by the same court that decided *Sunnyvale West* makes clear that an EIR may properly evaluate a project's impact by comparing the project with conditions in the future without the project. In *Pfeiffer v. City of Sunnyvale*, 200 Cal. App. 4th 1552 (2011), the court of appeal pointed out that *Sunnyvale West* "acknowledged" that "future conditions may be considered in determining a proposed project's impact on the environment." *Pfeiffer*, 200 Cal. App. 4th at 1573. The court further explained that *Sunnyvale West* had pointed out that discussion of "foreseeable changes and expected future conditions" in fact "may be necessary to an intelligent understanding of a project's impacts over time and full compliance with CEQA." *Pfeiffer, Id., quoting Sunnyvale West*, 190 Cal. App. 4th at 1381. The court emphasized that the CEQA document must give "due consideration to both the short-term and long-term effects. CEQA Guidelines §15126.2(a)." *Pfeiffer, Id.* at 1573. Finally, the court drew an analogy to the CEQA Guidelines applicable when a proposed project is compared with an adopted plan, in which case the analysis shall examine existing physical conditions at the time of the NOP *"as well as the potential future conditions discussed in the plan.* CEQA Guidelines §15125(e)." *Pfeiffer*, 200 Cal. App. 4th at 1574, *quoting Sunnyvale West*, 190 Cal. App. 4th at 1381 (emphasis by court of appeal). Accordingly, the *Pfeiffer* court made clear that a lead agency may measure significant impacts against a "future baseline," at least where the CEQA analysis also "included existing conditions...in its analysis of traffic impacts." *Pfeiffer*, 200 Cal. App. 4th at 1572.[2]

As noted in our earlier comments, we believe that CEQA not only allows but actually ***requires*** a determination of significant impacts that does not inaccurately credit the project with unrelated improvements in air quality that will occur anyway, and would be even greater without the project. The DEIR concludes that the "CEQA increment" for health risks (likelihood of contracting cancer) is a negative 160 in a million (based on comparing 2005 conditions without the project to future conditions with the project). This comparison improperly credits the project with the large improvements in air quality that will happen anyway, due to adopted rules, and that would be even greater without the project. The DEIR's determination of insignificance cannot be supported in this case, because it fails to identify the adverse impacts *"caused by the project."* CEQA Guidelines § 15064(d). Moreover, this error has real-world results, since it means that the DEIR fails to examine, and the lead agency will likely fail to require, feasible mitigation measures or alternatives that could substantially avoid or lessen the significant adverse impacts caused by the project, including a significant increase in cancer risk.

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[2] Another case has relied on *Sunnyvale West* to invalidate a CEQA analysis where it was not clear what baseline was used. *Madera Oversight Coalition, Inc., v. County of Madera*, 199 Cal. App. 4th 48 (2011). That case is not relevant here, however, because it appears that traffic conditions with the project (1,121 vehicles) may have been compared to future traffic conditions under full build-out rather than against existing undeveloped conditions (9 vehicles). *Id.* at 82. Thus, like *Sunnyvale West* itself, this case did not present the situation we have here, where future conditions will actually be better than existing conditions (cleaner air). In the case of SCIG, the comparison with existing conditions makes it artificially appear that the project makes the air cleaner, whereas it actually makes the air dirtier than it would be without the project.

Mr. Christopher Cannon
January 19, 2012
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We reiterate our request from our previous letter. If the Port continues to believe that *Sunnyvale West* always requires a comparison of future impacts with existing (2005) impacts, even where the project makes future conditions worse than they would otherwise be, the Port should prepare an analysis using a realistic baseline as well as one using the 2005 baseline. The Port must then consider the project impacts to be significant *if they are significant under either analysis.* This way, the Port can comply with its view of the *Sunnyvale West* case, yet also provide a realistic analysis of significant impacts, and must then require all feasible mitigation measures and consideration of a range of reasonable alternatives.

Should you have any questions or wish to discuss this issue, please contact me at (909)396-2302 or bbaird@aqmd.gov.

Sincerely,

Barbara Baird

Barbara Baird, District Counsel

BB/pa
e:\share\barbara\railroads\scig baseline 2d set.doc

cc: Barry R. Wallerstein, D. Env., Executive Officer

Attachments from Comment Letter 127

GRID - Green Rail Intelligent Development

Introduction - In 1991, the container shipping industry moved 100 million container units (Twenty-Foot Equivalent Units, or TEUs) through its global supply chain networks. This industry has experienced an over 500% increase during the past 20 years and is expected to surpass one billion TEUs globally by the year 2030. Consistently, the combined Ports of Los Angeles (POLA) and Long Beach (POLB) have held over a 4% market share of the Global Container Supply Chain network, making the Southern California conjoined twin ports the 5th largest trade gateway on Earth. Today, these North America ports are constantly pressured to support continuing growth in container shipments to and from Asian seaboards.

The Problem - Despite the self funding capabilities of the ports and the strong demand from shipping industries that POLA and POLB continue to expand their container throughput capacity, local community opposition to continued conventional growth of container terminals and rail yard facilities has been stifling. The central theme directed to the industry coming from the environmental organizations is to use new green technology to move containers through the supply chain. Unfortunately, the traditional plans for growth in this 50-year-old container supply chain are simply changing its scale, resulting in more pollution by way of unintended consequences to other areas within the supply chain. The Alameda Corridor rail route and the 710 Long Beach/Pasadena freeway for trucks serve as the two main arterial rights of way supporting many millions of containers flowing each year. Current proposals for Port capacity increases include: 1) building new rail facilities closer to the ports; and 2) widening the 710 freeway, requiring significant eminent domain destruction of hundreds of homes and businesses. Environmental justice groups and communities continue to resist and oppose.

The Solution - Design, Build, Own & Operate a New Container Supply Chain using Electrified Platforms. While in development, this supply chain will be 100% benign to the existing supply chain operations. Once operational it will centrally support the totality of the port complexes while increasing container volume throughput. The New Container Supply Chain will have three major components, as follows.

The Empty/loaded Container Storage and Transfer Center ("ECSTC") consolidates all ship/train loading for both Ports at one "super-dock."

1.) The SuperDock – labeled the Empty/loaded Container Storage and Transfer Center (ECSTC). ECSTC is a 1.5 mile-long container terminal with ship-to-rail interface providing:

- A high plurality of ship-to-shore cranes moving containers to and from ships.
- A combination of manually operated and automated cranes within the ECSTC superstructure that constantly inspects, processes, stores, and transfers containers.

- A dual rail platform serving: 1) a conventional rail facility with optimized train operations; and 2) an underground freight pipeline system, a new critical and valuable 3rd right of way supply chain asset.
- Consolidation of all rail-designated container traffic bound to and from class I railroad companies (UP and BNSF) to streamline movement of 44% of all container units transferred through the ports of LA and Long Beach today.

2.) The Freight Pipeline – A new, Genuine Zero Emissions "right of way" for shuttling containers cleanly, quietly, and automatically between the Ports and warehouse distribution centers in Los Angeles and the Inland Empire, thereby eliminating hundreds of millions of diesel truck miles from area freeways annually.

- Installation involves 15-ft diameter water-tight pipelines housing an electrified rail guide way, with rail drone trains to traverse the journey to the inland regions.
- The project installation will be nearly identical to that of a large water pipeline project, primarily using a technique called "cut and cover": dig a trench, lay pipe, cover pipe.
- Ameron International, a subsidiary of National Oilwell Varco, Inc., has expertise in this industry. The President of Ameron's Water Transmission Group is actively involved in developing this project.
- Unmanned trains will travel through the pipe, allowing greatly reduced costs for ventilation, lighting, and access when compared to mass transit tunnels.

3.) Electrified Container Transfer Facilities–Inland high-speed transloading structures similar to ECSTC (nicknamed "Mini-Me Terminals") to move containers to/from the Frieght Pipeline and local delivery trucks.

- Vehicle miles required by truck delivery to the Inland Empire will be reduced by 85% according to a METRANS USC/CSULB Report, making electrified truck fleets a viable alternative for completing the container supply chain since the truck/freeway component of the delivery supply chain has been eliminated.

The Impact

a.) A single truck will deliver 4 times more containers in each zone due to shorter truck delivery distance.
b.) Electrified trucks become viable because the daily travel distance will no longer include the 120-mile round trip between the Inland Empire and the Ports.
c.) The reduction of volumes of trucks in each region combined with electrified drayage provides a high likelihood of community support for the system.

Container throughput capacity increase could be achieved without the need to create significantly more land. This solves the fundamental problem as to why the ports cannot grow with conventional port expansion. Consolidation of container transfers through the ECSTC will also eliminate the need for thousands of Port acres currently needed for container storage, yielding those acres for other Port applications, businesses, and jobs.

Attachments from Comment Letter 132

Crit Rev Toxicol. 2006 Mar; 36(3):189-217

Attachment 1: A Review of Carbon Nanotube Toxicity and Assessment of Potential Occupational and Environmental Health Risks.

Lam CW, James JT, McCluskey R, Arepalli S, Hunter RL.
JSC Toxicology Group, Space Life Sciences, NASA Johnson Space Center, Wyle Laboratories; and Department of Pathology and Laboratory Medicine, University of Texas Medical School, Houston, Texas 77058, USA. Chiu-wing.Lam-1@nasa.gov

Abstract
Nanotechnology has emerged at the forefront of science research and technology development. Carbon nanotubes (CNTs) are major building blocks of this new technology. They possess unique electrical, mechanical, and thermal properties, with potential wide applications in the electronics, computer, aerospace, and other industries. CNTs exist in two forms, single-wall (SWCNTs) and multi-wall (MWCNTs). They are manufactured predominately by electrical arc discharge, laser ablation and chemical vapor deposition processes; these processes involve thermally stripping carbon atoms off from carbon-bearing compounds. SWCNT formation requires catalytic metals. **There has been a great concern that if CNTs, which are very light, enter the working environment as suspended particulate matter (PM) of respirable sizes, they could pose an occupational inhalation exposure hazard. Very recently, MWCNTs and other carbonaceous nanoparticles in fine (<2.5 micron) PM aggregates have been found in combustion streams of methane, propane, and natural-gas flames of typical stoves; indoor and outdoor fine PM samples were reported to contain significant fractions of MWCNTs.** Here we review several rodent studies in which test dusts were administered intratracheally or intrapharyngeally to assess the pulmonary toxicity of manufactured CNTs, and a few in vitro studies to assess biomarkers of toxicity released in CNT-treated skin cell cultures. The results of the rodent studies collectively showed that regardless of the process by which CNTs were synthesized and the types and amounts of metals they contained, CNTs were capable of producing inflammation, epithelioid granulomas (microscopic nodules), fibrosis, and biochemical/toxicological changes in the lungs. Comparative toxicity studies in which mice were given equal weights of test materials showed that SWCNTs were more toxic than quartz, which is considered a serious occupational health hazard if it is chronically inhaled; ultrafine carbon black was shown to produce minimal lung responses. **The differences in opinions of the investigators about the potential hazards of exposures to CNTs are discussed here.** Presented here are also the possible mechanisms of CNT pathogenesis in the lung and the impact of residual metals and other impurities on the toxicological manifestations. The toxicological hazard assessment of potential human exposures to airborne CNTs and occupational exposure limits for these novel compounds are discussed in detail. **Environmental fine PM is known to form mainly from combustion of fuels, and has been reported to be a major contributor to the induction of cardiopulmonary diseases by pollutants. Given that manufactured SWCNTs and MWCNTs were found to elicit pathological changes in the lungs, and SWCNTs (administered to the lungs of mice) were further shown to produce respiratory function impairments, retard bacterial clearance after bacterial inoculation, damage the mitochondrial DNA in aorta, increase the percent of aortic plaque, and induce**

atherosclerotic lesions in the brachiocephalic artery of the heart, it is speculated that exposure to combustion-generated MWCNTs in fine PM may play a significant role in air pollution-related cardiopulmonary diseases. Therefore, CNTs from manufactured and combustion sources in the environment could have adverse effects on human health.

Mutat Res. 2006 Nov-Dec; 613(2-3):103-22. Epub 2006 Sep 1.

Attachment 2: Toxicological Assessment of Ambient and Traffic-Related Particulate Matter: A Review of Recent Studies.

de Kok TM, Driece HA, Hogervorst JG, Briedé JJ.
Department of Health Risk Analysis and Toxicology, Maastricht University, P.O. Box 616, Maastricht, The Netherlands. t.dekok@grat.unimaas.nl

Abstract
Particulate air pollution (PM) is an important environmental health risk factor for many different diseases. This is indicated by numerous epidemiological studies on associations between PM exposure and occurrence of acute respiratory infections, lung cancer and chronic respiratory and cardiovascular diseases. **The biological mechanisms behind these associations are not fully understood, but the results of in vitro toxicological research have shown that PM induces several types of adverse cellular effects, including cytotoxicity, mutagenicity, DNA damage and stimulation of proinflammatory cytokine production. Because traffic is an important source of PM emission, it seems obvious that traffic intensity has an important impact on both quantitative and qualitative aspects of ambient PM, including its chemical, physical and toxicological characteristics.** In this review, the results are summarized of the most recent studies investigating physical and chemical characteristics of ambient and traffic-related PM in relation to its toxicological activity. This evaluation shows that, in general, the smaller PM size fractions (<PM(10)) have the highest toxicity, contain higher concentrations of extractable organic matter (comprising a wide spectrum of chemical substances), and possess a relatively high radical-generating capacity. Also, associations between chemical characteristics and PM toxicity tend to be stronger for the smaller PM size fractions. Most importantly, traffic intensity does not always explain local differences in PM toxicity, and these differences are not necessarily related to PM mass concentrations. **This implies that PM regulatory strategies should take PM-size fractions smaller than PM(10) into account.** Therefore, future research should aim at establishing the relationship between toxicity of these smaller fractions in relation to their specific sources.

J Environ Sci Health C Environ Carcinog Ecotoxicol Rev. 2008 Oct-Dec; 26(4):339-62.

Attachment 3: Airborne particulate matter and human health: toxicological assessment and importance of size and composition of particles for oxidative damage and carcinogenic mechanisms.

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Abstract
Air pollution has been considered a hazard to human health. In the past decades, many studies highlighted the role of ambient airborne particulate matter (PM) as an important environmental pollutant for many different cardiopulmonary diseases and lung cancer. Numerous epidemiological studies in the past 30 years found a strong exposure-response relationship between PM for short-term effects (premature mortality, hospital admissions) and long-term or cumulative health effects (morbidity, lung cancer, cardiovascular and cardiopulmonary diseases, etc). Current research on airborne particle-induced health effects investigates the critical characteristics of particulate matter that determine their biological effects. Several independent groups of investigators have shown that the size of the airborne particles and their surface area determine the potential to elicit inflammatory injury, oxidative damage, and other biological effects. These effects are stronger for fine and ultrafine particles because they can penetrate deeper into the airways of the respiratory tract and can reach the alveoli in which 50% are retained in the lung parenchyma. Composition of the PM varies greatly and depends on many factors. The major components of PM are transition metals, ions (sulfate, nitrate), organic compound, quinoid stable radicals of carbonaceous material, minerals, reactive gases, and materials of biologic origin. Results from toxicological research have shown that PM have several mechanisms of adverse cellular effects, such as cytotoxicity through oxidative stress mechanisms, oxygen-free radical-generating activity, DNA oxidative damage, mutagenicity, and stimulation of proinflammatory factors. In this review, the results of the most recent epidemiological and toxicological studies are summarized. **In general, the evaluation of most of these studies shows that the smaller the size of PM the higher the toxicity through mechanisms of oxidative stress and inflammation. Some studies showed that the extractable organic compounds (a variety of chemicals with mutagenic and cytotoxic properties) contribute to various mechanisms of cytotoxicity; in addition, the water-soluble faction (mainly transition metals with redox potential) play an important role in the initiation of oxidative DNA damage and membrane lipid peroxidation. Associations between chemical compositions and particle toxicity tend to be stronger for the fine and ultrafine PM size fractions.** Vehicular exhaust particles are found to be most responsible for small-sized airborne PM air pollution in urban areas. With these aspects in mind, future research should aim at establishing a cleared picture of the cytotoxic and carcinogenic mechanisms of PM in the lungs, as well as mechanisms of formation during internal engine combustion processes and other sources of airborne fine particles of air pollution

Attachments from Comment Letter 133

Surging Transload **ARTICLES FROM THE JOURNAL OF COMMERCE 2011**

Jan 24, 2011 Peter Tirschwell

Source:

The Journal of Commerce Online

As the smoke clears from the worst economic downturn since the Great Depression, it's possible to start drawing conclusions about how the transportation environment has changed. An example is the growing use of transloading — transferring contents from import containers into domestic equipment after discharge from a ship for onward movement within the U.S. via rail or truck.

There is abundant evidence that transloading came into its own during the recession as a strategic element of many companies' supply chains. That is a fundamental change from pre-recession days when transloading was embraced only by a few large importers such as Target and Wal-Mart while remaining mostly a short-term tactic for the rest to avoid high rail rates on marine container loads moving inland.

The freight rate sensitivity of transloading was evident as so-called inland-point-intermodal, or IPI, rates on intact containers began rising around 2006 as ocean carrier rail contracts expired and were replaced with the much-higher IPI rates. The pendulum swung back toward transloading after several years in which low IPI rates combined with the opening of large inland logistics parks made IPI the shippers' tactic of choice off the West Coast.

But transloading took off during the recession, particularly at the ports of Los Angeles and Long Beach. According to the Alameda Corridor Transportation Authority, the share of goods arriving at LA-Long Beach transloaded into domestic containers grew significantly during the recession — from 34 percent in 2006 to 45 percent in 2009. In 2006, 3.3 million TEUs of **intact containers** moved by rail out of LA-Long Beach, but that fell to 2.1 million TEUs in 2009.

Meanwhile, transloaded containers grew during the same period from 1.6 million to 1.7 million TEUs. "That means that transload has a greater market share now. The pendulum has swung to transload," said John Doherty, CEO of the authority.

What changed? The retrenchment of consumer spending during the recession forced retailers and consumer product suppliers to cut back on unneeded and under-optimized inventory. It's the classic example of dropping the display of lawn chair furniture in the spring in the midst of a cold snap.

By transloading goods, the importer postpones decisions on the positioning of inventory. The importer has two extra weeks to decide where to ultimately send merchandise, because the decision is made at the transload facility after arrival, while IPI moves generally demand decisions at the point of origin.

Transload facilities allow the contents of a single container to be divided among as many as 15 distribution centers, depending on demand. That's a critical benefit in an environment where retailers in a recent McKinsey survey on managing supply chains cited the increasing volatility of customer demand most frequently as their greatest challenge of the past three years.

"Because of the recession, everybody has had to sharpen their pencils," Doherty said. "In boom times, nobody cared whether you sent cargo to a particular part of the country because you would get rid of it."

Such advantages have attracted a new wave of retailer to transloading, and that has broader implications for U.S. transportation. Transload growth is benefiting West Coast ports because many importers new to transloading try the idea out first at LA-Long Beach before expanding to other gateways.

“We expect to see strong demand for transloading via 3PLs through 2011 as retailers continue inventory replenishment in response to consumer demand,” said Blaine Kelly, senior vice president in the global supply chain practice at industrial real estate developer CB Richard Ellis. “While much attention is placed on all-water service, West Coast ports, especially LA-Long Beach, will continue to garner a disproportionately high percentage of container volumes for the near term.”

Transloading may be one reason the West Coast in 2010 gained back 2 percentage points of import market share from the East Coast, expanding its share of U.S. import TEUs from 54 to 56 percent in year-to-date figures through November, according to PIERS, a sister company of The Journal of Commerce.

The growth of transloading shows how shippers are willing to put behind them bad memories of the LA-Long Beach gateway, including longshore strife, congestion and, more recently, efforts by Los Angeles to foster unionization of its harbor drayage drivers — if the basic execution of supply chain strategy gets the right goods at the right place at the right time.

Transloading also supports port-to-port service preferences among steamship lines because it allows boxes to be returned to the carrier and sent back to Asia much sooner than in IPI moves. If the trend toward transloading continues, it might also have an impact on Alameda Corridor finances; the corridor receives revenue only for intact containerloads that move along the 20-mile-long corridor, not transloads.

I’ll discuss more of the impact of this growing trend next week.

Peter Tirschwell is senior vice president for strategy at UBM Global Trade. Contact him at ptirschwell@joc.com and follow him at twitter.com/petertirschwell.

Transloading, Part II

Peter Tirschwell | Jan 31, 2011 5:00AM GMT
The Journal of Commerce Magazine - Commentary

Thanks to the recession, transloading is rapidly evolving from a tactic shippers used to avoid high rail rates for intact containers into a strategic tool in importers’ supply chains. During the downturn in global trade, in other words, transloading came into its own.

Transloading’s share of Los Angeles-Long Beach import volumes rose from 34 to 45 percent during the recession, according to the Alameda Corridor Transportation Authority. Transload volume grew slightly during the recession even as the volume of marine containers moving intact on the rails plummeted. What is behind the shift?

There have always been obvious economic benefits — transloading allows the contents of three international containers to be reloaded into two larger 53-foot trailers or domestic containers. But through the mid-2000s, ocean carriers, receiving low rates from the railroads, offered low pricing to ship intact containers inland. When the railroads started raising IPI rates in 2006 and ocean carriers sought to pass those higher rates on to shippers, IPI demand slipped while transloading started to grow. When the recession hit and shippers large and small went searching for transportation savings, transloading was a ready-made opportunity.

Not only did it often provide immediate cost savings, it opened the door to additional, more strategic inventory management benefits. Shippers, hard-pressed to help companies squeeze the maximum revenue from the leanest inventory, are less likely to abandon transload for IPI based solely on a freight rate play.

“Transload is seen as an enabler; some will do it if it’s cost-neutral, knowing that there are a lot of soft benefits that come later,” said James Armstrong, senior vice president of warehousing at NYK Logistics (Americas). Another way some importers get introduced to transloading is through rush orders that fall short of air freight pricing. These are the shipments that may arrive on the U.S. West Coast and then are transloaded into trucks that hightail it across the country to distribution center or directly to a store.

The benefits can be numerous. They begin with the well-documented flexibility that “postponement” brings, when the final decision on a distribution destination can be made two weeks later than decisions for IPI moves, where the decision on cargo moving in an intact container must be made in Asia two weeks before the merchandise reaches the U.S. That means two weeks’ more demand data fed into the supply chain to guide decisions on where to divert merchandise.

Transloading can assist in truck asset utilization if the outbound movement from the transload facility is in either a shipper-owned or -contracted truck that will carry the goods onward to the distribution center and haul goods out of the DC at the other end.

“You are triangulating equipment and utilizing assets better as opposed to paying for a round-trip move for an ocean container, which goes into the DC full and then has to get repositioned back to the West Coast,” Armstrong said.

Also, the use of 53-foot equipment rather than 40-foot containers means fewer trucks reaching a limited number of DC doors. And since merchandise for up to 15 DCs can be sorted at a transload facility, allowing greater accuracy in matching demand to DCs in a company’s network, a company can use less costly inter-DC distribution later, Armstrong said.

Transloading, especially to the West Coast, also can allow an importer to select from a wider range of ocean carriers, not simply those that offer IPI rates, possibly achieving lower ocean rates. And the ocean carrier may be further willing to negotiate if it knows the boxes will be returned to the seaport rather than to an inland railhead.

That helps explain why transloading is growing both on the West Coast and increasingly on the East Coast, where transloaders such as NYK have positioned facilities, knowing that carrier vessel deployments will always have a big impact on how cargo is routed.

Several 3PLs that handle transloads report shippers that once only sniffed around on transloading, putting out RFQs without committing to the strategy, now are fully engaged, leaving the only question as which transload provider they will use.

“Most of the RFQs the transloaders are now receiving are from shippers that have never transloaded before,” said Ron Sucik, a consultant who has studied transloading versus IPI trends for many years on behalf of the rail equipment provider TTX. With all of the domestic containers that reportedly are on order, it appears many of the 3PLs and motor carriers believe this level of transloading will continue for the immediate future.

One factor that could dim transloading’s gains is the growing popularity of 53-foot marine containers.

Although these are still a tiny percentage of marine containers in use, major shippers such as J.C. Penney have publicly called on container lines to expand their availability. They would remove the economic benefit achieved by transferring cargo from 40- to 53-foot containers.

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Harbor Dept
City of L.A.

December 14, 2005

Dr. Ralph Appy
Director of Environmental Management
Los Angeles Harbor Department
425 South Palos Verdes Street
San Pedro, CA 90731

Re: Comments on the Notice of Preparation (NOP) (dated September 19, 2005) and Supplemental NOP (dated October 31, 2005) for the proposed Southern California International Gateway (SCIG) Project to be operated by BNSF Railway

Dear Dr. Appy:

We submit these comments on the proposed Southern California International Gateway (SCIG) Project on behalf of the Community Outreach and Education Program of the Southern California Environmental Health Sciences Center, based at Keck School of Medicine of the University of Southern California.

Our Center is composed of scientists from USC and UCLA, many of whom conduct air pollution research. Our USC investigators have been conducting a decade-long study (known as the Children's Health Study) of the health effects of air pollution on the respiratory health of school children. Findings from this study show that children who grow up breathing polluted air have reduced lung function when they reach adulthood, that air pollution is linked to increased school absences, that children with asthma suffer other health problems (such as bronchitis) when they are exposed to high levels of particulate matter, and that children who live or go to school near busy roads or freeways have more asthma. These comments from our Center's Community Outreach and Education Program are submitted with these scientific studies - and dozens of other air pollution health investigations - in mind. These and other relevant studies of air pollution's effects on health are included on a CD submitted with this letter. (See Appendix A, List of References, and Appendix B, Full Scientific Articles on Compact Disk, CD).

As discussed in greater detail below, we have serious concerns about the potential health impacts of this project on residents and school children who live, play, and learn in close proximity to the planned intermodal container transfer facility. Our concerns relate to the anticipated increase in air pollution from the additional mobile sources the rail yard will introduce or

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attract to the area: big-rig trucks, yard equipment, locomotives on-site, Alameda Corridor locomotives, and locomotives operating along the San Pedro Branch tracks. The communities near the proposed rail yard are densely populated, contain many schools and other "sensitive receptor" facilities, including a homeless shelter and a school for homeless children, and they are already heavily impacted by the Port, Port traffic to and from the existing Union Pacific Intermodal Container Transfer Facility (ICTF), and nearby refineries. We believe that the additional health impacts related to air pollution and noise from the proposed SCIG project on nearby residents are significant and must be fully mitigated, adding no additional health burden, if the Port of Los Angeles continues to consider siting the SCIG project at the proposed location.

As background, a recent document by the California Air Resources Board entitled "Emission Reduction Plan for Ports and International Trade in California" states the following concerns:

> "...People living in communities with high pollution burdens [are a group] that is of particular concern when assessing the impacts of goods movement-related emissions. Sensitive groups, including children and infants, the elderly and people with heart or lung disease, can be at increased risk of experiencing harmful effects from exposure to air pollution. People living in communities close to sources of goods movement-related emissions, such as ports, rail yards, and inter-modal transfer facilities are likely to suffer greater health impacts and these impacts will likely add to an existing health burden." (p. A-22) ...
>
> "Many of these communities are made up of people from economically disadvantaged groups who would be least able to sustain the personal and financial impacts related to increased disease burden". (p. A-8)

The residents and school children living near the proposed SCIG project comprise a group "with a high pollution burden" (as described above) and many members of the population are both economically disadvantaged and minority (full demographic data for the three most heavily affected zip codes is attached as the final appendix).

Because we believe that the potential health impacts of the SCIG Project would be so detrimental, we respectfully request that the Los Angeles Harbor Department:

a) Investigate whether increased efficiencies of on-dock rail at both the Ports of L.A. and Long Beach would negate the need for this new facility. Increasing the efficiency of on-dock rail is specifically called for by the August 2005 Los Angeles Harbor Department Rail Policy, as well as the California Air Resources Board's Draft Emission Reduction Plan for Ports and International Goods Movement, p. III-50, which can be found at http://www.arb.ca.gov/planning/gmerp/gmerp.htm.
b) If on-dock rail is fully investigated and determined to be infeasible, search for alternative sites on which to build a new intermodal container transfer facility that can service the Alameda corridor with less significant public health impacts on nearby residents.
c) If an alternative site for a new ICTF is fully investigated and determined to be infeasible, and if the SCIG project moves forward, implement enforceable mitigation measures including use of the most innovative technology to reduce air pollution from the new rail yard, the trucks or other delivery system entering and leaving it, and the locomotives entering and leaving it on the San Pedro Tracks as well as on the Alameda Corridor in order to ensure protection of the health of residents in Wilmington, Carson, South Los Angeles and West Long Beach. This would include:

- Implementing non-diesel delivery systems for containers entering or leaving the SCIG. If the rail yard continues to be considered in lieu of preferable on-dock rail, it must be virtually "clean," adding no additional air pollution to the area. As the supplemental NOP indicates, the EIR must investigate alternative delivery systems such as magnetic levitation, electric conveyor belts, and other innovative non-diesel technology to move containers and reduce pollution. The EIR should also investigate non-diesel trucks, including having a dedicated fleet of electric or hybrid trucks or alternative fuels. A dedicated fleet of non-diesel/alternative fuel/electric trucks could be certified by the Port to carry containers back and forth between the rail yard and the Ports, with a requirement for them to meet strict entry requirements to enter either the SCIG or the Ports.
- Electrification of trains on the Alameda Corridor and Alameda Corridor East, as recommended in the No Net Increase Report, as well as electrifying the switching locomotives that will be doubling back and forth on the San Pedro line very close to homes and schools along their tracks.
- Implementing and enforcing all feasible mitigation measures if the SCIG project goes forward.
- Implementing all rail and trucking measures recommended in the No Net Increase Report, all measures in the 2005 California Air Resources Board (CARB) Railroad Memorandum Of Understanding, and any railroad/trucking/yard equipment rules of CARB or the South Coast Air Quality District (AQMD).

Detailed comments follow.

1. The EIR must address the existing physical environment in the vicinity of the proposed project to assess the significance of the impacts the new SCIG project will create, and must detail the full range of activities that will be generated by the project.

Although the current use of the land where the SCIG is proposed is "industrial," its impact on the surrounding community is minimal compared to what would occur with the SCIG. Baseline noise, air pollution, vibration and lighting must be evaluated. Currently, there is insignificant truck traffic on a daily basis in and out of the existing Cal Cartage facility (compared, for example, to the hundreds of trucks going in and out of the nearby Union Pacific ICTF), which is important to document because the SCIG would add a significant amount of new traffic and air pollution to the area. In addition, traffic counts on the nearby roads and freeways must be done in order to assess the current volume and the increased volume of trucks that will travel through the nearby communities if the SCIG is built. Finally, the impacts of emissions from thousands of diesel trucks a day queuing and operating inside the SCIG project must be evaluated regardless of the route the trucks take to reach the SCIG.

Specifically, the EIR must describe the following, which the SCIG NOP fails to describe:

- anticipated size of the SCIG
- number of lifts expected annually at start of project and maximum allowed over time
- number of trucks anticipated to enter the yard per year at start of project and maximum over time

- number of switching locomotives to be permanently on site at start of project and maximum over time
- number and types of cargo handling equipment to be on site and maximum over time
- number of locomotives that are anticipated to travel on the San Pedro tracks at start and maximum over time
- number of additional locomotives anticipated to be added to the Alameda Corridor at start of project and maximum over time
- where on the site the trains will "connect to" the Alameda Corridor
- where the "Haz Mat area" of the site will be (not included in the NOP maps)
- what actions BNSF or the Port plan to take to ensure that the system of delivery for containers coming to the facility does not bring additional pollution to the nearby neighborhoods, and
- what actions BNSF or the Port anticipates taking to ensure that the locomotives coming and going from the facility will not add additional pollution to the nearby communities.

2. The EIR must consider concurrent and future related projects, including the relocation of Cal Cartage and the expansion of the adjacent Union Pacific (UP) Intermodal Container Transfer Facility (ICTF).

The Supplemental NOP makes numerous mentions of Cal Cartage and other tenants and their plans for moving to a new area. It would seem appropriate for these companies to do their own EIR rather than "piggy-back" on the SCIG EIR. The Supplemental NOP states (p. 6) that there are residential land uses immediately to the East of the proposed site for Cal Cartage that may have adverse impacts. If a separate EIR is not warranted, then there must be much more specific information about Cal Cartage (and other affected property owners/lessees) activities in the SCIG EIR. E.g., future "warehousing activities" at Cal Cartage described in the NOP may introduce more trucks to the area than does existing use of the land by Cal Cartage and others; this needs to be evaluated.

Additionally, the EIR must address the future (and possibly simultaneous) expansion of the UP-ICTF, located adjacent to the proposed SCIG site. The UP ICTF currently brings hundreds of thousands of trucks a year into the very same community that will be affected by the trucks, yard operations, and locomotives at the SCIG if it is built here. Any expansion of the UP ICTF should be discussed in the SCIG EIR because of the related, additional health impacts associated with increased operations in the community that will be all the more serious due to the cumulative nature of the effects.

3. The EIR must detail what is already known about local air pollution and health risks in the area, including studies that have been done at Hudson School and forthcoming work of the MATES III project, both conducted by the South Coast Air Quality Management District (AQMD) — as well as other studies underway —so that the cumulative effects of this project can be accurately analyzed. The SCIG will add to existing pollution from the Union Pacific ICTF, refineries and other local air pollution sources, and all cumulative

impacts combined must be considered in the EIR. The EIR should evaluate PM_{10}, $PM_{2.5}$, ultrafine particles, elemental carbon, toxic air contaminants (1,3-butadiene, aldehydes, diesel particulate, etc.), NOx and other emissions in the local area, at baseline and emission projections with the SCIG in place.

AQMD Monitoring Studies. Some insights into existing health threats in the area can be obtained by reviewing AQMD reports of measured pollutants at several Long Beach and Wilmington Schools, comparing them to the North Long Beach Station and occasionally to the downtown L.A. monitoring site. One of the schools studied is Hudson School (K-8), of the Long Beach Unified School District. Hudson School is adjacent to the Terminal Island (TI) Freeway, about 1/3 of a mile from the Union Pacific Intermodal Facility, and directly across the TI Freeway from both the San Pedro Train Tracks and the proposed SCIG facility. In fact, the Hudson School playing fields are separated from the TI Freeway only by a chain link fence.

The AQMD has been monitoring selected air pollutants at Hudson and several other schools in Wilmington (Wilmington Childcare Center) and Long Beach (Hudson and Edison Schools) since 1998. The measured pollutants at each site have been compared to each other and to the local AQMD monitoring stations. Monitoring results show that Hudson School routinely has the highest levels of measured pollutants among the schools and stations monitored in the Wilmington and Long Beach areas, a clear indication that children in this geographic area are already seriously impacted by air pollution. AQMD Reports #7, 9, and 11 are attached as examples for the record.

- *PM_{10} measurements.* AQMD Report #9 on sampling during October – November 2003 and Report #11 on sampling during October - December 2004 both conclude: "The current monitoring and previous monitoring studies indicate that PM_{10} and EC concentrations measured at Hudson School site are often higher than the other study sites, and higher than many AQMD network sites for PM_{10}." … "PM_{10} averaged 49ug/m^3 at Hudson School during the study compared to values ranging from 35-39 ug/m^3 at the other sites." Of the seven 24-hour samples taken at Hudson School and reported in Report #9, four were higher than 50 ug/m^3 (the state's 24-hour standard), with the maximum at Hudson for 24 hours of 71 ug/m^3.

  Report #11 also states that: For all [11] studies except the fall/winter 2000 study, the Hudson School site exhibited the highest PM_{10} average…. These trends suggest that Hudson School consistently experiences higher PM_{10} concentrations than elsewhere in the study area."

- *Elemental carbon levels:* Initially, the South Coast AQMD started conducting their measurements at schools in Wilmington and Long Beach because of concerns about petroleum coke dust blowing into the neighborhood from nearby "coke piles." According to AQMD specialists, by the year 2000 the coke piles were in compliance with mandated mitigation measures, including enclosure, and levels of Elemental Carbon (EC) were found to drop from 1998-2000. Since the year 2000, however, the levels of EC have not dropped further, with the Hudson School EC levels significantly higher than at other schools and AQMD monitoring stations in the area. Recent AQMD studies conclude that mobile sources in the area of Hudson School may now be the dominant factor rather than the coke dust. This is consistent with the increased volume of traffic on the TI Freeway adjacent to Hudson School and the increased diesel-related truck and locomotive activity in the area, including a dramatic increase in "lifts" at the UP ICTF since 1998.

- *Elemental carbon levels during the Port lockout:* A natural experiment occurred during the Port lockout (work stoppage) in the fall of 2002. AQMD conducted sampling during this time and found unusually low levels of elemental carbon during the lockout, when the Port was not operating, with increasing levels as the backlog of ships was unloaded and containers finally headed by truck to the railyards. Please review Appendix E and the attached AQMD reports and note how much higher the levels of elemental carbon were at Hudson School than at other schools in the area. The lockout was from September 29, 2002 – October 9, 2002. In the figures of Appendix E, please note how low the levels of elemental carbon were on October 9, 2002 (less than 4 ug/m^3, much lower than normal fall averages). Also, please note now high the levels of elemental carbon were in mid-November. Reports on the lockout say that it took more than 40 days from the beginning of the lockout for the backlog of containers to be resolved, resulting in much higher truck traffic during this period in November.

  Also note in Appendix E how levels of Elemental Carbon at Hudson School compare during the lockout and during other years of AQMD measurements. The attached AQMD reports (and the graphs in Appendix E) show how much higher the levels of Elemental Carbon (EC) were at Hudson School when there was a huge influx of diesel trucks moving cargo containers after the lockout, compared to the more typical levels in November. We conclude from these various analyses of the AQMD data that the main "driver" of the currently elevated Elemental Carbon levels at Hudson School is diesel exhaust from trucks going to the ICTF and from locomotives at the ICTF and on the San Pedro lines as well as other diesel equipment operating in the area. When there are few trucks on the TI Freeway and the UP ICTF is not operating, there is significantly low Elemental Carbon at Hudson School. When there is lots of activity on the TI Freeway and the ICTF is unusually busy, there is significantly elevated Elemental Carbon at Hudson School.

- *AQMD Report #9* on sampling in October – November 2003 states: "During this study, the average EC [Elemental Carbon] at Hudson School (7.5 ug/m^3) was 50% higher than any other study site."

- *MATES III study.* . The AQMD has selected a site east of the Terminal Island Freeway for one of its MATES III monitoring sites. Results from this study must be included in the EIR, along with a description of the findings of any other published studies on the area by the AQMD.

Truck counts. CalTrans apparently does not count traffic on the TI Freeway. On a weekday afternoon in May 2005, south of Hudson School and standing in the community park, we counted 600 big-rig trucks in one hour passing by on the TI Freeway, heading from the Ports to the nearby Union Pacific ICTF. Although not a lengthy study of any sort, the truck count is an indication of what school students face on a given afternoon in their community. We have noted from numerous trips to the area that trucks often back up where the TI Freeway dead-ends into Willow Street, as they attempt to turn left onto Sepulveda to go to the ICTF. The EIR must conduct truck counting on the TI Freeway at baseline and make projections about the future truck traffic load.

Health Effects Institute Study. Dr. Eric Fujita of the Desert Research Institute (DRI) is conducting a study of air pollution, with measurements being taken in the area of the Cambodian Temple on Willow Street and the Terminal Island Freeway. Results from his study, when published, must be evaluated in the EIR.

4. The EIR must detail the significant health effects that the SCIG project is expected to have on the local community from the addition of thousands of diesel trucks, as well as air pollution from long-haul and switching locomotives and any other pollution-producing equipment used or related to the SCIG.

In particular, we are concerned about the following health-related issues, all of which should be addressed in the EIR. Relevant scientific articles can be found as a list in Appendix A and on the CD in Appendix B.

- *The body of scientific evidence showing that children who grow up in polluted communities suffer reduced lung function and other respiratory effects.* USC studies in Southern California show that a package of mobile source pollutants (NOx, PM, acid vapor and elemental carbon) are correlated with reduced lung function. In the USC study, three times as many children in North Long Beach, where levels of Elemental Carbon (EC) are high, had reduced lung function than children in less polluted communities. (Gauderman, 2004). The study is important because medical experts believe that reduced lung function is a significant predictor of mortality in the elderly.

  It is important for the EIR to examine the levels of EC at Hudson School, less than .25 miles from the proposed SCIG. During recent fall-winter measurements, the levels were 1 ½ times higher at Hudson than at the North Long Beach station – raising significant concerns about the potential for reduced lung function in this west Long Beach community, even with the levels of elemental carbon currently existing (SCAQMD Rule 1458 reports, 1998-2004, attached).

- *The body of scientific evidence showing that living or going to school in close proximity to busy roads and freeways (that is, close to mobile source exhaust) is linked to asthma and respiratory effects in children, as well as other effects in adults.* (Gauderman, 2005; McConnell, 2004; Brauer, 2002). (Please see Appendix A and submitted CD for related scientific articles and references). The EIR must examine the increased risk of asthma and other respiratory effects from living or going to school in close proximity to busy roads and freeways.

- *The body of scientific evidence showing that elevated levels of particulate* *matter are linked to cardiovascular disease and increased mortality.* (Pope, 2002; Jerrett, 2005; Please see submitted CD for these and related scientific articles). In response to the growing body of evidence, the American Heart Association issued a scientific statement in 2004 concluding: "Exposure to air pollution contributes to the development of cardiovascular diseases." PM_{10} levels are consistently higher at Hudson School than at other sites measured in AQMD studies in the Wilmington/Long Beach area. $PM_{2.5}$ measurements will be collected in the MATES III study of AQMD. These studies on increased cardiovascular disease and mortality from particulate exposure must be reviewed in the EIR.

- *Scientific studies showing that pregnant women who live near busy roads and freeways (and exposed to current levels of air pollution) are more likely to give birth to low-birth weight, premature infants.* (Wilhelm, 2005). (Please see submitted CD for these and related references and refer to pages A-22 of Appendix A of the CARB Emission Reduction Plan for additional discussion of these impacts). Residential areas, including a homeless shelter, are located in the vicinity of the proposed SCIG east of the TI Freeway and also immediately adjacent to the San Pedro tracks north of Sepulveda. Studies cited on the CD must be reviewed in the EIR.

- *Dozens of studies showing increased lung cancer risks among workers exposed to diesel exhaust, including the most recent study on railroad workers.* Based on these studies, diesel was declared a Toxic Air Contaminant in the state of California. (See most recent study by Garshick, 2004) The EIR must evaluate cancer risks that will result from the proposed SCIG, by doing a mandated Health Risk Assessment. The EIR must also review the Health Risk Assessment done by the California Air Resources Board at the Roseville Rail Yard, which showed significant risk of exposure to diesel exhaust for nearby community residents. Since the Roseville Yard is not an intermodal facility, the SCIG EIR must take into account the thousands of diesel trucks that are currently proposed to enter the SCIG. These trucks would not be in the area but for the UP ICTF and the newly proposed SCIG . Harbor Commission President David Freeman, at the NOP Scoping Meetings, made it clear that the trucks must be considered when evaluating the potential risks of this SCIG railyard project; any HRA must also include diesel exhaust cancer risk from the trucks that will be attracted to the facility.

- *Numerous studies have shown that diesel exhaust particles can enhance allergies and allergic asthma.* These studies by scientists at UCLA Medical School (Diaz-Sanchez, Nel, and Saxon) are described in greater detail on pages A20-21 of Appendix A of the CARB Emission Reduction Plan, found on the CD.) The EIR must evaluate the potential for enhancement of allergies and asthma from the diesel exhaust at the SCIG and trucks delivering containers to it.

- *Emerging studies showing the health impacts of breathing ultrafine particles, including neurologic effects.* (Oberdorster, 2002, 2004) Some of these studies are reviewed in the articles by Delfino and Sioutas found on the CD. The emerging data on the health effects of ultrafine particles must be evaluated in the EIR. In addition, exposure studies (Zhu,

2002) showing that ultrafine particles are higher close to freeways must also be examined in the EIR.

- *Studies showing that elevated noise levels are linked to learning issues in the classroom, as well as to cardiovascular disease and other impacts. (Scanberg, 2002) (See this and related references on the attached CD).* The EIR must evaluate the noise levels at baseline and projected and evaluate their effects on residents' health (including cardiovascular disease) and sleep patterns as well as their potential effects on students' learning.

Many of these scientific findings are also described in Appendix A of the California Air Resources Board's (CARB) Emission Reduction Plan for Ports and International Trade in California (CARB Emission Reduction Plan), which can be found at http://www.arb.ca.gov/planning/gmerp/gmerp.htm

5. The EIR analysis for the SCIG must assess "the feasibility of an alternative location for the proposed rail facility including consideration of an on-dock alternative" (quotes from Supplemental NOP cover letter signed by Dr. Appy).

We request that the Port of Los Angeles (POLA) carefully investigate why on-dock rail capacity is not being maximized at the Ports, and that the Port of Long Beach (POLB) be requested to do a similar investigation at its Port, since POLB would be using the proposed SCIG facility as well, if it is built. The EIR must, as part of a comprehensive evaluation of an on-dock alternative, address all factors currently constraining greater on-dock use at the ports and identify methods to maximize use of existing on-dock facilities. The EIR should also evaluate Agile Port Systems methods, which could potentially increase throughput 200 to 300 percent, according to a demonstration study by the Center for the Commercial Deployment of Transportation Technologies (CCDoTT) which we witnessed in Long Beach in November 2005. If on-dock rail can be maximized at both Ports, this SCIG facility would potentially not be needed and a more suitable alternative location could be found over time for an intermodal facility – if additional capacity is needed in the future.

The value of on-dock rail in reducing air pollution is clear, according to the San Pedro Bay Ports Rail Market Study, published on April 22, 2004, and authored by the Parsons Transportation Group:

> "Consider that a single container ship may unload 5,000 twenty-foot equivalent units (TEU) to be delivered outside the Port boundaries by a fleet of trucks. Alternatively, the movement of cargo by trains loaded at on-dock ICTFs is an effective method of reducing the truck traffic. Every train that is loaded on-dock can eliminate over 700 truck trips from the highway, and a single ship can generate 5 trains worth of intermodal cargo. That means on-dock rail can potentially eliminate 3,500 truck trips for every vessel call."

From all accounts, however, existing on-dock rail yards at the Ports are not operating anywhere near capacity or with efficiencies. The Rail Market Study goes on to state that on-dock capacity will be allowed to increase in the future only by resolving some current constraints in the operating mode of the yards:

> "The yards are assumed to operate in 2005 in the same mode as they have in the past; in 2010 the rail yards are assumed to increase their hours of operation to two shifts per day; in 2015 the yards are assumed to operate three shifts per day; and in 2020 the yards are assumed to operate three shifts per day and with work rules and practices more in line with Class I railroad facilities instead of the current Pacific Maritime Association policies.

All constraints to maximizing efficiency of on-dock rail must be investigated and solved before building a new rail yard facility so near a residential community with so much additional pollution.

In addition, we request that the Los Angeles Harbor Department's Rail Policy be revisited by the new commissioners. This policy was adopted by the previous Harbor Commissioners last summer with 30 days of public comment, the month before the SCIG NOP was released. The Policy does not preferentially weight on-dock rail over near-dock intermodal facilities (and, we argue, it should, it terms of overall reduction of air pollution); it does not adopt the No Net Increase recommendations on rail, as would have been appropriate; and it does not address reducing pollution from diesel trucks delivering containers to rail yard facilities, which Harbor Commission President David Freeman so vigorously called for at the SCIG NOP Scoping Meeting in October.

6. The EIR analysis must accurately reflect what will happen with traffic on the I-710 Freeway if the SCIG is constructed. It is inappropriate for the NOP to claim that the SCIG will "divert" trucks from the I-710 freeway to the SCIG, thereby reducing pollution. The SCIG is being built for one purpose: to increase the capacity of the Ports to handle escalating cargo volume.

The SCIG is being proposed to increase capacity of the Ports to handle rising international cargo volume. Already, the yards at Hobart/East L.A. are virtually at capacity and more intermodal capacity is needed. Yet the NOP (as well as BSNF comments at the Scoping hearings and other meetings) makes an argument that the rail facility would divert traffic off the I-710 Freeway, thereby reducing truck vehicle miles traveled and reducing air pollution emissions regionally.[1] This does not appear to be supported by the facts. The BNSF rail yard in East L.A./City of Commerce, approached by the I-710 Freeway from the Port, attracts hundreds of thousands of trucks to its facility each year. With the Ports expanding and the other BNSF rail yard near capacity, no reduction in truck trips on the I-710 seems foreseeable. In fact, BNSF is trying to "squeeze" as much capacity out of its Hobart Yard as possible and operate at the fullest capacity possible, which will attract as many, if not more, trucks:

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[1] This same argument (that it would divert trucks off the I-710) was made years ago for the Alameda Corridor:

> "The Alameda Corridor in Southern California is a nationally known rail consolidation project and dedicated freight corridor that will reduce truck trips on Interstate 710 and other Los Angeles corridors" *[Citation: California Department of Transportation Planning Program Jan 12, 1998. Issue Paper #7, p.5.]*.

"The Hobart Intermodal Facility is located in City of Commerce of Washington Street near the I-5 and I-710 freeways. The yard occupies approximately 160 acres and has 17 ramp tracks, typically 3,000 feet long, but five of those tracks are train-length (approximately 7,200 feet long). Hobart performed about 1.2 million lifts in 2002. With planned track expansion and satellite storage yards, the facility could reach 1.5 million lifts annually. The BNSF envisions finding layout and operational improvements to squeeze 2 million lifts out of Hobart. Hobart operates 24 hours per day, and 7 days per week throughout the year." *Source: San Pedro Bay Ports Rail Market Study. 4/24/04 Parsons Transportation Group. Prepared for Port of Los Angeles.*

Most important for the EIR to consider is the anticipated increase of air pollution and potential for exposure in the immediate vicinity of the rail yard, an area already severely impacted by Port-related emissions, including from the existing Union Pacific ICTF. The EIR must evaluate the severe health impacts anticipated from adding 1.5 million trucks to the area's existing 1.5 million trucks going to the UP ICTF. The EIR must include measurements of emissions at the UP ICTF or another BNSF facility and develop calculations on the additional emissions to be pumped into the area by the equipment at the SCIG, the trucks along the Terminal Island Freeway, the Alameda Corridor trains, and the San Pedro Track trains/locomotives. It must look at the SCIG's contributions to both local and regional pollution.

7. The EIR must assess the feasibility of non-diesel delivery systems for transporting containers between the Ports and the SCIG.

The SCIG is located only four miles from the Ports, offering an ideal situation for utilizing the most innovative technology on such a short route. The supplemental NOP mentions evaluating Maglev and other non-diesel delivery systems for transporting containers to and from the Ports. All other magnetic levitation systems for freight movement must also be considered and we recommend that the Port staff meet as soon as possible with the developers of this technology. In addition, we recommend that the following sites be explored thoroughly since much work around the world is occurring on innovative non-diesel truck methods of moving freight:

List of Web sites on automated freight and goods movement technologies:
http://faculty.washington.edu/~jbs/itrans/afreight.htm

List of Web sites on Maglev technologies:
http://faculty.washington.edu/jbs/itrans/maglevq.htm

In addition, contact should be made with the organizers of the "Fourth International Symposium on Underground Freight Transportation by Capsule Pipelines and other Tube/Tunnel Systems" held in Shanghai, China, October, 2005, to see what technologies their conference discussed as promising.
http://www.csueus.com/isuft2005/zhengwen-e.htm

Each of these companies and their technologies should be pursued as a possibility for moving containers to the SCIG as an alternative to heavy duty diesel trucks. The EIR should reference this list and explain why each of the technologies was or was not possible for use in the SCIG before selecting a diesel truck alternative.

SPECIFIC COMMENTS ON SECTIONS OF THE NOP AND SUPPLEMENTAL NOP

Project description: maps and figures

- The EIR must include a map to identify and show the proximity to all schools in the area, including parochial schools, as well as other facilities such as homeless shelters, housing for homeless veterans, daycare centers, community gardens, parks and recreational areas, many of which are within .25 miles of the proposed facility. The map included with the NOP is insufficient to show the impacted communities in all directions from the proposed project.

- The EIR must specify if the Alameda Corridor Long Beach South Lead Track, the South Lead Track, and the ACTA Bridge and Track Improvements are located in the vicinity of homes or schools.

- The "train switching area" is adjacent to homes and immediately north of Hudson School and other sensitive receptors. The EIR must describe what will happen at the switching area, how many switching locomotives will be operating, and what will happen on this track.

  In addition, the switching area is identified as an "Area of Less Frequent Train Movements." "Less frequent" is meaningless without specifying the actual anticipated number of train movement. This track is immediately adjacent to homes north of Willow. South of Willow the track is near school playing fields and very close to the Cambodian Temple. Any additional locomotives traveling along this corridor – even closer to the schools and homes than the SCIG would be – should not be allowed unless all trains are completely "green" or electrified. The EIR must calculate a baseline of exposure to pollutants from this track and switching area and an anticipated future range of pollutants. Please see Appendix F for a photo taken before the sound wall was built near the UP ICTF, showing how close the locomotives are to homes in the area.

- The NOP's truck route map indicates that no trucks will be traveling on the Terminal Island Freeway to reach the BNSF rail yard, although there will be a gate at the northern end of the facility. The attached map of the SCIG (Appendix C) (not a map included with the NOP) shows a truck queuing area near Sepulveda, raising questions about whether trucks will actually enter on that side. The EIR must be explicit that only the southern gate will be used and that the northern gate will not be used except in emergencies, since this would add a tremendous amount of additional traffic to the already truck-congested Terminal Island Freeway which is separated by nearby schools, parks, daycare centers, churches, and homeless shelters only by a chain link fence. If there are plans to expand the UP ICTF also or to merge the two facilities into one, then the entire issue of truck routing must be revisited. No additional diesel trucks should be added to the TI Freeway by either ICTF since the community is already demonstrated to have higher air pollution levels than other communities studied.

Comments on Environmental Checklist and Impact Analysis

- Project location. This section mentions additional rail tracks from Sepulveda Bridge north to Wardlow Road. It is unclear if this means that an additional track will be built. These tracks are immediately adjacent to hundreds of homes and several schools. The claim that the tracks "would be subject to less frequent train movements that the proposed Project Area" must be explained, since no volume of train movements in the Project Area is detailed. The homes north of Sepulveda near the train line are only a matter of feet from the trains and if there are to be more locomotives traveling on that line they must be non-diesel or electric.

- Surrounding land uses. This section needs to be expanded to specify precisely all the sensitive receptor facilities in the vicinity of the area, including schools, parks, churches, shelters, and residences.

Evaluation of Environmental Impacts
Section III. Air Quality

- **Would the project conflict with or obstruct implementation of the applicable air quality plans?**

  The bolded sentence added to this section of the supplemental NOP must be amended. It states that "non-diesel container delivery system alternatives will be evaluated in an effort to reduce identified regional emissions impacts" (emphasis added). The EIR must evaluate alternatives to reduce BOTH regional emissions and those localized emissions in close proximity to homes; schools, playfields, parks, community gardens, homeless shelters and other sensitive receptor facilities.

Section VII. Hazards and Hazardous Materials.

- **a/b. Would the project create a significant hazard to the public or the environment through the routine transport... of hazardous materials?**

- This section of the NOP states: "Trains using the intermodal facility may potentially transport hazardous materials." A map of the SCIG shown in a presentation at the Mobility 21 Conference (Appendix C) actually shows the Haz Mat area of the SCIG located directly across the Terminal Island from the homeless facilities and daycare center on San Gabriel Avenue. (Compare location of Haz Mat area on map in Appendix C with location of homeless shelter, transitional school for homeless children, and a daycare center less than .25 miles from the proposed SCIG, Appendix D). We recommend that this Checklist response be changed to "potentially significant impact," and that the EIR present a thorough evaluation of the risk of exposure, including identification of what types of hazardous materials will be handled at the facility. It would seem prudent to locate a Haz Mat area of the SCIG much further away from young children. In addition, the Emergency Response Plan should involve input from the adjacent community.

- **Would the project emit hazardous emissions or handle hazardous materials... within .25 miles of an existing or proposed school?**

  The list of schools needs to be updated; for example, Cabrillo High School is not mentioned, yet its playing fields are adjacent to the Terminal Island (103) Freeway and Hudson is a K-8 school, not a middle school. In light of the extremely close proximity of these schools and the [number of] children who attend them, the EIR should address what kinds of hazardous materials will be handled and exactly what response actions would be necessary—including communications systems and warning plans—in the case of an accidental release to ensure the safety of the children and staff at these schools, as well as local residents.

Section XI. Noise

The NOP appropriately states that the proposed intermodal facility and operation of the San Pedro tracks north of Sepulveda, along with a widened rail bridge, could increase traffic noise in the area, and that there could be noise from onsite heavy equipment. In addition, the NOP states that "the impact is potentially significant." The NOP states that the widened rail bridge would increase traffic and noise and argues that "it is not adjacent to residences." The rail bridge is actually close to the Cambodian Temple and less than ¼ mile from Hudson School. In addition, from Cabrillo High School near the school's playing fields, students playing can hear the rumbling sound of locomotives approaching on the San Pedro track (See photo in Appendix G). The EIR must specifically state what mitigation measures will be implemented to reduce noise and vibration from any trains operating in or entering and leaving the SCIG Project, as well as providing the baseline and project noise increases as suggested earlier. In addition, noise levels at baselines and projected forward for the Wilmington side of this project must be also be evaluated.

Noise was considered in the EIR of the Union Pacific ICTF, adjacent to the proposed SCIG. A sound wall was constructed, but even with the wall residents continue to complain about objectionable noise levels in the area from yard hostlers, locomotives, trucks on the road and at the UP ICTF, back up signals, screeching of trains on tracks when not lubricated and other issues. Feasible technology (in addition to any necessary sound walls) to reduce noise generated by sources connected to the proposed SCIG project must be thoroughly investigated in the EIR process.

Section XIII. Public Services and Section XIV. Recreation

- The NOP states that "the proposed project does not involve... direct impacts to any existing parks or recreational facilities. No impacts would occur. This issue will not be addressed in the EIR." This is not accurate. The proposed project would impact the public park directly across from the proposed SCIG. The park is south of Hudson School's playing fields and north of Cabrillo High School's playing fields. In addition, next to the park is a community garden. The park and garden are separated from the Terminal Island Freeway by a chain link fence. On the other side of the freeway is the

San Pedro train track, which is apparently to be expanded, and the proposed SCIG project. The park and garden would be impacted by noise, dust, tire/clutch/engine debris, air pollution, the potential for hazardous materials releases at the rail yard, and more.

For these reasons, the impacts should be considered "potentially significant" for both of these sections of the NOP

- In addition, at a time when physical activity is extremely important to all residents, especially youngsters in whom obesity is an increasingly significant health problem, it is imperative that no degradation of air quality occur in the park, playfields and recreational facilities in the area (including the Boys and Girls Club, Cabrillo fields, Hudson playing areas, the daycare center play area off San Gabriel Avenue and all other recreational facilities and parks in the area), as these facilities represent critical opportunities for the physical activities that are necessary for maintaining the health of children and young adults. Please see photo of the daycare center (Appendix H) to see the proximity of big-rig trucks currently through the chain-link fence that is the toddlers' only protection.

  The proximity to existing high levels of pollutants on the nearby TI Freeway and the UP ICTF raises serious questions about children exercising in that type of environment. BNSF must consider, in conjunction with the UP ICTF (if any expansion is to occur there), whether appropriate mitigation measures would include air filtration for the community's schools and/or building air-conditioned gyms, for which parents of school children and teachers have been calling.

In sum, we are deeply concerned that the NOP inadequately addresses the health effects that the SCIG will have on the people who live, learn, play, and work in the vicinity of the project area. The EIR should fully address all aspects of the SCIG's impacts, including the numerous impacts created by the delivery of containers to the site as well as impacts that arise from the increase in goods movement through the ports, on the rail lines, and on the freeways that this project will enable. We expect the EIR to address a broad range of alternatives, including alternative siting and maximization of on-dock facilities, and fully confront the health risks posed by the project and the alternatives. Finally, the EIR must identify and implement and implement mitigation measures to reduce the impacts of all aspects of the SCIG to health-protective, no-increase levels.

Sincerely yours,

Andrea M Hricko

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Appendices

Table of contents

Attached: South Coast Air Quality Management District Monitoring and Analysis: Rule 1158 Follow-up Studies #7, #9, and #11.

Appendix A.

List of Scientific References on Air Pollution's Effects on Health for Consideration in the EIR Process. All articles and abstracts can be found in Appendix B, on the Compact Disk (CD).

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Appendix B. CD with Scientific Articles for Consideration in the EIR Process.
Please see attached CD.

[Please contact Port of Los Angeles Environmental Management Division for information contained on this CD]

Attachments from Comment Letter 135

Table 4.1: Guideline values for community noise in specific environments.

Specific environment	Critical health effect(s)	LAeq [dB]	Time base [hours]	LAmax, fast [dB]
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50	16 16	- -
Dwelling, indoors Inside bedrooms	Speech intelligibility and moderate annoyance, daytime and evening Sleep disturbance, night-time	35 30	16 8	 45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60
School class rooms and pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35	during class	-
Pre-school bedrooms, indoors	Sleep disturbance	30	sleeping -time	45
School, playground outdoor	Annoyance (external source)	55	during play	-
Hospital, ward rooms, indoors	Sleep disturbance, night-time Sleep disturbance, daytime and evenings	30 30	8 16	40 -
Hospitals, treatment rooms, indoors	Interference with rest and recovery	#1		
Industrial, commercial shopping and traffic areas, indoors and outdoors	Hearing impairment	70	24	110
Ceremonies, festivals and entertainment events	Hearing impairment (patrons:<5 times/year)	100	4	110
Public addresses, indoors and outdoors	Hearing impairment	85	1	110
Music through headphones/ earphones	Hearing impairment (free-field value)	85 #4	1	110
Impulse sounds from toys, fireworks and firearms	Hearing impairment (adults) Hearing impairment (children)	- -	- -	140 #2 120 #2
Outdoors in parkland and conservation areas	Disruption of tranquillity	#3		

#1: as low as possible;
#2: peak sound pressure (not LAmax, fast), measured 100 mm from the ear;
#3: existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low;
#4: under headphones, adapted to free-field values

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GUIDELINES FOR COMMUNITY NOISE

Edited by

Birgitta Berglund
Thomas Lindvall
Dietrich H Schwela

This WHO document on the *Guidelines for Community Noise* is the outcome of the WHO-expert task force meeting held in London, United Kingdom, in April 1999. It bases on the document entitled "Community Noise" that was prepared for the World Health Organization and published in 1995 by the Stockholm University and Karolinska Institute.

World Health Organization, Geneva
Cluster of Sustainable Development and Healthy Environment (SDE)
Department for Protection of the Human Environment (PHE)
Occupational and Environmental Health (OEH)

Environmental Justice Community Noise Standard

1. Environmental Justice Community Noise Standard

Environment	Day 7:00am – 5:00pm	Night 5:00pm-7:00am	Night Sleep Time 9:00pm – 7:00am
Outdoor	50dBA	40dBA	
School Indoor	35dBA	35dBA	
Preschool Sleep Time	30dBA		
Residence Indoor	35dBA	35dBA	
Residence Indoor Sleep Time			30dBA
Residence Indoor Low Frequency			25dBA

1.1 General Ambient Noise Level

Los Angeles Noise Ordinance – Chapter XI Noise Regulation, Article 1 General Provisions Sec. 111.00 Declaration of Policy and Sec. 111.03 Minimum Ambient Noise Level Table II Zone A1, A2, RA, RE, RS, RD, RW1, RW2, R1, R2, R3, R4, R5 Presumed Ambient Noise Level Day dBA 50 and Night 40dBA and Article 6 General Noise Sec.116.01 Loud, Unnecessary and Unusual Noise.

1.2 Community Ambient Noise Protection

World Health Organization – Guidelines for Community Noise, Table 1 & Table 4.1 Guidelines Values for Community Noise in Specific Environments – Specific Environment: Inside Bedrooms 30dBA, Preschool Sleep 30dBA and School Class Rooms 35dBA.

1.3 Specific Low Frequency Noise Protection

World Health Organization – Guidelines for Community Noise, 4.2.3 Sleep Disturbance Effects states, “For noise with a large proportion of low frequency sounds a still lower guideline lower than 30dBA is recommended,” and “Since A-weighting underestimates the sound pressure level of noise with low frequency components, a better assessment of health effects would be to use C-weighting.”

1.4 American Industry Standard

The American National Standards Institute (ANSI) ANSI S12.60-2002 Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Table 1 pg. 5 for Learning space 35dBA.

Environmental Justice Project Community Advisory Committee

1.0 Project Community Advisory Committee Purpose

TBD

2.0 PCAC Goals & Objectives

TBD

3.0 PCAC Membership

Community Advisory Committee membership shall consist of 80% local residents, 10% stakeholders and 10% representatives from local community organizations. All residents and stakeholder members must live in Wilmington, Long Beach or Carson.

4.0 PCAC Meetings

TBD

5.0 PCAC Website

TBD

6.0 Project Noise Monitoring Program

TBD

7.0 Project Traffic & Equipment Monitoring Plan

Preconstruction, Construction and Post Construction TBD

8.0 Community Noise Survey

8.1 Preconstruction Community Noise Survey
8.2 During Construction and Post Construction Community Noise Survey TBD.

9.0 Community Noise Complaint Procedure

4.1. Community Information & Complaint Hotline
4.2. Community Complaint Form
4.3. Complaint Investigation
4.4. Problem Corrective Action
4.5. Complaint Resolution

9.0 Project Noise Monitoring Status Reporting

TBD

10.0 Community Complaints Status Reporting

TBD

11.0 PCAC Termination

TBD.

Environmental Justice Community Preconstruction Noise Survey

1. The community should have a say in defining the Community Noise Standard?

   Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

2. The community should have a say in determining construction work days and hours?

   Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

3. There should be no construction work on weekends and holidays?

   Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

4. All construction contractors and subcontractor workers should attend a noise class?

   Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

5. The noise standards should provide the maximum public health & welfare protection?

   Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

6. Indoor school classrooms should have a stricter noise standard than day?

   Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

7. Preschool classrooms should have a stricter noise standard than day?

   Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

8. Senior housing & Hospice Facilities should have a stricter noise standard than day?

   Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

9. Hospitals should have a stricter noise standard than day?

   Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

10. Day time residential near Intermodal facilities should have a stricter noise standard?

    Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

11. Night time residential areas should have a stricter noise standard than day?

    Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

12. Sleep times should have a stricter noise standard than standard night?

    Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

13. A noise monitoring plan should be required as part of the project?

    Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

14. A Community Advisory Committee should be required as part of the project?

    Strongly Agree [ ] Agree [ ] Disagree [ ] Undecided [ ]

15. Penalties and fines should be established for noise violations?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

16. There should be a public information hotline & complaint line?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

17. Project Noise should be mitigated to eliminate and reduce noise to less than significant?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

18. Port truck traffic volume near residential homes & schools should be limited to prevent increasing noise?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

19. Port train traffic volume near residential homes & schools should be limited to prevent increasing noise?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

20. Project sponsors should require and provide incentives to purchase zero emissions and near noiseless trucks?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

21. Project sponsors should require and provide incentives to purchase zero emissions and hear noiseless trains?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

22. Schools, residential homes and all sensitive receptors locations should be sound proofed to eliminate noise or reduce to less than significant?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

23. Environmental and public health mitigation costs should be included in project budget?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

24. Excessive noise disturbs my ability to sleep?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

25. Excessive noise disturbs my mental peacefulness?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

26. Excessive noise disturbs my ability to relax, watch TV and listen to music?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

27. Excessive noise makes me unable to concentrate and perform my daily activities?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

28. Train & Truck noise is a major problem in my community and has been increasing?

Strongly Agree [ ]   Agree [ ]   Disagree [ ]   Undecided [ ]

AMERICAN NATIONAL STANDARD

ACOUSTICAL PERFORMANCE CRITERIA, DESIGN REQUIREMENTS, AND GUIDELINES FOR SCHOOLS

Accredited Standards Committee S12, Noise

Standards Secretariat
Acoustical Society of America
35 Pinelawn Road, Suite 114E
Melville, NY 11747-3177

Environmental Justice Community Fence-Line Monitoring Program

1.0 Noise Monitoring Program

Complete detail description TBD.

2.0 Community Advisory Committee Establishment

Community Advisory Committee to be established 90 days before construction begins.

3.0 Environmental Justice Community Noise Standard

3.1 Environmental Justice Community Noise Standard

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Residence Indoor Sleep Time			30dBA
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3.3 Community Ambient Noise Protection

World Health Organization – Guidelines for Community Noise, Table 1 & Table 4.1 Guidelines Values for Community Noise in Specific Environments – Specific Environment: Inside Bedrooms 30dBA, Preschool Sleep 30dBA and School Class Rooms 35dBA.

3.4 Specific Low Frequency Noise Protection

World Health Organization – Guidelines for Community Noise, 4.2.3 Sleep Disturbance Effects states, “For noise with a large proportion of low frequency sounds a still lower guideline lower than 30dBA is recommended,” and “Since A-weighting underestimates the sound pressure level of noise with low frequency components, a better assessment of health effects would be to use C-weighting.”

3.5 American Industry Standard

The American National Standards Institute (ANSI) ANSI S12.60-2002 Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Table 1 pg. 5 for Learning space 35dBA.

4.0 Technical Approach

Community On-Site Monitoring Technical Approach TBD.

5.0 Real Time Ambient Noise Level Monitoring

5.1 Real Time Ambient Noise Level Monitoring shall as a minimum measure Leq, L10, Ldn, Lmax, SEL and CNEL. A-Frequency Weighting and C-Frequency Weighting shall be monitored and recorded.

5.2 All measurements must be continuous and recorded.

6.0 Real Time Noise Sound Recording

6.1 Real time ambient noise shall be recorded to determine source and types of noises.

6.2 Noise sound recording will be continuous non-stop recording either analog or digital 24hrs. per day with digital preferred.

7.0 Noise Sound Level Meter

7.1 The Noise Sound Level Meter shall be a Type I to ANSI S1.4-1998 or most recent revision.

7.2 A Sound Level Meter with data-logging capability for recording a minimum of 24 hrs. continuously recording and 7 days non-stop is preferred.

7.3 A Sound Level Meter capable of recording ambient noise sound a minimum of 24 hrs. continuously and 7 days non-stop is preferred.

7.4 Sound Level Meters, Data Logging and Sound Recording Equipment and accessories must be capable of withstanding outdoor inclement weather.

8.0 Noise Monitoring Locations

Locations TBD.

9.0 Noise Monitoring

Protocol TBD

10.0 Noise Monitoring Schedule

Schedule TBD.

11.0 Frequency of Noise Monitoring

11.1 Measurements shall as a minimum be every 15 minutes for 24hrs. per day or as may be determined necessary.

12.0 Equipment Calibration

12.1 Equipment calibration shall be traceable to the National Bureau of Standards and the American National Standards Institute (ANSI) S1.4-1998 or most recent revision.

12.2 Records shall be maintained and provided upon request.

13.0 Equipment Inspection & Monitoring

On-Site Equipment Inspection & Monitoring Plan TBD.

14.0 Record Keeping Procedures

Procedures TBD.

15.0 Noise Monitoring Quality Assurance

QA Plan TBD.

16.0 Noise Monitoring Reports

Noise Monitoring Reports will be produced monthly, quarterly and annually.

17.0 Data Analysis & Review

Format TBD.

18.0 Corrective Action

CA TBD.

NOISE CONTROL ACT OF 1972

HISTORY: Public Law 92-574, Oct. 27, 1972; 86 Stat. 1234; 42 USC 4901 et seq.; Amended by PL 94-301, May 31, 1976; PL 95-609, Nov. 8, 1978; PL 100-418, Aug. 23, 1988

SEC. 1 [42 U.S.C. 4901 nt], Short Title.

This Act may be cited as the "Noise Control Act of 1972."

SEC. 2 [42 U.S.C. 4901]Findings and Policy.

(a) The Congress finds--

(1) that inadequately controlled noise presents a growing danger to the health and welfare of the Nation's population, particularly in urban areas;

(2) that the major sources of noise include transportation vehicles and equipment, machinery, appliances, and other products in commerce; and

(3) that, while primary responsibility for control of noise rests with State and local governments, Federal action is essential to deal with major noise sources in commerce control of which require national uniformity of treatment.

(b) The Congress declares that it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare. To that end, it is the purpose of this Act to establish a means for effective coordination of Federal research and activities in noise control, to authorize the establishment of Federal noise emission standards for products distributed in commerce, and to provide information to the public respecting the noise emission and noise reduction characteristics of such products.

SEC. 3 [42 U.S.C. 4902] Definitions.

For purposes of this Act:

(1) The term "Administrator" means the Administrator of the Environmental Protection Agency.

(2) The term "person" means an individual, corporation, partnership, or association, and (except as provided in sections 11(e) and 12(a)) includes any officer, employee, department, agency, or instrumentality of

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Air Quality Appendices

AQ-1 Expert Witness Letter Dr. Jonathan Heller, PHD

AQ-2 Jonathan Heller CV

AQ-3 Health Impact Assessment Information

AQ-4 Medical Health Studies Index A-1 / A-10

HUMAN IMPACT PARTNERS

304 12th St. Suite 3B Oakland CA 94607 510 452 9442

January 27, 2012

Jesse N. Marquez
Executive Director
Coalition For A Safe Environment
1601 N. Wilmington Blvd.
Wilmington, CA 90744

Dear Mr. Marquez,
This letter describes why, in the opinion of Human Impact Partners, Environmental Impact Reports under the California Environmental Quality Act (CEQA) and Environmental Impact Statements the National Environmental Protection Act (NEPA) require a comprehensive analysis of health, how Health Impact Assessments (HIAs) can be conducted to address that requirement, and how Health Risk Assessments (HRAs) as currently conducted do not meet that requirement and are different from HIAs.

About Human Impact Partners (HIP)

Founded in June 2006, Human Impact Partners is an independent non-profit corporation (501(c)3) based in Oakland, California. HIP's mission is to increase the consideration of health and equity in decision-making. In doing so, we work to transform the policies and places people need to live healthy lives. As research indicates that approximately 55% of health status is determined by social and environmental conditions, the fundamental premise of our work is that decision-makers must understand how community-level factors, such as housing, land use, and transportation systems affect health and health disparities in order to take action to improve those conditions, and thereby improve health.

While it seems commonsense that major decisions regarding land use and transportation planning should incorporate health considerations, mechanisms for doing so often do not exist, and local and regional agencies do not have the resources or expertise to incorporate health into planning-related decisions. HIP is addressing this through its work conducting Health Impact Assessments and similar health-based analyses in collaboration with government agencies and community organizations, with a focus on communities facing health disparities. Human Impact Partners has conducted HIAs and similar analyses on the local, state and federal levels – with experience in communities across the country, from California to Maine. Our findings have been integrated into policy-making, planning and projects. To date, HIP has conducted over fifteen HIAs on land use and transportation plans and development projects.

Health Impact Assessments

Understanding and consideration of health and equity consequences of land use, transportation, goods movement, and other decisions and of potential mitigations to adverse consequences could yield policies, plans, and projects that result in better outcomes for all, but especially for vulnerable populations that currently face inequities. HIA is a public engagement and decision-support tool that can be used to assess the health impacts of planning and policy proposals, and make recommendations to improve health outcomes associated with those proposals. In a recent book by the National Research Council, HIA is formally defined as "a systematic process that uses an array of data sources and analytic methods and considers input from stakeholders to determine the potential effects of a proposed policy, plan, program or project on the health of a population and the distribution of those effects within the population. Health impact assessment provides recommendations on monitoring and managing those effects."[1]

Environmental, social, demographic, and economic conditions drive the health and wellbeing of communities. Factors such as housing, transportation, employment and income, noise, air quality, access to goods and services, access to parks, and social networks have well-demonstrated and reproducible links to health outcomes. An HIA analyzes health from a broad perspective by evaluating how a proposed project, plan, or policy affects these factors – often collectively referred to as "determinants of health" in the public health literature – and in turn, how impacts to these factors are likely to positively or adversely influence health.

Overall, the information from an HIA, and close collaboration between public health experts, affected communities, and the decision-makers on a project, lead to practical, evidence-driven recommendations that address identified health concerns to the extent possible within the limitations of the regulatory or decision-making process. Conducting an HIA can offer many benefits:

- HIAs provide sound, objective data on health impacts. By using this information, potentially unexpected health consequences and unanticipated costs can be identified and thus avoided.
- HIA helps develop healthier communities by identifying design solutions that address the root causes of many prominent health problems like asthma, diabetes, and cardiovascular disease.
- The HIA process can be used to build consensus and buy-in by addressing the affected community's fears about a project directly and transparently and by providing practical solutions.
- HIAs help focus community involvement on real health concerns and on feasible mitigations to those health issues.
- Health issues are typically important to community members and HIA can serve to engage community residents in decisions that impact their lives.
- HIAs give project proponents a way to recognize positive health contributions of projects on communities. It also given businesses the information they need to distinguish themselves as smart planners and build positive working relationships with the community.
- HIAs help decision-makers by ensuring that any potential concerns about a project are identified and addressed early on.

HIA may use both qualitative and quantitative data and methods to predict potential impacts. Where feasible and data allows, HIA uses quantitative modeling to increase the precision of analysis and to support significance judgments. Because of substantial data requirements, using quantitative forecasting methods exclusively may

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[1] National Research Council (NRC). 2011. Improving Health in the United States: The Role of Health Impact Assessment. Available at: http://www.nap.edu/catalog.php?record_id=13229.

present a partial or biased accounting of health effects. Quantification can also be resource intensive and divert from other impact assessment activities. Qualitative analyses provide valuable data when quantitative analyses are not possible.

In 2011, the National Research Council of the National Academies of Science formed a Committee on Health Impact Assessment and released a book entitled Improving Health in the United States: The Role of Health Impact Assessment.[2] The book provides guidance on conducting HIAs and makes a strong case that HIAs should be integrated into the environmental review process. Additionally, The North American Health Impact Assessment Working Group released a second edition of practice standards for conducting HIAs in 2010. Those standards are attached to this letter.

The Human Impact Partners website (http://www.humanimpact.org/) contains information, tools, and resources regarding HIA. Other good resources include the Centers for Disease Control website (http://www.cdc.gov/healthyplaces/hia.htm), the Health Impact Project website (www.healthimpactproject.org), and the UCLA HIA Clearinghouse website (http://www.ph.ucla.edu/hs/hiaclic/).

NEPA and CEQA require a comprehensive analysis of health impacts and HIA is a tool that can fill this requirement

As stated in "Public Health Analysis Under the National Environmental Policy Act", a white paper by Aaron Wernham (the Director of the Health Impact Project, a collaboration of the Robert Wood Johnson Foundation and the Pew Charitable Trusts) and Dinah Bear (former General Counsel for the Council on Environmental Quality):

> The inclusion of a robust, systematic approach to public health is supported by NEPA, the regulations issued by the Council on Environmental Quality (CEQ), the agency in the Executive Office of the President charged with overseeing implementation of NEPA, Executive Orders 12898 and 13045, and available guidance on NEPA and environmental justice.
>
> *Congressional Intent*
> In using the term "human environment," Congress signaled that protection of human communities was a fundamental purpose of the legislation. In the debates leading to NEPA's enactment, Senator Henry Jackson stated: "When we speak of the environment, basically, we are talking about the relationship between man and these physical and biological and social forces that impact upon him. A public policy for the environment basically is not a public policy for those things out there. It is a policy for people."
>
> *Health in NEPA*
> NEPA mentions health a total of six times. Among NEPA's fundamental purposes is: "promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man." NEPA § 102 [42 USC § 4321]
>
> NEPA is intended, furthermore, to: "assure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings." [42 USC § 4331]
>
> And finally to: "attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences." [42 USC § 4331]
>
> *Health in the CEQ Regulations*

[2] National Research Council (NRC). 2011. Improving Health in the United States: The Role of Health Impact Assessment. Available at: http://www.nap.edu/catalog.php?record_id=13229.

Several general provisions of CEQ's NEPA regulations support the inclusion of health.

First, agencies respond to substantive public concerns in the draft EIS [40 CFR § 1503.4]. When, therefore, an agency can anticipate substantive health concerns based on scoping, it is sensible to include these issues for analysis in the DEIS.

Second, in determining whether an effect may be significant (and therefore require analysis in the EIS) one of the factors that agencies should consider is "the degree to which the effects on the human environment are likely to be highly controversial" [40 CFR § 1508.27 (b) 4]. Commonly, health often figures among the strongest concerns expressed by affected communities.

The CEQ regulations also specifically define health as one of the effects that must be considered in an EIS or an EA. In defining "effects," the regulations state that: "Effects" includes ecological, aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative." [40 C.F.R. § 1508.8] And, the regulations instruct agencies to consider "the degree to which the proposed action affects public health or safety" in determining significance. [40 C.F.R. § 1508.27]

Health in Executive Orders

Executive Order 12898 instructs agencies to: "make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States."

Similarly, Executive Order 13045 states that agencies must: "make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children; and ... shall ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks."

Statements relevant to NEPA-based health analysis in Federal Guidance

CEQ guidance on implementing Executive Order 12898 contains several suggestions relevant to public health analysis, including:

- Lead agencies should involve public health agencies and clinics
- Agencies should review relevant public health data (as for any other resource)
- Agencies should consider how interrelated cultural, social, occupational, historical, or economic factors may contribute to health effects of the proposed action and alternatives.

The California Environmental Quality Act contains similar requirements for conducting comprehensive health analyses. Potentially significant impacts on health trigger Environmental Impact Reports:

A lead agency shall find that a project may have a significant effect on the environment and thereby require an EIR to be prepared for the project where there is substantial evidence, in light of the whole record, that any of the following conditions may occur ... (4) ***The environmental effects of a project will cause substantial adverse effects on human beings, either directly or indirectly****. (CCR§15065(a))*

EIRs under CEQA must discuss public health impacts:

The discussion should include relevant specifics of the area, the resources involved, physical changes, alterations to ecological systems, and changes induced in population distribution, population concentration, the human use of the land (including commercial and residential development), ***health and safety problems*** *caused by the physical changes, and other aspects of the resource base such as water, historical resources, scenic quality, and public services. (CCR§15126.2(a))*

Several court opinions in California support the inclusion of health impacts in EIRs, including, for example, Bakersfield Citizens for Local Control vs. City of Bakersfield (2004) and Californians for Alternatives to Toxics v. CDFA (2005).

Furthermore, CEQA recognizes interactions among social and environmental effects:

If the physical change causes adverse economic or social effects on people, those adverse effects may be used as a factor in determining whether the physical change is significant (CCR§15064).

And:

Where a physical change is caused by economic or social effects of a project, the physical change may be regarded as a significant effect in the same manner as any other physical change resulting from the project. (CCR § 15064)

Currently, there are three ways in which health is incorporated into an EIR/EIS: 1) as a health risk assessment for a discrete exposure (see below); 2) as a discussion of risk factors for health (e.g., air quality, traffic flow), but the link between those risk factors and health is not often made explicitly; and 3) as a demonstration of compliance with a health-based environmental regulation, such as the Clean Air Act. These approaches do not fully address the requirement for an analysis of potential public health effects according to the format/process established by NEPA and CEQA.

A more complete analysis of health effects responsive to NEPA and CEQA would consider all potentially significant direct, indirect and cumulative health impacts associated with the proposed action and alternatives. The analysis would include descriptions of baseline heath status and determinants of health for the affected population. These elements would generally be achieved through the implementation of an integrated HIA which would:

- Include a systematic scoping of potentially significant direct, indirect, and cumulative health impacts;
- Analyze baseline health conditions and determinants of health;
- Analyze direct and indirect health impacts of the project; and
- Analyze cumulative impacts related to health outcomes.

The steps of Health Impact Assessment parallel the steps of Environmental Impact Assessment (EIA) and, therefore, the two processes can be easily integrated. By integrating HIA and EIA, redundancy in data collection and analysis is avoided, as information collected in the EIA process provides inputs into the health analysis. To conduct a HIA as part of an EIR/EIS, one would:

- Scope potential direct, indirect, and cumulative health concerns in the EIR/EIS Scoping stage. HIA Scoping includes stakeholder meetings to ensure the scope is complete and uses stakeholder knowledge and experience to prioritize the health concerns to analyze.
- Assess prioritized health concerns identified during Scoping. This assessment will include:
    - new analyses (e.g., collecting existing data on health conditions and on existing determinants of health; analyzing impacts not previously analyzed as a result of the expanded Scope);
    - extensions of existing analyses (e.g., using traffic data such as vehicle trips and volume to predict impacts on traffic injuries and physical activity); and

- o developing potential mitigation measures to address significant health impacts.

  In addition, HIA assessment could include methods that involve stakeholder participation, such as community surveys and focus groups.
- Report and receive public comment on baseline health conditions and determinants of health, the analysis of health impacts, and potential mitigation measures in the Draft EIR/EIS and respond to comments to develop the Final EIR/EIS.

To date, HIAs have been included in five published NEPA documents, all in Alaska.[3] In San Francisco, the health department collaborates with the planning department to ensure the inclusion of health analyses for environmental analysis conducted under CEQA. An HIA was recently completed on the I-710 Corridor Project in Los Angeles and Caltrans is reviewing it and will decide if/how to incorporate it into the DEIR/DEIS. Other jurisdictions around the country are conducting HIAs that may be integrated into the environmental review process, including one that is currently starting on the location of a new intermodal facility in Maryland.

Health Impact Assessment and Health Risk Assessment (HRA)

Health Risk Assessments are sometimes conducted as part of EIRs or EISs and sometimes conducted outside the EIR/EIS process. This is true of HIA as well. While there is significant overlap between HIA and the theoretical framework for HRA, in practice, HIA and HRA differ substantially because HRA is carried out in a manner much more limited than its theoretical framework allows for. Below we compare and contrast existing practice of HRA and HIA:

- The purpose of HIA is to make evidence based judgments on the health impacts of a decision and to make health-promoting recommendations while the purpose of HRA is to quantify the health risk from a change in exposure to a particular hazard.
- HIA uses a broad framework to predict all of the potentially significant health effects that could result from changes in the physical, social, and economic environment. In doing so, HIA includes analysis of impacts on the determinants of health, such as housing, transportation, employment and income, noise, air quality, access to goods and services, access to parks, and social networks. HRAs are typically used to analyze discrete relationships between a single environmental contaminant (e.g., diesel) and a single health outcome (e.g., lung cancer).
- Following the basic pattern of an EIA, HIA starts with an analysis of existing conditions in a community and, in particular, identifies special sub-populations who may be particularly vulnerable, or in which there are significant baseline health inequities. For example, HIA examines existing burdens to EJ communities and assesses impacts cumulatively. HRA does not typically take existing health conditions or disparities into consideration.

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[3] Wernham, A. (2007) Inupiat Health and Proposed Alaskan Oil Development: Results of the First Integrated Health Impact Assessment/ Environmental Impact Statement for Proposed Oil Development on Alaska's North Slope. Ecohealth. No. 4, p. 500.

- HIA uses both quantitative and qualitative/descriptive methods in analysis, while HRA uses modeling to quantify risks. If there is strong evidence of the existence of a hazard but data does not exist to quantify a prediction, HRA will not consider that hazard while HIA will. Currently, sufficient data to conduct HRA exist for only a limited number of health-relevant environmental exposures and conditions. It is important to note that NEPA and CEQA regulations do not require quantitative analysis and that many predictions in EISs and EIRs are descriptive. Indeed, simple descriptions of *possible* causal links between the proposed action and a given outcome may be more legally defensible than quantitative modeling, and can still provide valuable insights into differences between the alternatives and potential mitigation measures.
- The HIA process can be used to engage stakeholders, including community residents, and build consensus, while HRA is typically conducted by expert risk assessors.
- HRAs can be a useful tool to analyze potential impacts, but they do not comply with the form and process required by NEPA as can an integrated HIA/EIA approach (see below).
- HRA is one analytical tool that could be used in the assessment phase of HIA.

Conclusion

Based on our understanding of NEPA, CEQA, HIA, and HRA, it is the opinion of Human Impact Partners that 1) HIA can be used to meet the requirements for a comprehensive health analysis under NEPA and CEQA; and 2) that conducting HRA does not fulfill this requirement; and 3) there are many additional benefits that can be derived from conducting HIA.

If you have any questions or would like to discuss this matter further, please feel free to contact me.

Sincerely,

Jonathan Heller
Executive Director and Co-Founder
Human Impact Partners

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Education

University of California Berkeley, CA
1993 - 1997. Ph.D., Biophysics. Howard Hughes Fellow. Dissertation: "Solid-State Nuclear Magnetic Resonance Studies of Prion Proteins and Peptides." Advisor: Professor David Wemmer; Collaborators: Professors Alexander Pines and Stanley Prusiner. Experience in structural biology, protein chemistry, molecular biology and physical chemistry.

Harvard University Cambridge, MA
1985 - 1989. B.A., *Cum Laude*, Applied Mathematics.

Experience

Human Impact Partners Executive Director & Co-founder
May 2006 – Present. HIP, a non-profit, believes that health should be considered in all decision making. We raise awareness of and collaboratively use innovative data, processes and tools that evaluate health impacts and inequities in order to transform the policies, institutions and places people need to live healthy lives. Through training and mentorship we also build the capacity of impacted communities and their advocates, workers, public agencies, and elected officials to conduct health-based analyses and use them to take action. To pursue this mission, we are applying Health Impact Assessment as our primary approach to identifying and mitigating adverse policy and development impacts on health.

Responsibilities

- Carry out all aspects of Health Impact Assessments (HIAs) including: outreach to communities, working with residents of communities and staff of community organizations, forming stakeholder groups and collaborations, leading/facilitating HIA meetings, collaborating with and informing county health departments and elected officials, screening and scoping projects, research, reporting, evaluation;
- Conduct HIA training and mentoring;
- Strategic planning;
- Grant writing and other fundraising;
- Legislative strategy development;
- Overseeing day-to-day operations of HIP;
- Personnel management.

Accomplishments

- Built relationships and secured funding for carrying out HIAs across California, in other states, and at the federal level;
- Built HIP to a staff of 8 FTEs;
- Completed over 15 HIAs on land use, transportation and other policies;
- Improved health outcomes for several plans and projects and built awareness regarding the connections between health and policy among elected officials and the general public;
- Conducted over 20 HIA trainings and provided technical assistance to over 15 organizations, nation-wide, conducting HIAs.

Predicant Biosciences Vice President, Information and Project Planning
Mar. 2002 – Dec. 2005. Predicant developed a novel platform to transform patient care by providing physicians a clinically reliable method of detecting, diagnosing and monitoring complex disease states through the analysis of protein patterns in blood. We developed an integrated system incorporating proprietary separation, detection and informatics technologies to provide reliable, reproducible and sensitive measurements for protein pattern discovery and clinical assay. I was the first employee at Predicant and participated in founding the company.

Responsibilities
- Provided technical leadership in informatics, pattern recognition, and bioanalytical chemistry as well as overall company leadership (business, IP, cultural, etc.);
- Project planning and management – developed strategy and timelines for research and development towards product introduction;
- Business development – in-licensing, clinical sample acquisition, collaboration with academic labs, and assessment of external technologies and opportunities for partnership;
- Intellectual property – led company's efforts in working with counsel to patent novel technologies;
- Communication and presentation – developed and delivered key presentations to Board of Directors, potential investors, potential corporate partners, and scientific community;
- Management of 11 employees.

Accomplishments
- Built company to ~50 employees (including hiring a CEO); raised ~$37M of funding from 4 top-tier venture capital firms; established cooperative, collaborative company culture;
- Led planning and development of a novel microfluidics-mass spectrometry based diagnostics platform and data analysis methods; set key performance characteristics for components and the platform (e.g. reproducibility, sensitivity) and designed system characterization plan to demonstrate that the platform met specifications;
- Designed studies, acquired samples for and led first clinical studies that led to the discovery of protein biomarkers in prostate cancer and lung cancer;
- Developed corporate strategies (e.g. technology, business, IP, hiring, etc.) and business plan;
- Led in-licensing efforts to allow us freedom-to-operate and to build a competitive advantage;
- Represented company in Congressional hearings.

SurroMed
Oct. 2000 – Mar. 2002. Director, Informatics

Exelixis
Dec. 1999 – Sept. 2000. Research Scientist II
Dec. 1998 – Nov. 1999. Research Scientist I
Sept. 1997 – Nov. 1998. Associate Research Scientist II

Peace Corps, Papua New Guinea Volunteer
1990 – 1992. Taught high school science and mathematics. Chaired science department. Supervised dormitories for 150 boarding students. Raised funds and initiated construction of school water supply. Had chloroquine-resistant malaria twice.

Awards

1993 – 1997. Howard Hughes Medical Institute Predoctoral Fellow
1993. National Science Foundation Fellowship (declined)
1987 and 1989. Harvard College Scholarship

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Minimum Elements and Practice Standards for Health Impact Assessment

North American HIA Practice Standards Working Group

Version 2
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Endorsements

The following HIA practitioners and organizations are committed to utilizing these working practice standards, to the greatest extent possible, in their health impact assessment practice. These organizations are listed below:

Environmental Resources Management
Georgia Health Policy Center
Habitat Health Impact Consulting Corp.
Human Impact Partners
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Introduction

Health Impact Assessment (HIA) is a practice to make visible the interests of public health in decision-making. The International Association of Impact Assessment defines HIA as: *a combination of procedures, methods and tools that systematically judges the potential, and sometimes unintended, effects of a policy, plan, program or project on the health of a population and the distribution of those effects within the population. HIA identifies appropriate actions to manage those effects.* With roots in the practice of Environmental Impact Assessment (EIA), HIA aims to inform the public and decision-makers when decisions about policies, plans, programs, and projects have the potential to significantly impact human health, and to advance the values of democracy, equity, sustainable development, the ethical use of evidence and a comprehensive approach to health.

While available guidance documents for HIA describe the procedural steps and products of each stage of the HIA process, there exists considerable diversity in the practice and products of HIA due to the variety of decisions assessed, diverse practice settings, and the nascent evolution of the field. This document, a collective product of a HIA practitioners' workgroup in North America, intends to translate the values underlying HIA along with key lessons from HIA practice into specific "standards for practice" for each phase of the HIA process. Participants at the first *North American Conference on Health Impact Assessment* held in Oakland, California in September 2008 identified the development of standards as a priority need for the field. Subsequent to the 2008 conference, participants collectively developed the first version of these practice standards. This document reflects the second version of those standards, and has been revised to include a set of "minimum elements" of HIA practice.

In this document, *Minimum Elements* answer the question of "what essential elements constitute an HIA"; this is distinct from *Practice Standards*, which answer the question, "how to best conduct an HIA."

Minimum Elements can serve as a basis to identify and promulgate examples of HIA within the field of practice and in broader social discourse, distinguishing HIA from other practices and methods that also aim to ensure the consideration of and action on health interests in public policy. These *Minimum Elements* apply to HIA whether conducted independently or integrated within an environmental, social or strategic impact assessment.

The *Practice Standards* are not rigid criteria for acceptability but rather guidance for effective practice. A practitioner may use the *Practice Standards* as benchmarks for their own HIA practice, to stimulate discussion about HIA content and quality, and to evaluate this emerging field.

These standards are intended support the development and institutionalization of HIA, and are aligned with the central concepts and suggested approaches described in the World Health Organization's 1999 Gothenburg Consensus Paper on HIA, a guiding document in the HIA field. The members of the North American HIA Practice Standards Working Group recognize that real-world constraints and varying levels of capacity and experience will result in appropriate and ongoing diversity of HIA practice. Every practice standard in this document may not be achieved in every example of HIA. Overall, we hope that these standards will be viewed as relevant, instructive and motivating for advancing HIA quality.

Minimum Elements of HIA

A health impact assessment (HIA) must include the following minimum elements, which together distinguish HIA from other processes. An HIA:

1. Is initiated to inform a decision-making process, and conducted in advance of a policy, plan, program, or project decision;
2. Utilizes a systematic analytic process with the following characteristics:
    - 2.1. Includes a scoping phase that comprehensively considers potential impacts on health outcomes as well as on social, environmental, and economic health determinants, and selects potentially significant issues for impact analysis;
    - 2.2. Solicits and utilizes input from stakeholders;
    - 2.3. Establishes baseline conditions for health, describing health outcomes, health determinants, affected populations, and vulnerable sub-populations;
    - 2.4. Uses the best available evidence to judge the magnitude, likelihood, distribution, and permanence of potential impacts on human health or health determinants;
    - 2.5. Rests conclusions and recommendations on a transparent and context-specific synthesis of evidence, acknowledging sources of data, methodological assumptions, strengths and limitations of evidence and uncertainties;
3. Identifies appropriate recommendations, mitigations and/or design alternatives to protect and promote health;
4. Proposes a monitoring plan for tracking the decision's implementation on health impacts/determinants of concern;
5. Includes transparent, publicly-accessible documentation of the process, methods, findings, sponsors, funding sources, participants and their respective roles.

HIA Practice Standards

Adherence to the following standards is recommended to advance effective HIA practice:

1. **General standards for the HIA process**
    1.1. An HIA should include, at a minimum, the stages of **screening, scoping, assessment, recommendations,** and **reporting** described below.

    1.2. **Monitoring** is an important follow-up activity in the HIA process. The HIA should include a follow-up monitoring plan to track the outcomes of a decision and its implementation.

    1.3. **Evaluation** of the HIA process and impacts is necessary for field development and practice improvement. Each HIA process should begin with explicit, written goals that can be evaluated as to their success at the end of the process.

    1.4. HIA should respect the needs and timing of the decision-making process it evaluates.

    1.5. HIA requires integration of knowledge from many disciplines; the practitioner or practitioner team must take reasonable and available steps to identify, solicit and utilize the expertise, including from the community, needed to both identify and answer questions about potentially significant health impacts.

    1.6. Meaningful and inclusive stakeholder participation (e.g., community, public agency, decision-maker) in each stage of the HIA supports HIA quality and effectiveness. Each HIA should have a specific engagement and participation approach that utilizes available participatory or deliberative methods suitable to the needs of stakeholders and context.

    1.7. HIA is a forward looking activity intended to inform an anticipated decision; however, HIA may appropriately conduct or utilize analysis, or evaluate an existing policy, project or plan to prospectively inform a contemporary decision or discussion.

    1.8. Where integrated impact assessment is required and conducted, and requirements for impact assessment include responsibility to analyze health impacts, HIA should be part of an integrated impact assessment process to advance efficiency, to allow for inter-disciplinary analysis and to maximize the potential for advancing health promoting mitigations or improvements.

    1.9. HIA integrated within another impact assessment process should adhere to these practice standards to the greatest extent possible.

2. **Standards for the screening stage**
    2.1. Screening should clearly identify all the decision alternatives under consideration by decision-makers at the time the HIA is considered.

    2.2. Screening should determine whether an HIA would add value to the decision-making process. The following factors may be among those weighed in the screening process:

        2.2.1. The potential for the decision to result in substantial effects on public health, particularly those effects which are avoidable, involuntary, adverse, irreversible or catastrophic

        2.2.2. The potential for unequally distributed impacts

        2.2.3. Stakeholder and decision-maker concerns about a decision's health effects

        2.2.4. The potential for the HIA to result in timely changes to a policy plan, policy or program

        2.2.5. The availability of data, methods, resources and technical capacity to conduct analyses

2.2.6. The availability, application, and effectiveness of alternative opportunities or approaches to evaluate and communicate the decision's potential health impacts

2.3. Sponsors of the HIA should document the explicit goals of the HIA and should notify, to the extent feasible, decision-makers, identified stakeholders, affected individuals and organizations, and responsible public agencies on their decision to conduct an HIA.

3. Standards for the scoping phase

3.1. Scoping of health issues and public concerns related to the decision should include identification of: 1) the decision and decision alternatives that will be studied; 2) potential significant health impacts and their pathways (e.g., a logic model); 3) research questions for impact analysis; 4) demographic, geographical and temporal boundaries for impact analysis; 5) evidence sources and research methods expected for each research question in impacts analysis; 6) the identity of vulnerable subgroups of the affected population; 7) an approach to the evaluation of the distribution of impacts; 8) roles for experts and key informants; 9) the standards or process, if any, that will be used for determining the significance of health impacts; 10) a plan for external and public review; and 11) a plan for dissemination of findings and recommendations.

3.2. The scoping process should establish the individual or team responsible for conducting the HIA and should define their roles.

3.3. Scoping should include consideration of all potential pathways that could reasonably link the decision and/or proposed activity to health, whether direct, indirect, or cumulative.

3.4. The consideration of potential pathways should be informed by the expertise and experience of assessors as well as perspectives of the affected communities, health officials and decision-makers. The assessment team should solicit input from public health officials and local medical practitioners to ensure adequate representation by the entities responsible for and knowledgeable about health conditions. The assessment team should solicit input from members of affected communities or representative organizations via public meetings, written comments, or interviews to understand their views and concerns. The assessment team should solicit input from decision-makers to understand their views on the decision's relationship to health.

3.5. The final scope should focus on those impacts with the greatest potential significance, with regards to factors including but not limited to magnitude, certainty, permanence, stakeholder priorities, and equity.

3.6. The scope should include an approach to evaluate any potential inequities in impacts based on population characteristics, including but not limited to age, gender, income, place (disadvantaged locations), and race or ethnicity.

3.7. The HIA scoping process should identify a mechanism to incorporate new, relevant information and evidence into the scope as it becomes available, including through expert or stakeholder feedback.

4. Standards for the assessment phase

4.1. Assessment should include, at a minimum, a baseline conditions analysis and qualified judgments of potential health impacts:

4.1.1. Documentation of baseline conditions should include the documentation of both population health vulnerabilities (based on the population characteristics described above) and inequalities in health outcomes among subpopulations or places.

4.1.2. Evaluation of potential health impacts should be based on a synthesis of the best available evidence, as qualified below.

4.1.3. To support determinations of impact significance, the HIA should characterize health impacts according to characteristics such as direction, magnitude, likelihood, distribution within the population, and permanence.

4.2. Judgments of health impacts should be based on a synthesis of the best available evidence. This means:

4.2.1. Evidence considered may include existing data, empirical research, professional expertise and local knowledge, and the products of original investigations.

4.2.2. When available, practitioners should utilize evidence from well-designed and peer-reviewed systematic reviews.

4.2.3. HIA practitioners should consider published evidence, both supporting and refuting particular health impacts.

4.2.4. The expertise and experience of affected members of the public (local knowledge), whether obtained via the use of participatory methods, collected via formal qualitative research methods, or reflected in public testimony, is potential evidence.

4.2.5. Justification for the selection or exclusion of particular methodologies and data sources should be made explicit (e.g., resource constraints).

4.2.6. The HIA should acknowledge when available methods were not utilized and why (e.g., resource constraints).

4.3. Impact analysis should explicitly acknowledge methodological assumptions as well as the strengths and limitations of all data and methods used.

4.3.1. The HIA should identify data gaps that prevent an adequate or complete assessment of potential impacts.

4.3.2. Assessors should describe the uncertainty in predictions.

4.3.3. Assumptions or inferences made in the context of modeling or predictions should be made explicit.

4.4. The lack of formal, scientific, quantitative or published evidence should not preclude reasoned predictions of health impacts.

5. Standards for the recommendations phase

5.1. The HIA should include specific recommendations to manage the health impacts identified, including alternatives to the decision, modifications to the proposed policy, program, or project, or mitigation measures.

5.2. Where needed, expert guidance should be utilized to ensure recommendations reflect current effective practices.

5.3. The following criteria may be considered in developing recommendations and mitigation measures: responsiveness to predicted impacts; specificity; technical feasibility; enforceability; and authority of decision-makers.

5.4. Recommendations may include those for monitoring, reassessment, and adaptations to help manage uncertainty in impact assessment.

6. Standards for the reporting phase

6.1. The responsible parties should complete a report of the HIA findings and recommendations.

6.2. To support effective, inclusive communication of the principal HIA findings and recommendations, a succinct summary should be created that communicates findings in a way that allows all stakeholders to understand, evaluate, and respond to the findings.

6.3. The full HIA report should document the screening and scoping processes and identify the sponsor of the HIA and the funding source, the team conducting the HIA, and all other participants in the HIA and their roles and contributions. Any potential conflicts of interest should be acknowledged.

6.4. The full HIA report should, for each specific health issue analyzed, discuss the available scientific evidence, describe the data sources and analytic methods used for the HIA including their rationale, profile existing conditions, detail the analytic results, characterize the health impacts and their significance, list corresponding recommendations for policy, program, or project alternatives, design or mitigations, and describe the limitations of the HIA.

6.5. Recommendations for decision alternatives, policy recommendations, or mitigations should be specific and justified. The criteria used for prioritization of recommendations should be explicitly stated and based on scientific evidence and, ideally, informed by an inclusive process that accounts for stakeholder values.

6.6. Distribute HIA and/or findings to stakeholders that were involved in the HIA. The HIA reporting process should offer stakeholders and decision-makers a meaningful opportunity to critically review evidence, methods, findings, conclusions, and recommendations. Ideally, a draft report should be made available and readily accessible for public review and comment. The HIA practitioners should address substantive criticisms either through a formal written response or HIA report revisions before finalizing the HIA report.

6.7. The final HIA report should be made publicly accessible.

7. Standards for the monitoring phase

7.1. The HIA should include a follow-up monitoring plan to track the decision outcomes as well as the effect of the decision on health impacts and/or determinants of concern.

7.2. The monitoring plan should include: 1) goals for short- and long-term monitoring; 2) outcomes and indicators for monitoring; 3) lead individuals or organizations to conduct monitoring; 4) a mechanism to report monitoring outcomes to decision-makers and HIA stakeholders; 5) triggers or thresholds that may lead to review and adaptation in decision implementation; and 6) identified resources to conduct, complete, and report the monitoring.

7.3. Where possible, recommended mitigations should be further developed and integrated into an HIA (or other) management plan, which clearly outlines how each mitigation measure will be implemented. Management plans commonly include information on: deadlines, responsibilities, management structure, potential partnerships, engagement activities and monitoring and evaluation related to the implementation of the HIA mitigations. For greater effectiveness, HIA management plans should be developed in collaboration with, or at least with the input from, the entity responsible for implementing the plan. Management plans are living documents that will need to be revised and improved on an on-going basis.

7.4. When monitoring is conducted, methods and results from monitoring should be made available to the public.

Coalition For A Safe Environment

Public Health Impact Studies Index

(1.15.2011)

APPENDIX A:

Appendix A-1:	**Respiratory and Children's Health Study**
Appendix A-2:	**Traffic Proximity**
Appendix A-3:	**Particulate Matter**
Appendix A-4:	**Cardiovascular and Neurologic**
Appendix A-5:	**Reproductive and Developmental**
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Appendix A-7:	**Noise**
Appendix A-8:	**Petroleum Industry**
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Note:
1. Primary Public Health Studies Research Conducted By: USC Southern California Environmental Health Sciences Center - Children's Environmental Health Center
2. Petroleum Industry & light Pollution Public Health Studies Research Conducted By: Coalition For A Safe Environment
3. List is periodically updated by the Coalition For A Safe Environment

Appendix A-1: Respiratory and Children's Health Study

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GUIDELINES FOR COMMUNITY NOISE

Edited by

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This WHO document on the *Guidelines for Community Noise* is the outcome of the WHO-expert task force meeting held in London, United Kingdom, in April 1999. It bases on the document entitled "Community Noise" that was prepared for the World Health Organization and published in 1995 by the Stockholm University and Karolinska Institute.

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Department for Protection of the Human Environment (PHE)
Occupational and Environmental Health (OEH)

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Foreword

Noise has always been an important environmental problem for man. In ancient Rome, rules existed as to the noise emitted from the ironed wheels of wagons which battered the stones on the pavement, causing disruption of sleep and annoyance to the Romans. In Medieval Europe, horse carriages and horse back riding were not allowed during night time in certain cities to ensure a peaceful sleep for the inhabitants. However, the noise problems of the past are incomparable with those of modern society. An immense number of cars regularly cross our cities and the countryside. There are heavily laden lorries with diesel engines, badly silenced both for engine and exhaust noise, in cities and on highways day and night. Aircraft and trains add to the environmental noise scenario. In industry, machinery emits high noise levels and amusement centres and pleasure vehicles distract leisure time relaxation.

In comparison to other pollutants, the control of environmental noise has been hampered by insufficient knowledge of its effects on humans and of dose-response relationships as well as a lack of defined criteria. While it has been suggested that noise pollution is primarily a "luxury" problem for developed countries, one cannot ignore that the exposure is often higher in developing countries, due to bad planning and poor construction of buildings. The effects of the noise are just as widespread and the long term consequences for health are the same. In this perspective, practical action to limit and control the exposure to environmental noise are essential. Such action must be based upon proper scientific evaluation of available data on effects, and particularly dose-response relationships. The basis for this is the process of risk assessment and risk management.

The extent of the noise problem is large. In the European Union countries about 40 % of the population are exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB(A) daytime and 20 % are exposed to levels exceeding 65 dB(A). Taking all exposure to transportation noise together about half of the European Union citizens are estimated to live in zones which do not ensure acoustical comfort to residents. More than 30 % are exposed at night to equivalent sound pressure levels exceeding 55 dB(A) which are disturbing to sleep. The noise pollution problem is also severe in cities of developing countries and caused mainly by traffic. Data collected alongside densely travelled roads were found to have equivalent sound pressure levels for 24 hours of 75 to 80 dB(A).

The scope of WHO's effort to derive guidelines for community noise is to consolidate actual scientific knowledge on the health impacts of community noise and to provide guidance to environmental health authorities and professional trying to protect people from the harmful effects of noise in non-industrial environments. Guidance on the health effects of noise exposure of the population has already been given in an early publication of the series of Environmental Health Criteria. The health risk to humans from exposure to environmental noise was evaluated and guidelines values derived. The issue of noise control and health protection was briefly addressed.

At a WHO/EURO Task Force Meeting in Düsseldorf, Germany, in 1992, the health criteria and guideline values were revised and it was agreed upon updated guidelines in consensus. The essentials of the deliberations of the Task Force were published by Stockholm University and

Karolinska Institute in 1995. In an recent Expert Task Force Meeting convened in April 1999 in London, United Kingdom, the Guidelines for Community Noise were extended to provide global coverage and applicability, and the issues of noise assessment and control were addressed in more detail. This document is the outcome of the consensus deliberations of the WHO Expert Task Force.

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Preface

Community noise (also called environmental noise, residential noise or domestic noise) is defined as noise emitted from all sources except noise at the industrial workplace. Main sources of community noise include road, rail and air traffic, industries, construction and public work, and the neighbourhood. The main indoor sources of noise are ventilation systems, office machines, home appliances and neighbours. Typical neighbourhood noise comes from premises and installations related to the catering trade (restaurant, cafeterias, discotheques, etc.); from live or recorded music; sport events including motor sports; playgrounds; car parks; and domestic animals such as barking dogs. Many countries have regulated community noise from road and rail traffic, construction machines and industrial plants by applying emission standards, and by regulating the acoustical properties of buildings. In contrast, few countries have regulations on community noise from the neighbourhood, probably due to the lack of methods to define and measure it, and to the difficulty of controlling it. In large cities throughout the world, the general population is increasingly exposed to community due to the sources mentioned above and the health effects of these exposures are considered to be a more and more important public health problem. Specific effects to be considered when setting community noise guidelines include: interference with communication; noise-induced hearing loss; sleep disturbance effects; cardiovascular and psycho-physiological effects; performance reduction effects; annoyance responses; and effects on social behaviour.

Since 1980, the World Health Organization (WHO) has addressed the problem of community noise. Health-based guidelines on community noise can serve as the basis for deriving noise standards within a framework of noise management. Key issues of noise management include abatement options; models for forecasting and for assessing source control action; setting noise emission standards for existing and planned sources; noise exposure assessment; and testing the compliance of noise exposure with noise immission standards. In 1992, the WHO Regional Office for Europe convened a task force meeting which set up guidelines for community noise. A preliminary publication of the Karolinska Institute, Stockholm, on behalf of WHO, appeared in 1995. This publication served as the basis for the globally applicable *Guidelines for Community Noise* presented in this document. An expert task force meeting was convened by WHO in March 1999 in London, United Kingdom, to finalize the guidelines.

The *Guidelines for Community Noise* have been prepared as a practical response to the need for action on community noise at the local level, as well as the need for improved legislation, management and guidance at the national and regional levels. WHO will be pleased to see that these guidelines are used widely. Continuing efforts will be made to improve its content and structure. It would be appreciated if the users of the *Guidelines* provide feedback from its use and their own experiences. Please send your comments and suggestions on the WHO *Guidelines for Community Noise – Guideline document* to the Department of the Protection of the Human Environment, Occupational and Environmental Health, World Health Organization, Geneva, Switzerland (Fax: +41 22-791 4123, e-mail: schwelad@who.int).

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Executive Summary

1. Introduction

Community noise (also called environmental noise, residential noise or domestic noise) is defined as noise emitted from all sources except noise at the industrial workplace. Main sources of community noise include road, rail and air traffic; industries; construction and public work; and the neighbourhood. The main indoor noise sources are ventilation systems, office machines, home appliances and neighbours.

In the European Union about 40% of the population is exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB(A) daytime, and 20% are exposed to levels exceeding 65 dB(A). When all transportation noise is considered, more than half of all European Union citizens is estimated to live in zones that do not ensure acoustical comfort to residents. At night, more than 30% are exposed to equivalent sound pressure levels exceeding 55 dB(A), which are disturbing to sleep. Noise pollution is also severe in cities of developing countries. It is caused mainly by traffic and alongside densely-travelled roads equivalent sound pressure levels for 24 hours can reach 75–80 dB(A).

In contrast to many other environmental problems, noise pollution continues to grow and it is accompanied by an increasing number of complaints from people exposed to the noise. The growth in noise pollution is unsustainable because it involves direct, as well as cumulative, adverse health effects. It also adversely affects future generations, and has socio-cultural, esthetic and economic effects.

2. Noise sources and measurement

Physically, there is no distinction between sound and noise. Sound is a sensory perception and the complex pattern of sound waves is labeled noise, music, speech etc. Noise is thus defined as unwanted sound.

Most environmental noises can be approximately described by several simple measures. All measures consider the frequency content of the sounds, the overall sound pressure levels and the variation of these levels with time. Sound pressure is a basic measure of the vibrations of air that make up sound. Because the range of sound pressures that human listeners can detect is very wide, these levels are measured on a logarithmic scale with units of decibels. Consequently, sound pressure levels cannot be added or averaged arithmetically. Also, the sound levels of most noises vary with time, and when sound pressure levels are calculated, the instantaneous pressure fluctuations must be integrated over some time interval.

Most environmental sounds are made up of a complex mix of many different frequencies. Frequency refers to the number of vibrations per second of the air in which the sound is propagating and it is measured in Hertz (Hz). The audible frequency range is normally considered to be 20–20 000 Hz for younger listeners with unimpaired hearing. However, our hearing systems are not equally sensitive to all sound frequencies, and to compensate for this various types of filters or frequency weighting have been used to determine the relative strengths of frequency components making up a particular environmental noise. The A-weighting is most commonly used and weights lower frequencies as less important than mid- and higher-frequencies. It is intended to approximate the frequency response of our hearing system.

The effect of a combination of noise events is related to the combined sound energy of those events (the equal energy principle). The sum of the total energy over some time period gives a level equivalent to the average sound energy over that period. Thus, LAeq,T is the energy average equivalent level of the A-weighted sound over a period T. LAeq,T should be used to measure continuing sounds, such as road traffic noise or types of more-or-less continuous industrial noises. However, when there are distinct events to the noise, as with aircraft or railway noise, measures of individual events such as the maximum noise level (LAmax), or the weighted sound exposure level (SEL), should also be obtained in addition to LAeq,T. Time-varying environmental sound levels have also been described in terms of percentile levels.

Currently, the recommended practice is to assume that the equal energy principle is approximately valid for most types of noise and that a simple LAeq,T measure will indicate the expected effects of the noise reasonably well. When the noise consists of a small number of discrete events, the A-weighted maximum level (LAmax) is a better indicator of the disturbance to sleep and other activities. In most cases, however, the A-weighted sound exposure level (SEL) provides a more consistent measure of single-noise events because it is based on integration over the complete noise event. In combining day and night LAeq,T values, night-time weightings are often added. Night-time weightings are intended to reflect the expected increased sensitivity to annoyance at night, but they do not protect people from sleep disturbance.

Where there are no clear reasons for using other measures, it is recommended that LAeq,T be used to evaluate more-or-less continuous environmental noises. Where the noise is principally composed of a small number of discrete events, the additional use of LAmax or SEL is recommended. There are definite limitations to these simple measures, but there are also many practical advantages, including economy and the benefits of a standardized approach.

3. Adverse health effects of noise

The health significance of noise pollution is given in chapter 3 of the *Guidelines* under separate headings according to the specific effects: noise-induced hearing impairment; interference with speech communication; disturbance of rest and sleep; psychophysiological, mental-health and performance effects; effects on residential behaviour and annoyance; and interference with intended activities. This chapter also considers vulnerable groups and the combined effects of mixed noise sources.

Hearing impairment is typically defined as an increase in the threshold of hearing. Hearing deficits may be accompanied by tinnitus (ringing in the ears). Noise-induced hearing impairment occurs predominantly in the higher frequency range of 3 000–6 000 Hz, with the largest effect at 4 000 Hz. But with increasing LAeq,8h and increasing exposure time, noise-induced hearing impairment occurs even at frequencies as low as 2 000 Hz. However, hearing impairment is not expected to occur at LAeq,8h levels of 75 dB(A) or below, even for prolonged occupational noise exposure.

Worldwide, noise-induced hearing impairment is the most prevalent irreversible occupational hazard and it is estimated that 120 million people worldwide have disabling hearing difficulties.

In developing countries, not only occupational noise but also environmental noise is an increasing risk factor for hearing impairment. Hearing damage can also be caused by certain diseases, some industrial chemicals, ototoxic drugs, blows to the head, accidents and hereditary origins. Hearing deterioration is also associated with the ageing process itself (presbyacusis).

The extent of hearing impairment in populations exposed to occupational noise depends on the value of LAeq,8h, the number of noise-exposed years, and on individual susceptibility. Men and women are equally at risk for noise-induced hearing impairment. It is expected that environmental and leisure-time noise with a LAeq,24h of 70 dB(A) or below will not cause hearing impairment in the large majority of people, even after a lifetime exposure. For adults exposed to impulse noise at the workplace, the noise limit is set at peak sound pressure levels of 140 dB, and the same limit is assumed to be appropriate for environmental and leisure-time noise. In the case of children, however, taking into account their habits while playing with noisy toys, the peak sound pressure should never exceed 120 dB. For shooting noise with LAeq,24h levels greater than 80 dB(A), there may be an increased risk for noise-induced hearing impairment.

The main social consequence of hearing impairment is the inability to understand speech in daily living conditions, and this is considered to be a severe social handicap. Even small values of hearing impairment (10 dB averaged over 2 000 and 4 000 Hz and over both ears) may adversely affect speech comprehension.

Speech intelligibility is adversely affected by noise. Most of the acoustical energy of speech is in the frequency range of 100–6 000 Hz, with the most important cue-bearing energy being between 300–3 000 Hz. Speech interference is basically a masking process, in which simultaneous interfering noise renders speech incapable of being understood. Environmental noise may also mask other acoustical signals that are important for daily life, such as door bells, telephone signals, alarm clocks, fire alarms and other warning signals, and music.

Speech intelligibility in everyday living conditions is influenced by speech level; speech pronunciation; talker-to-listener distance; sound level and other characteristics of the interfering noise; hearing acuity; and by the level of attention. Indoors, speech communication is also affected by the reverberation characteristics of the room. Reverberation times over 1 s produce loss in speech discrimination and make speech perception more difficult and straining. For full sentence intelligibility in listeners with normal hearing, the signal-to-noise ratio (i.e. the difference between the speech level and the sound level of the interfering noise) should be at least 15 dB(A). Since the sound pressure level of normal speech is about 50 dB(A), noise with sound levels of 35 dB(A) or more interferes with the intelligibility of speech in smaller rooms. For vulnerable groups even lower background levels are needed, and a reverberation time below 0.6 s is desirable for adequate speech intelligibility, even in a quiet environment.

The inability to understand speech results in a large number of personal handicaps and behavioural changes. Particularly vulnerable are the hearing impaired, the elderly, children in the process of language and reading acquisition, and individuals who are not familiar with the spoken language.

Sleep disturbance is a major effect of environmental noise. It may cause primary effects during sleep, and secondary effects that can be assessed the day after night-time noise exposure. Uninterrupted sleep is a prerequisite for good physiological and mental functioning, and the primary effects of sleep disturbance are: difficulty in falling asleep; awakenings and alterations of sleep stages or depth; increased blood pressure, heart rate and finger pulse amplitude; vasoconstriction; changes in respiration; cardiac arrhythmia; and increased body movements. The difference between the sound levels of a noise event and background sound levels, rather than the absolute noise level, may determine the reaction probability. The probability of being awakened increases with the number of noise events per night. The secondary, or after-effects, the following morning or day(s) are: reduced perceived sleep quality; increased fatigue; depressed mood or well-being; and decreased performance.

For a good night's sleep, the equivalent sound level should not exceed 30 dB(A) for continuous background noise, and individual noise events exceeding 45 dB(A) should be avoided. In setting limits for single night-time noise exposures, the intermittent character of the noise has to be taken into account. This can be achieved, for example, by measuring the number of noise events, as well as the difference between the maximum sound level and the background sound level. Special attention should also be given to: noise sources in an environment with low background sound levels; combinations of noise and vibrations; and to noise sources with low-frequency components.

Physiological Functions. In workers exposed to noise, and in people living near airports, industries and noisy streets, noise exposure may have a large temporary, as well as permanent, impact on physiological functions. After prolonged exposure, susceptible individuals in the general population may develop permanent effects, such as hypertension and ischaemic heart disease associated with exposure to high sound levels. The magnitude and duration of the effects are determined in part by individual characteristics, lifestyle behaviours and environmental conditions. Sounds also evoke reflex responses, particularly when they are unfamiliar and have a sudden onset.

Workers exposed to high levels of industrial noise for 5–30 years may show increased blood pressure and an increased risk for hypertension. Cardiovascular effects have also been demonstrated after long-term exposure to air- and road-traffic with $L_{Aeq,24h}$ values of 65–70 dB(A). Although the associations are weak, the effect is somewhat stronger for ischaemic heart disease than for hypertension. Still, these small risk increments are important because a large number of people are exposed.

Mental Illness. Environmental noise is not believed to cause mental illness directly, but it is assumed that it can accelerate and intensify the development of latent mental disorders. Exposure to high levels of occupational noise has been associated with development of neurosis, but the findings on environmental noise and mental-health effects are inconclusive. Nevertheless, studies on the use of drugs such as tranquillizers and sleeping pills, on psychiatric symptoms and on mental hospital admission rates, suggest that community noise may have adverse effects on mental health.

Performance. It has been shown, mainly in workers and children, that noise can adversely affect performance of cognitive tasks. Although noise-induced arousal may produce better performance in simple tasks in the short term, cognitive performance substantially deteriorates for more complex tasks. Reading, attention, problem solving and memorization are among the cognitive effects most strongly affected by noise. Noise can also act as a distracting stimulus and impulsive noise events may produce disruptive effects as a result of startle responses.

Noise exposure may also produce after-effects that negatively affect performance. In schools around airports, children chronically exposed to aircraft noise under-perform in proof reading, in persistence on challenging puzzles, in tests of reading acquisition and in motivational capabilities. It is crucial to recognize that some of the adaptation strategies to aircraft noise, and the effort necessary to maintain task performance, come at a price. Children from noisier areas have heightened sympathetic arousal, as indicated by increased stress hormone levels, and elevated resting blood pressure. Noise may also produce impairments and increase in errors at work, and some accidents may be an indicator of performance deficits.

Social and Behavioural Effects of Noise; Annoyance. Noise can produce a number of social and behavioural effects as well as annoyance. These effects are often complex, subtle and indirect and many effects are assumed to result from the interaction of a number of non-auditory variables. The effect of community noise on annoyance can be evaluated by questionnaires or by assessing the disturbance of specific activities. However, it should be recognized that equal levels of different traffic and industrial noises cause different magnitudes of annoyance. This is because annoyance in populations varies not only with the characteristics of the noise, including the noise source, but also depends to a large degree on many non-acoustical factors of a social, psychological, or economic nature. The correlation between noise exposure and general annoyance is much higher at group level than at individual level. Noise above 80 dB(A) may also reduce helping behaviour and increase aggressive behaviour. There is particular concern that high-level continuous noise exposures may increase the susceptibility of schoolchildren to feelings of helplessness.

Stronger reactions have been observed when noise is accompanied by vibrations and contains low-frequency components, or when the noise contains impulses, such as with shooting noise. Temporary, stronger reactions occur when the noise exposure increases over time, compared to a constant noise exposure. In most cases, LAeq,24h and L_{dn} are acceptable approximations of noise exposure related to annoyance. However, there is growing concern that all the component parameters should be individually assessed in noise exposure investigations, at least in the complex cases. There is no consensus on a model for total annoyance due to a combination of environmental noise sources.

Combined Effects on Health of Noise from Mixed Sources. Many acoustical environments consist of sounds from more than one source, i.e. there are mixed sources, and some combinations of effects are common. For example, noise may interfere with speech in the day and create sleep disturbance at night. These conditions certainly apply to residential areas heavily polluted with noise. Therefore, it is important that the total adverse health load of noise be considered over 24 hours, and that the precautionary principle for sustainable development be applied.

Vulnerable Subgroups. Vulnerable subgroups of the general population should be considered when recommending noise protection or noise regulations. The types of noise effects, specific environments and specific lifestyles are all factors that should be addressed for these subgroups. Examples of vulnerable subgroups are: people with particular diseases or medical problems (e.g. high blood pressure); people in hospitals or rehabilitating at home; people dealing with complex cognitive tasks; the blind; people with hearing impairment; fetuses, babies and young children; and the elderly in general. People with impaired hearing are the most adversely affected with respect to speech intelligibility. Even slight hearing impairments in the high-frequency sound range may cause problems with speech perception in a noisy environment. A majority of the population belongs to the subgroup that is vulnerable to speech interference.

4. Guideline values

In chapter 4, guideline values are given for specific health effects of noise and for specific environments.

Specific health effects.

Interference with Speech Perception. A majority of the population is susceptible to speech interference by noise and belongs to a vulnerable subgroup. Most sensitive are the elderly and persons with impaired hearing. Even slight hearing impairments in the high-frequency range may cause problems with speech perception in a noisy environment. From about 40 years of age, the ability of people to interpret difficult, spoken messages with low linguistic redundancy is impaired compared to people 20–30 years old. It has also been shown that high noise levels and long reverberation times have more adverse effects in children, who have not completed language acquisition, than in young adults.

When listening to complicated messages (at school, foreign languages, telephone conversation) the signal-to-noise ratio should be at least 15 dB with a voice level of 50 dB(A). This sound level corresponds on average to a casual voice level in both women and men at 1 m distance. Consequently, for clear speech perception the background noise level should not exceed 35 dB(A). In classrooms or conference rooms, where speech perception is of paramount importance, or for sensitive groups, background noise levels should be as low as possible. Reverberation times below 1 s are also necessary for good speech intelligibility in smaller rooms. For sensitive groups, such as the elderly, a reverberation time below 0.6 s is desirable for adequate speech intelligibility even in a quiet environment.

Hearing Impairment. Noise that gives rise to hearing impairment is by no means restricted to occupational situations. High noise levels can also occur in open air concerts, discotheques, motor sports, shooting ranges, in dwellings from loudspeakers, or from leisure activities. Other important sources of loud noise are headphones, as well as toys and fireworks which can emit impulse noise. The ISO standard 1999 gives a method for estimating noise-induced hearing impairment in populations exposed to all types of noise (continuous, intermittent, impulse) during working hours. However, the evidence strongly suggests that this method should also be used to calculate hearing impairment due to noise exposure from environmental and leisure time activities. The ISO standard 1999 implies that long-term exposure to LAeq,24h noise levels of up to 70 dB(A) will not result in hearing impairment. To avoid hearing loss from impulse noise exposure, peak sound pressures should never exceed 140 dB for adults, and 120 dB for children.

Sleep Disturbance. Measurable effects of noise on sleep begin at LAeq levels of about 30 dB. However, the more intense the background noise, the more disturbing is its effect on sleep. Sensitive groups mainly include the elderly, shift workers, people with physical or mental disorders and other individuals who have difficulty sleeping.

Sleep disturbance from intermittent noise events increases with the maximum noise level. Even if the total equivalent noise level is fairly low, a small number of noise events with a high maximum sound pressure level will affect sleep. Therefore, to avoid sleep disturbance, guidelines for community noise should be expressed in terms of the equivalent sound level of the noise, as well as in terms of maximum noise levels and the number of noise events. It should be noted that low-frequency noise, for example, from ventilation systems, can disturb rest and sleep even at low sound pressure levels.

When noise is continuous, the equivalent sound pressure level should not exceed 30 dB(A) indoors, if negative effects on sleep are to be avoided. For noise with a large proportion of low-frequency sound a still lower guideline value is recommended. When the background noise is low, noise exceeding 45 dB LAmax should be limited, if possible, and for sensitive persons an even lower limit is preferred. Noise mitigation targeted to the first part of the night is believed to be an effective means for helping people fall asleep. It should be noted that the adverse effect of noise partly depends on the nature of the source. A special situation is for newborns in incubators, for which the noise can cause sleep disturbance and other health effects.

Reading Acquisition. Chronic exposure to noise during early childhood appears to impair reading acquisition and reduces motivational capabilities. Evidence indicates that the longer the exposure, the greater the damage. Of recent concern are the concomitant psychophysiological changes (blood pressure and stress hormone levels). There is insufficient information on these effects to set specific guideline values. It is clear, however, that daycare centres and schools should not be located near major noise sources, such as highways, airports, and industrial sites.

Annoyance. The capacity of a noise to induce annoyance depends upon its physical characteristics, including the sound pressure level, spectral characteristics and variations of these properties with time. During daytime, few people are highly annoyed at LAeq levels below 55 dB(A), and few are moderately annoyed at LAeq levels below 50 dB(A). Sound levels during the evening and night should be 5–10 dB lower than during the day. Noise with low-frequency components require lower guideline values. For intermittent noise, it is emphasized that it is necessary to take into account both the maximum sound pressure level and the number of noise events. Guidelines or noise abatement measures should also take into account residential outdoor activities.

Social Behaviour. The effects of environmental noise may be evaluated by assessing its interference with social behavior and other activities. For many community noises, interference with rest/recreation/watching television seem to be the most important effects. There is fairly consistent evidence that noise above 80 dB(A) causes reduced helping behavior, and that loud noise also increases aggressive behavior in individuals predisposed to aggressiveness. In schoolchildren, there is also concern that high levels of chronic noise contribute to feelings of helplessness. Guidelines on this issue, together with cardiovascular and mental effects, must await further research.

Specific environments.

A noise measure based only on energy summation and expressed as the conventional equivalent measure, LAeq, is not enough to characterize most noise environments. It is equally important to measure the maximum values of noise fluctuations, preferably combined with a measure of the number of noise events. If the noise includes a large proportion of low-frequency components, still lower values than the guideline values below will be needed. When prominent low-frequency components are present, noise measures based on A-weighting are inappropriate. The difference between dB(C) and dB(A) will give crude information about the presence of low-frequency components in noise, but if the difference is more than 10 dB, it is recommended that a frequency analysis of the noise be performed. It should be noted that a large proportion of low-frequency components in noise may increase considerably the adverse effects on health.

In Dwellings. The effects of noise in dwellings, typically, are sleep disturbance, annoyance and speech interference. For bedrooms the critical effect is sleep disturbance. Indoor guideline values for bedrooms are 30 dB LAeq for continuous noise and 45 dB LAmax for single sound events. Lower noise levels may be disturbing depending on the nature of the noise source. At night-time, outside sound levels about 1 metre from facades of living spaces should not exceed 45 dB LAeq, so that people may sleep with bedroom windows open. This value was obtained by assuming that the noise reduction from outside to inside with the window open is 15 dB. To enable casual conversation indoors during daytime, the sound level of interfering noise should not exceed 35 dB LAeq. The maximum sound pressure level should be measured with the sound pressure meter set at "Fast".

To protect the majority of people from being seriously annoyed during the daytime, the outdoor sound level from steady, continuous noise should not exceed 55 dB LAeq on balconies, terraces and in outdoor living areas. To protect the majority of people from being moderately annoyed during the daytime, the outdoor sound level should not exceed 50 dB LAeq. Where it is practical and feasible, the lower outdoor sound level should be considered the maximum desirable sound level for new development.

In Schools and Preschools. For schools, the critical effects of noise are speech interference, disturbance of information extraction (e.g. comprehension and reading acquisition), message communication and annoyance. To be able to hear and understand spoken messages in class rooms, the background sound level should not exceed 35 dB LAeq during teaching sessions. For hearing impaired children, a still lower sound level may be needed. The reverberation time in the classroom should be about 0.6 s, and preferably lower for hearing impaired children. For assembly halls and cafeterias in school buildings, the reverberation time should be less than 1 s. For outdoor playgrounds the sound level of the noise from external sources should not exceed 55 dB LAeq, the same value given for outdoor residential areas in daytime.

For preschools, the same critical effects and guideline values apply as for schools. In bedrooms in preschools during sleeping hours, the guideline values for bedrooms in dwellings should be used.

In Hospitals. For most spaces in hospitals, the critical effects are sleep disturbance, annoyance, and communication interference, including warning signals. The LAmax of sound events during the night should not exceed 40 dB(A) indoors. For ward rooms in hospitals, the guideline values indoors are 30dB LAeq, together with 40 dB LAmax during night. During the day and evening the guideline value indoors is 30 dB LAeq. The maximum level should be measured with the sound pressure instrument set at "Fast".

Since patients have less ability to cope with stress, the LAeq level should not exceed 35 dB in most rooms in which patients are being treated or observed. Attention should be given to the sound levels in intensive care units and operating theaters. Sound inside incubators may result in health problems for neonates, including sleep disturbance, and may also lead to hearing impairment. Guideline values for sound levels in incubators must await future research.

Ceremonies, Festivals and Entertainment Events. In many countries, there are regular ceremonies, festivals and entertainment events to celebrate life periods. Such events typically produce loud sounds, including music and impulsive sounds. There is widespread concern about the effect of loud music and impulsive sounds on young people who frequently attend concerts, discotheques, video arcades, cinemas, amusement parks and spectator events. At these events, the sound level typically exceeds 100 dB LAeq. Such noise exposure could lead to significant hearing impairment after frequent attendances.

Noise exposure for employees of these venues should be controlled by established occupational standards; and at the very least, the same standards should apply to the patrons of these premises. Patrons should not be exposed to sound levels greater than 100 dB LAeq during a four-hour period more than four times per year. To avoid acute hearing impairment the LAmax should always be below 110 dB.

Headphones. To avoid hearing impairment from music played back in headphones, in both adults and children, the equivalent sound level over 24 hours should not exceed 70 dB(A). This implies that for a daily one hour exposure the LAeq level should not exceed 85 dB(A). To avoid acute hearing impairment LAmax should always be below 110 dB(A). The exposures are expressed in free-field equivalent sound level.

Toys, Fireworks and Firearms. To avoid acute mechanical damage to the inner ear from impulsive sounds from toys, fireworks and firearms, adults should never be exposed to more than 140 dB(lin) peak sound pressure level. To account for the vulnerability in children when playing, the peak sound pressure produced by toys should not exceed 120 dB(lin), measured close to the ears (100 mm). To avoid acute hearing impairment LAmax should always be below 110 dB(A).

Parkland and Conservation Areas. Existing large quiet outdoor areas should be preserved and the signal-to-noise ratio kept low.

Table 1 presents the WHO guideline values arranged according to specific environments and critical health effects. The guideline values consider all identified adverse health effects for the specific environment. An adverse effect of noise refers to any temporary or long-term impairment of physical, psychological or social functioning that is associated with noise exposure. Specific noise limits have been set for each health effect, using the lowest noise level that produces an adverse health effect (i.e. the critical health effect). Although the guideline values refer to sound levels impacting the most exposed receiver at the listed environments, they are applicable to the general population. The time base for LAeq for "daytime" and "night-time" is 12–16 hours and 8 hours, respectively. No time base is given for evenings, but typically the guideline value should be 5–10 dB lower than in the daytime. Other time bases are recommended for schools, preschools and playgrounds, depending on activity.

It is not enough to characterize the noise environment in terms of noise measures or indices based only on energy summation (e.g., LAeq), because different critical health effects require different descriptions. It is equally important to display the maximum values of the noise fluctuations, preferably combined with a measure of the number of noise events. A separate characterization of night-time noise exposures is also necessary. For indoor environments, reverberation time is also an important factor for things such as speech intelligibility. If the noise includes a large proportion of low-frequency components, still lower guideline values should be applied. Supplementary to the guideline values given in Table 1, precautions should be taken for vulnerable groups and for noise of certain character (e.g. low-frequency components, low background noise).

Table 1: Guideline values for community noise in specific environments.

Specific environment	Critical health effect(s)	L_{Aeq} [dB(A)]	Time base [hours]	L_{Amax} fast [dB]
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50	16 16	- -
Dwelling, indoors Inside bedrooms	Speech intelligibility & moderate annoyance, daytime & evening Sleep disturbance, night-time	35 30	16 8	 45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60
School class rooms & pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35	during class	-
Pre-school bedrooms, indoor	Sleep disturbance	30	sleeping-time	45
School, playground outdoor	Annoyance (external source)	55	during play	-
Hospital, ward rooms, indoors	Sleep disturbance, night-time Sleep disturbance, daytime and evenings	30 30	8 16	40 -
Hospitals, treatment rooms, indoors	Interference with rest and recovery	#1		
Industrial, commercial shopping and traffic areas, indoors and outdoors	Hearing impairment	70	24	110
Ceremonies, festivals and entertainment events	Hearing impairment (patrons:<5 times/year)	100	4	110
Public addresses, indoors and outdoors	Hearing impairment	85	1	110
Music and other sounds through headphones/ earphones	Hearing impairment (free-field value)	85 #4	1	110
Impulse sounds from toys, fireworks and firearms	Hearing impairment (adults) Hearing impairment (children)	- -	- -	140 #2 120 #2
Outdoors in parkland and conservations areas	Disruption of tranquillity	#3		

#1: As low as possible.
#2: Peak sound pressure (not LAF, max) measured 100 mm from the ear.

#3: Existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low.
#4: Under headphones, adapted to free-field values.

5. Noise Management

Chapter 5 is devoted to noise management with discussions on: strategies and priorities in managing indoor noise levels; noise policies and legislation; the impact of environmental noise; and on the enforcement of regulatory standards.

The fundamental goals of noise management are to develop criteria for deriving safe noise exposure levels and to promote noise assessment and control as part of environmental health programmes. These basic goals should guide both international and national policies for noise management. The United Nation's Agenda 21 supports a number of environmental management principles on which government policies, including noise management policies, can be based: the principle of precaution; the "polluter pays" principle; and noise prevention. In all cases, noise should be reduced to the lowest level achievable in the particular situation. When there is a reasonable possibility that the public health will be endangered, even though scientific proof may be lacking, action should be taken to protect the public health, without awaiting the full scientific proof. The full costs associated with noise pollution (including monitoring, management, lowering levels and supervision) should be met by those responsible for the source of noise. Action should be taken where possible to reduce noise at the source.

A legal framework is needed to provide a context for noise management. National noise standards can usually be based on a consideration of international guidelines, such as these *Guidelines for Community Noise*, as well as national criteria documents, which consider dose-response relationships for the effects of noise on human health. National standards take into account the technological, social, economic and political factors within the country. A staged program of noise abatement should also be implemented to achieve the optimum health protection levels over the long term.

Other components of a noise management plan include: noise level monitoring; noise exposure mapping; exposure modeling; noise control approaches (such as mitigation and precautionary measures); and evaluation of control options. Many of the problems associated with high noise levels can be prevented at low cost, if governments develop and implement an integrated strategy for the indoor environment, in concert with all social and economic partners. Governments should establish a "National Plan for a Sustainable Noise Indoor Environment" that applies both to new construction as well as to existing buildings.

The actual priorities in rational noise management will differ for each country. Priority setting in noise management refers to prioritizing the health risks to be avoided and concentrating on the most important sources of noise. Different countries have adopted a range of approaches to noise control, using different policies and regulations. A number of these are outlined in chapter 5 and Appendix 2, as examples. It is evident that noise emission standards have proven insufficient and that the trends in noise pollution are unsustainable.

The concept of environmental an environmental noise impact analysis is central to the philosophy of managing environmental noise. Such an analysis should be required before implementing any project that would significantly increase the level of environmental noise in a community (typically, greater than a 5 dB increase). The analysis should include: a baseline description of the existing noise environment; the expected level of noise from the new source; an assessment of the adverse health effects; an estimation of the population at risk; the calculation of exposure-response relationships; an assessment of risks and their acceptability; and a cost-benefit analysis.

Noise management should:

1. Start monitoring human exposures to noise.
2. Have health control require mitigation of noise immissions, and not just of noise source emissions. The following should be taken into consideration:
   - specific environments such as schools, playgrounds, homes, hospitals.
   - environments with multiple noise sources, or which may amplify the effects of noise.
   - sensitive time periods such as evenings, nights and holidays.
   - groups at high risk, such as children and the hearing impaired.
3. Consider the noise consequences when planning transport systems and land use.
4. Introduce surveillance systems for noise-related adverse health effects.
5. Assess the effectiveness of noise policies in reducing adverse health effects and exposure, and in improving supportive "soundscapes".
6. Adopt these *Guidelines for Community Noise* as intermediary targets for improving human health.
7. Adopt precautionary actions for a sustainable development of the acoustical environments.

Conclusions and recommendations

In chapter 6 are discussed: the implementation of the guidelines; further WHO work on noise; and research needs are recommended.

Implementation. For implementation of the guidelines it is recommended that:

- Governments should protection the population from community noise and consider it an integral part of their policy of environmental protection.
- Governments should consider implementing action plans with short-term, medium-term and long-term objectives for reducing noise levels.
- Governments should adopt the *Health Guidelines for Community Noise* values as targets to be achieved in the long-term.
- Governments should include noise as an important public health issue in environmental impact assessments.
- Legislation should be put in place to allow for the reduction of sound levels.
- Existing legislation should be enforced.
- Municipalities should develop low noise implementation plans.

- Cost-effectiveness and cost-benefit analyses should be considered potential instruments for meaningful management decisions.
- Governments should support more policy-relevant research.

Future Work. The Expert Task Force worked out several suggestions for future work for the WHO in the field of community noise. WHO should:

- Provide leadership and technical direction in defining future noise research priorities.
- Organize workshops on how to apply the guidelines.
- Provide leadership and coordinate international efforts to develop techniques for designing supportive sound environments (e.g. "soundscapes").
- Provide leadership for programs to assess the effectiveness of health-related noise policies and regulations.
- Provide leadership and technical direction for the development of sound methodologies for environmental and health impact plans.
- Encourage further investigation into using noise exposure as an indicator of environmental deterioration (e.g. black spots in cities).
- Provide leadership and technical support, and advise developing countries to facilitate development of noise policies and noise management.

Research and Development. A major step forward in raising the awareness of both the public and of decision makers is the recommendation to concentrate more research and development on variables which have monetary consequences. This means that research should consider not only dose-response relationships between sound levels, but also politically relevant variables, such as noise-induced social handicap; reduced productivity; decreased performance in learning; workplace and school absenteeism; increased drug use; and accidents.

In Appendices 1–6 are given: bibliographic references; examples of regional noise situations (African Region, American Region, Eastern Mediterranean Region, South East Asian Region, Western Pacific Region); a glossary; a list of acronyms; and a list of participants.

1. Introduction

Community noise (also called environmental noise, residential noise or domestic noise) is defined as noise emitted from all sources, except noise at the industrial workplace. Main sources of community noise include road, rail and air traffic, industries, construction and public work, and the neighbourhood. Typical neighbourhood noise comes from premises and installations related to the catering trade (restaurant, cafeterias, discotheques, etc.); from live or recorded music; from sporting events including motor sports; from playgrounds and car parks; and from domestic animals such as barking dogs. The main indoor sources are ventilation systems, office machines, home appliances and neighbours. Although many countries have regulations on community noise from road, rail and air traffic, and from construction and industrial plants, few have regulations on neighbourhood noise. This is probably due to the lack of methods to define and measure it, and to the difficulty of controlling it. In developed countries, too, monitoring of compliance with, and enforcement of, noise regulations are weak for lower levels of urban noise that correspond to occupationally controlled levels (>85 dB LAeq,8h; Frank 1998). Recommended guideline values based on the health effects of noise, other than occupationally-induced effects, are often not taken into account.

The extent of the community noise problem is large. In the European Union about 40% of the population is exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dBA daytime; and 20% is exposed to levels exceeding 65 dBA (Lambert & Vallet 19 1994). When all transportation noise is considered, about half of all European Union citizens live in zones that do not ensure acoustical comfort to residents. At night, it is estimated that more than 30% is exposed to equivalent sound pressure levels exceeding 55 dBA, which are disturbing to sleep. The noise pollution problem is also severe in the cities of developing countries and is caused mainly by traffic. Data collected alongside densely traveled roads were found to have equivalent sound pressure levels for 24 hours of 75–80 dBA (e.g. National Environment Board Thailand 19 1990; Mage & Walsh 19 1998).

(a) In contrast to many other environmental problems, noise pollution continues to grow, accompanied by an increasing number of complaints from affected individuals. Most people are typically exposed to several noise sources, with road traffic noise being a dominant source (OECD-ECMT 19 1995). Population growth, urbanization and to a large extent technological development are the main driving forces, and future enlargements of highway systems, international airports and railway systems will only increase the noise problem. Viewed globally, the growth in urban environmental noise pollution is unsustainable, because it involves not simply the direct and cumulative adverse effects on health. It also adversely affects future generations by degrading residential, social and learning environments, with corresponding economical losses (Berglund 1998). Thus, noise is not simply a local problem, but a global issue that affects everyone (Lang 1999; Sandberg 1999) and calls for precautionary action in any environmental planning situation.

The objective of the World Health Organization (WHO) is the attainment by all peoples of the highest possible level of health. As the first principle of the WHO Constitution the definition of ‘health’ is given as: “A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”. This broad definition of health embraces the concept of well-being and, thereby, renders noise impacts such as population annoyance, interference with communication, and impaired task performance as ‘health’ issues. In 1992, a WHO Task Force also identified the following specific health effects for the general population that may result from community noise: interference with communication; annoyance responses; effects on sleep, and on the cardiovascular and psychophysiological systems; effects on performance, productivity, and social behavior; and noise-induced hearing impairment (WHO 1993; Berglund & Lindvall 1995; *cf.* WHO 1980). Hearing damage is expected to result from both occupational and environmental noise, especially in developing countries, where compliance with noise regulation is known to be weak (Smith 1998).

Noise is likely to continue as a major issue well into the next century, both in developed and in developing countries. Therefore, strategic action is urgently required, including continued noise control at the source and in local areas. Most importantly, joint efforts among countries are necessary at a system level, in regard to the access and use of land, airspace and seawaters, and in regard to the various modes of transportation. Certainly, mankind would benefit from societal reorganization towards healthy transport. To understand noise we must understand the different types of noise and how we measure it, where noise comes from and the effects of noise on human beings. Furthermore, noise mitigation, including noise management, has to be actively introduced and in each case the policy implications have to be evaluated for efficiency.

This document is organized as follows. In Chapter 2 noise sources and measurement are discussed, including the basic aspects of source characteristics, sound propagation and transmission. In Chapter 3 the adverse health effects of noise are characterized. These include noise-induced hearing impairment, interference with speech communication, sleep disturbance, cardiovascular and physiological effects, mental health effects, performance effects, and annoyance reactions. This chapter is rounded out by a consideration of combined noise sources and their effects, and a discussion of vulnerable groups. In Chapter 4 the Guideline values are presented. Chapter 5 is devoted to noise management. Included are discussions of: strategies and priorities in the management of indoor noise levels; noise policies and legislation; environmental noise impact; and enforcement of regulatory standards. In Chapter 6 implementation of the WHO Guidelines is discussed, as well as future WHO work on noise and its research needs. In Appendices 1–6 are given: bibliographic references; examples of regional noise situations (African Region, American Region, Eastern Mediterranean Region, South East Asian Region, Western Pacific Region); a glossary; a list of acronyms; and a list of participants.

2. Noise sources and their measurement

2.1.Basic Aspects of Acoustical Measurements

Most environmental noises can be approximately described by one of several simple measures. They are all derived from overall sound pressure levels, the variation of these levels with time and the frequency of the sounds. Ford (1987) gives a more extensive review of various environmental noise measures. Technical definitions are found in the glossary in Appendix 3.

2.1.1. Sound pressure level

The sound pressure level is a measure of the air vibrations that make up sound. All measured sound pressures are referenced to a standard pressure that corresponds roughly to the threshold of hearing at 1 000 Hz. Thus, the sound pressure level indicates how much greater the measured sound is than this threshold of hearing. Because the human ear can detect a wide range of sound pressure levels (10–102 Pascal (Pa)), they are measured on a logarithmic scale with units of decibels (dB). A more technical definition of sound pressure level is found in the glossary.

The sound pressure levels of most noises vary with time. Consequently, in calculating some measures of noise, the instantaneous pressure fluctuations must be integrated over some time interval. To approximate the integration time of our hearing system, sound pressure meters have a standard *Fast* response time, which corresponds to a time constant of 0.125 s. Thus, all measurements of sound pressure levels and their variation over time should be made using the *Fast* response time, to provide sound pressure measurements more representative of human hearing. Sound pressure meters may also include a *Slow* response time with a time constant of 1 s, but its sole purpose is that one can more easily estimate the average value of rapidly fluctuating levels. Many modern meters can integrate sound pressures over specified periods and provide average values. It is not recommended that the *Slow* response time be used when integrating sound pressure meters are available.

Because sound pressure levels are measured on a logarithmic scale they cannot be added or averaged arithmetically. For example, adding two sounds of equal pressure levels results in a total pressure level that is only 3 dB greater than each individual sound pressure level. Consequently, when two sounds are combined the resulting sound pressure level will be significantly greater than the individual sound levels only if the two sounds have similar pressure levels. Details for combining sound pressure levels are given in Appendix 2.

2.1.2. Frequency and frequency weighting

The unit of frequency is the Hertz (Hz), and it refers to the number of vibrations per second of the air in which the sound is propagating. For tonal sounds, frequency is associated with the perception of pitch. For example, orchestras often tune to the frequency of 440 Hz. Most environmental sounds, however, are made up of a complex mix of many different frequencies. They may or may not have discrete frequency components superimposed on noise with a broad frequency spectrum (i.e. sound with a broad range of frequencies). The audible frequency range is normally considered to range from 20–20 000 Hz. Below 20 Hz we hear individual sound pulses rather than recognizable tones. Hearing sensitivity to higher frequencies decreases with age and exposure to noise. Thus, 20 000 Hz represents an upper limit of audibility for younger listeners with unimpaired hearing.

Our hearing systems are not equally sensitive to all sound frequencies (ISO 1987a). Thus, not all frequencies are perceived as being equally loud at the same sound pressure level, and when calculating overall environmental noise ratings it is necessary to consider sounds at some frequencies as more important than those at other frequencies. Detailed frequency analyses are commonly performed with standard sets of octave or 1/3 octave bandwidth filters. Alternatively, Fast Fourier Transform techniques or other types of filters can be used to determine the relative strengths of the various frequency components making up a particular environmental noise.

Frequency weighting networks provide a simpler approach for weighting the importance of different frequency components in one single number rating. The A-weighting is most commonly used and is intended to approximate the frequency response of our hearing system. It weights lower frequencies as less important than mid- and higher-frequency sounds. C-weighting is also quite common and is a nearly flat frequency response with the extreme high and low frequencies attenuated. When no frequency analysis is possible, the difference between A-weighted and C-weighted levels gives an indication of the amount of low frequency content in the measured noise. When the sound has an obvious tonal content, a correction to account for the additional annoyance may be used (ISO 1987b).

2.1.3. Equivalent continuous sound pressure level

According to the equal energy principle, the effect of a combination of noise events is related to the combined sound energy of those events. Thus, measures such as the equivalent continuous sound pressure level (LAeq,T) sum up the total energy over some time period (T) and give a level equivalent to the average sound energy over that period. Such average levels are usually based on integration of A-weighted levels. Thus LAeq,T is the average energy equivalent level of the A-weighted sound over a period T.

2.1.4. Individual noise events

It is often desired to measure the maximum level (LAmax) of individual noise events. For cases such as the noise from a single passing vehicle, LAmax values should be measured using the *Fast* response time because it will give a good correlation with the integration of loudness by our hearing system. However, for very short-duration impulsive sounds it is often desirable to measure the instantaneous peak amplitude to assess potential hearing-damage risk. If actual instantaneous pressure cannot be determined, then a time-integrated 'peak' level with a time constant of no more than 0.05 ms should be used (ISO 1987b). Such peak readings are often made using the C- (or linear) frequency weightings.

Alternatively, discrete sound events can be evaluated in terms of their A-weighted sound exposure level (SEL, for defintion see appendix 5). The total amount of sound energy in a particular event is assessed by the SEL. One can add up the SEL values of individual events to calculate a LAeq,T over some time period, T, of interest. In some cases the SEL may provide more consistent evaluations of individual noise events because they are derived from the complete history of the event and not just one maximum value. However, A-weighted SEL measurements have been shown to be inadequate for assessing the (perceived) loudness of complex impulsive sounds, such as those from large and small weapons (Berglund et al. 1986). In contrast, C-weighted SEL values have been found useful for rating impulsive sounds such as gun shots (Vos 1996; Buchta 1996; ISO 1987b).

2.1.5. Choice of noise measure

LAeq,T should be used to measure continuing sounds such as road traffic noise, many types of industrial noises and noise from ventilation systems in buildings. When there are distinct events to the noise such as with aircraft or railway noise, measures of the individual events should be obtained (using, for example, LAmax or SEL), in addition to LAeq,T measurements.

In the past, time-varying environmental sound levels have also been described in terms of percentile levels. These are derived from a statistical distribution of measured sound levels over some period. For example, L10 is the A-weighted level exceeded 10% of the time. L10 values have been widely used to measure road-traffic noise, but they are usually found to be highly correlated measures of the individual events, as are LAmax and SEL. L90 or L95 can be used as a measure of the general background sound pressure level that excludes the potentially confounding influence of particular local noise events.

2.1.6. Sound and noise

Physically, there is no distinction between sound and noise: sound is a sensory perception evoked by physiological processes in the auditory brain. The complex pattern of sound waves is perceptually classified as "Gestalts" and are labeled as noise, music, speech, etc. Consequently, it is not possible to define noise exclusively on the basis of the physical parameters of sound. Instead, it is common practice to define noise simply as unwanted sound. However, in some situations noise may adversely affect health in the form of acoustical energy.

2.2. Sources of Noise

This section describes various sources of noise that can affect a community. Namely, noise from industry, transportation, and from residential and leisure areas. It should be noted that equal values of LAeq,T for different sources do not always imply the same expected effect.

2.2.1. Industrial noise

Mechanized industry creates serious noise problems. It is responsible for intense noise indoors as well as outdoors. This noise is due to machinery of all kinds and often increases with the power of the machines. Sound generation mechanisms of machinery are reasonably well understood. The noise may contain predominantly low or high frequencies, tonal components, be impulsive or have unpleasant and disruptive temporal sound patterns. Rotating and reciprocating machines generate sound that includes tonal components; and air-moving equipment tends also to generate noise with a wide frequency range. The high sound pressure levels are caused by components or gas flows that move at high speed (for example, fans, steam pressure relief valves), or by operations involving mechanical impacts (for example, stamping, riveting, road breaking). Machinery should preferably be silenced at the source.

Noise from fixed installations, such as factories or construction sites, heat pumps and ventilation systems on roofs, typically affect nearby communities. Reductions may be achieved by encouraging quieter equipment or by zoning of land into industrial and residential areas. Requirements for passive (sound insulating enclosures) and active noise control, or restriction of operation time, may also be effective.

2.2.2. Transportation noise

Transportation noise is the main source of environmental noise pollution, including road traffic, rail traffic and air traffic. As a general rule, larger and heavier vehicles emit more noise than smaller and lighter vehicles. Exceptions would include: helicopters and 2- and 3-wheeled road vehicles.

The noise of road vehicles is mainly generated from the engine and from frictional contact between the vehicle and the ground and air. In general, road-contact noise exceeds engine noise at speeds higher than 60 km/h. The physical principle responsible for generating noise from tire-road contact is less well understood. The sound pressure level from traffic can be predicted from the traffic flow rate, the speed of the vehicles, the proportion of heavy vehicles, and the nature of the road surface. Special problems can arise in areas where the traffic movements involve a change in engine speed and power, such as at traffic lights, hills, and intersecting roads; or where topography, meteorological conditions and low background levels are unfavourable (for example, mountain areas).

Railway noise depends primarily on the speed of the train, but variations are present depending upon the type of engine, wagons, and rails and their foundations, as well as the roughness of wheels and rails. Small radius curves in the track, such as may occur for urban trains, can lead to very high levels of high-frequency sound referred to as wheel squeal. Noise can be generated in stations because of running engines, whistles and loudspeakers, and in marshaling yards because of shunting operations. The introduction of high-speed trains has created special noise problems with sudden, but not impulsive, rises in noise. At speeds greater than 250 km/h, the proportion of high-frequency sound energy increases and the sound can be perceived as similar to that of overflying jet aircraft. Special problems can arise in areas close to tunnels, in valleys or in areas where the ground conditions help generate vibrations. The long-distance propagation of noise from high-speed trains will constitute a problem in the future if otherwise environment-friendly railway systems are expanded.

Aircraft operations generate substantial noise in the vicinity of both commercial and military airports. Aircraft takeoffs are known to produce intense noise, including vibration and rattle. The landings produce substantial noise in long low-altitude flight corridors. The noise is produced by the landing gear and automatic power regulation, and also when reverse thrust is applied, all for safety reasons. In general, larger and heavier aircraft produce more noise than lighter aircraft. The main mechanism of noise generation in the early turbojet-powered aircraft was the turbulence created by the jet exhaust mixing with the surrounding air. This noise source has been significantly reduced in modern high by-pass ratio turbo-fan engines that surround the high-velocity jet exhaust with lower velocity airflow generated by the fan. The fan itself can be a significant noise source, particularly during landing and taxiing operations. Multi-bladed turbo-prop engines can produce relatively high levels of tonal noise. The sound pressure level from aircraft is, typically, predicted from the number of aircraft, the types of airplanes, their flight paths, the proportions of takeoffs and landings and the atmospheric conditions. Severe noise problems may arise at airports hosting many helicopters or smaller aircraft used for private business, flying training and leisure purposes. Special noise problems may also arise inside airplanes because of vibration. The noise emission from future superjets is unknown.

A sonic boom consists of a shock wave in the air, generated by an aircraft when it flies at a speed slightly greater than the local speed of sound. An aircraft in supersonic flight trails a sonic boom that can be heard up to 50 km on either side of its ground track, depending upon the flight altitude and the size of the aircraft (Warren 1972). A sonic boom can be heard as a loud double-boom sound. At high intensity it can damage property.

Noise from military airfields may present particular problems compared to civil airports (von Gierke & Harris 1987). For example, when used for night-time flying, for training interrupted landings and takeoffs (so-called touch-and-go), or for low-altitude flying. In certain instances, including wars, specific military activities introduce other intense noise pollution from heavy vehicles (tanks), helicopters, and small and large fire-arms.

2.2.3. Construction noise and building services noise

Building construction and excavation work can cause considerable noise emissions. A variety of sounds come from cranes, cement mixers, welding, hammering, boring and other work processes. Construction equipment is often poorly silenced and maintained, and building operations are sometimes carried out without considering the environmental noise consequences. Street services such as garbage disposal and street cleaning can also cause considerable disturbance if carried out at sensitive times of day. Ventilation and air conditioning plants and ducts, heat pumps, plumbing systems, and lifts (elevators), for example, can compromise the internal acoustical environment and upset nearby residents.

2.2.4. Domestic noise and noise from leisure activities

In residential areas, noise may stem from mechanical devices (e.g. heat pumps, ventilation systems and traffic), as well as voices, music and other kinds of sounds generated by neighbours (e.g. lawn movers, vacuum cleaners and other household equipment, music reproduction and noisy parties). Aberrant social behavior is a well-recognized noise problem in multifamily dwellings, as well as at sites for entertainment (e.g. sports and music events). Due to predominantly low-frequency components, noise from ventilation systems in residential buildings may also cause considerable concern even at low and moderate sound pressure levels.

The use of powered machines in leisure activities is increasing. For example, motor racing, off-road vehicles, motorboats, water skiing, snowmobiles etc., and these contribute significantly to loud noises in previously quiet areas. Shooting activities not only have considerable potential for disturbing nearby residents, but can also damage the hearing of those taking part. Even tennis playing, church bell ringing and other religious activities can lead to noise complaints.

Some types of indoor concerts and discotheques can produce extremely high sound pressure levels. Associated noise problems outdoors result from customers arriving and leaving. Outdoor concerts, fireworks and various types of festivals can also produce intense noise. The general problem of access to festivals and leisure activity sites often adds to road traffic noise problems. Severe hearing impairment may also arise from intense sound produced as music in headphones or from children's toys.

2.3. The Complexity of Noise and Its Practical Implications

2.3.1. The problem

One must consider many different characteristics to describe environmental noises completely. We can consider the sound pressure level of the noise and how this level varies over a variety of periods, ranging from minutes or seconds to seasonal variations over several months. Where sound pressure levels vary quite substantially and rapidly, such as in the case of low-level jet aircraft, one might also want to consider the rate of change of sound pressure levels (Berry 1995; Kerry et al. 1997). At the same time, the frequency content of each noise will also determine its effect on people, as will the number of events when there are relatively small numbers of discrete noisy events. Combinations of these characteristics determine how each type of environmental noise affects people. These effects may be annoyance, sleep disturbance, speech interference, increased stress, hearing impairment or other health-related effects.

Thus, in total there is a very complex multidimensional relationship between the various characteristics of the environmental noise and the effects it has on people. Unfortunately, we do not completely understand all of the complex links between noise characteristics and the resulting effects on people. Thus, current practice is to reduce the assessment of environmental noise to a small number of quite simple quantities that are known to be reasonably well related to the effects of noise on people (LAeq,T for continuing sounds and LAmax or SEL where there are a small number of distinct noise events). These simple measures have the distinct advantage that they are relatively easy and inexpensive to obtain and hence are more likely to be widely adopted. On the other hand, they may ignore some details of the noise characteristics that relate to particular types of effects on people.

2.3.2. Time variation

There is evidence that the pattern of noise variation with time relates to annoyance (Berglund et al. 1976). It has been suggested that the equal-energy principle is a simple concept for obtaining a measure representative of the annoyance of a number of noise events. For example, the LAeq,T of the noise from a busy road may be a good indicator of the annoyance this noise may cause for nearby residents. However, such a measure may not be very useful for predicting the disturbance to sleep of a small number of very noisy aircraft fly-overs. The disturbance caused by small numbers of such discrete events is usually better related to maximum sound pressure levels and the number of events.

While using LAeq,T measures is the generally accepted approach, it is still important to appreciate the limitations and errors that may occur. For example, some years ago measures that assessed the variation of sound pressure levels with time were popular. Subsequently, these have been shown not to improve predictions of annoyance with road traffic noise (Bradley 1978). However, it is possible that time variations may contribute to explaining the very different amounts of annoyance caused by equal LAeq,T levels of road-traffic noise, train noise and aircraft noise (*cf.* Miedema & Vos 1998).

More regular variations of sound pressure levels with time have been found to increase the annoying aspects of the noise. For example, noises that vary periodically to create a throbbing or pulsing sensation can be more disturbing than continuous noise (Bradley 1994b). Research suggests that variations at about 4 per second are most disturbing (Zwicker 1989). Noises with very rapid onsets could also be more disturbing than indicated by their LAeq,T (Berry 1995; Kerry et al. 1997).

LAeq,T values can be calculated for various time periods and it is very important to specify this period. It is quite common to calculate LAeq,T values separately for day- and night-time periods. In combining day and night LAeq,T values it is usually assumed that people will be more sensitive to noise during the night-time period. A weighting is thus normally added to night-time LAeq,T values when calculating a combined measure for a 24 hour period. For example, day-night sound pressure measures commonly include a 10 dB night-time weighting. Other night-time weightings have been proposed, but it has been suggested that it is not possible to determine precisely an optimum value for night-time weightings from annoyance survey responses, because of the large variability in responses within groups of people (Fields 1986; see also Berglund & Lindvall 1995). Night-time weightings are intended to indicate the expected increased sensitivity to annoyance at night and do not protect people from sleep disturbance.

2.3.3. Frequency content and loudness

Noise can also be characterized by its frequency content. This can be assessed by various types of frequency analysis to determine the relative contributions of the frequency components to the total noise. The combined effects of the different frequencies on people, perceived as noise, can be approximated by simple frequency weightings. The A-weighting is now widely used to obtain an approximate, single-number rating of the combined effects of the various frequencies. The A-weighting response is a simplification of an equal-loudness contour. There is a family of these equal-loudness contours (ISO 1987a) that describe the frequency response of the hearing system for a wide range of frequencies and sound pressure levels. These equal-loudness contours can be used to determine the perceived loudness of a single frequency sound. More complicated procedures have been derived to estimate the perceived loudness of complex sounds (ISO 1975). These methods involve determining the level of the sound in critical bands and the mutual masking of these bands.

Many studies have compared the accuracy of predictions based on A-weighted levels with those based on other frequency weightings, as well as more complex measures such as loudness levels and perceived noise levels (see also Berglund & Lindvall 1995). The comparisons depend on the particular effect that is being predicted, but generally the correlation between the more complex measures and subjective scales are a little stronger. A-weighted measures have been particularly criticized as not being accurate indicators of the disturbing effects of noises with strong low-frequency components (Kjellberg et al. 1984; Persson & Björkman 1988; Broner & Leventhall 1993; Goldstein 1994). However, these differences in prediction accuracy are usually smaller than the variability of responses among groups of people (Fields 1986; see also Berglund & Lindvall 1995). Thus, in practical situations the limitations of A-weighted measures may not be so important.

In addition to equal-loudness contours, equal-noisiness contours have also been developed for calculating perceived noise levels (PNL) (Kryter 1959; Kryter 1994; see also section 2.7.2). Critics have pointed out that in addition to equal-loudness and equal-noisiness contours, we could have many other families of equal-sensation contours corresponding to other attributes of the noises (Molino 1974). There seems to be no limit to the possible complexity and number of such measures.

2.3.4. Influence of ambient noise level

A number of studies have suggested that the annoyance effect of a particular noise would depend on how much that noise exceeded the level of ambient noise. This has been shown to be true for noises that are relatively constant in level (Bradley 1993), but has not been consistently found for time-varying noises such as aircraft noise (Gjestland et al. 1990; Fields 1998). Because at some time during an aircraft fly-over the noise almost always exceeds the ambient level, responses to this type of noise are less likely to be influenced by the level of the ambient noise.

2.3.5. Types of noise

A number of studies have concluded that equal levels of different noise types lead to different annoyance (Hall et al. 1981; Griffiths 1983; Miedema 1993; Bradley 1994a; Miedema & Vos 1998). For example, equal LAeq,T levels of aircraft noise and road traffic noise will not lead to the same mean annoyance in groups of people exposed to these noises. This may indicate that the LAeq,T measure is not a completely satisfactory description of these noises and perhaps does not completely reflect the characteristics of these noises that lead to annoyance. Alternatively, the differences may be attributed to various other factors that are not part of the noise characteristics (e.g. Flindell & Stallen 1999). For example, it has been said that aircraft noise is more disturbing, because of the associated fear of aircraft crashing on people's homes (cf. Berglund & Lindvall 1995).

2.3.6. Individual differences

Finally, there is the problem of individual response differences. Different people will respond quite differently to the same noise stimulus (Job 1988). These individual differences can be quite large and it is often most useful to consider the average response of groups of people exposed to the same sound pressure levels. In annoyance studies the percentage of highly annoyed individuals is usually considered, because it correlates better with measured sound pressure levels. Individual differences also exist for susceptibility to hearing impairment (e.g. Katz 1994).

2.3.7. Recommendations

In many cases we do not have specific, accurate measures of how annoying sound will be and must rely on the simpler quantities. As a result, current practice is to assume that the equal energy principle is approximately valid for most types of noise, and that a simple LAeq,T type measure will indicate reasonably well the expected effects of the noise. Where the noise consists of a small number of discrete events, the A-weighted maximum level (LAmax) will be a better indicator of the disturbance to sleep and other activities. However, in most cases the A-weighted sound exposure level (SEL) will provide a more consistent measure of such single-noise events, because it is based on an integration over the complete noise event.

2.4. Measurement Issues

2.4.1. Measurement objectives

The details of noise measurements must be planned to meet some relevant objective or purpose. Some typical objectives would include:

a. Investigating complaints.
b. Assessing the number of persons exposed.
c. Compliance with regulations.
d. Land use planning and environmental impact assessments.
e. Evaluation of remedial measures.
f. Calibration and validation of predictions.
g. Research surveys.
h. Trend monitoring.

The sampling procedure, measurement location, type of measurements and the choice of equipment should be in accord with the objective of the measurements.

2.4.2. Instrumentation

The most critical component of a sound pressure meter is the microphone, because it is difficult to produce microphones with the same precision as the other, electronic components of a pressure meter. In contrast, it is usually not difficult to produce the electronic components of a microphone with the desired sensitivity and frequency-response characteristics. Lower quality microphones will usually be less sensitive and so cannot measure very low sound pressure levels. They may also not be able to accurately measure very high sound pressure levels found closer to loud noise sources. Lower quality microphones will also have less well-defined frequency-response characteristics. Such lower quality microphones may be acceptable for survey type measurements of overall A-weighted levels, but would not be preferred for more precise measurements, including detailed frequency analysis of the sounds.

Sound pressure meters will usually include both A- and C-weighting frequency-response curves. The uses of these frequency weightings were discussed above. They may also include a linear weighting. Linear weightings are not defined in standards and may in practice be limited by the response of the particular microphone being used. Instead of, or in addition to, frequency-response weightings, more complex sound pressure meters can also include sets of standard bandpass filters, to permit frequency analysis of sounds. For acoustical measurements, octave and one-third octave bandwidth filters are widely used with centre frequencies defined in standards (ISO 1975b).

The instantaneous sound pressures are integrated with some time constant to provide sound pressure levels. As mentioned above most meters will include both *Fast*- and *Slow*-response times. *Fast*-response corresponds to a time constant of 0.125 s and is intended to approximate the time constant of the human hearing system. *Slow*-response corresponds to a time constant of 1 s and is an old concept intended to make it easier to obtain an approximate average value of fluctuating levels from simple meter readings.

Standards (IEC 1979) classify sound pressure meters as type 1 or type 2. Type 2 meters are adequate for broad band A-weighted level measurements, where extreme precision is not required and where very low sound pressure levels are not to be measured. Type 1 meters are usually much more expensive and should be used where more precise results are needed, or in cases where frequency analysis is required.

Many modern sound pressure meters can integrate sound pressure levels over some specified time period, or may include very sophisticated digital processing capabilities. Integrating meters make it possible to directly obtain accurate measures of LAeq,T values over a user-specified time interval, T. By including small computers in some sound pressure meters, quite complex calculations can be performed on the measured levels and many such results can be stored for later read out. For example, some meters can determine the statistical distribution of sound pressure levels over some period, in addition to the simple LAeq,T value. Recently, hand-held meters that perform loudness calculations in real time have become available. Continuing rapid developments in instrumentation capabilities are to be expected.

2.4.3. Measurement locations

Where local regulations do not specify otherwise, measurements of environmental noise are usually best made close to the point of reception of the noise. For example, if there is concern about residents exposed to road traffic noise it is better to measure close to the location of the residents, rather than close to the road. If environmental noises are measured close to the source, one must then estimate the effect of sound propagation to the point of reception. Sound propagation can be quite complicated and estimates of sound pressure levels at some distance from the source will inevitably introduce further errors into the measured sound pressure levels. These errors can be avoided by measuring at locations close to the point of reception.

Measurement locations should normally be selected so that there is a clear view of the sound source and so that the propagation of the sound to the microphone is not shielded or blocked by structures that would reduce the incident sound pressure levels. For example, measurements of aircraft noise should be made on the side of the building directly exposed to the noise. The position of the measuring microphone relative to building façades or other sound-reflective surfaces is also important and will significantly influence measured sound pressure levels (ISO 1978). If the measuring microphone is located more than several meters from reflecting surfaces, it will provide an unbiased indication of the incident sound pressure level. At the other extreme, when a measuring microphone is mounted on a sound-reflecting surface, such as a building façade, sound pressure levels will be increased by 6 dB, because the direct and reflected sound will coincide. Some standards recommend a position 2 m from the façade and an associated 3 dB correction (ISO 1978; ASTM 1992). The effect of façade reflections must be accounted for to represent the true level of the incident sound. Thus, while locating the measuring microphone close to the point of reception is desirable, it leads to some other issues that must be considered to accurately interpret measurement results. Where exposures are measured indoors, it is necessary to measure at several positions to characterize the average sound pressure level in a room. In other situations, it may be necessary to measure at the position of the exposed person.

2.4.4. Sampling

Many environmental noises vary over time, such as for different times of day or from season to season. For example, road traffic noise may be considerably louder during some hours of the day but much quieter at night. Aircraft noise may vary with the season due to different numbers of aircraft operations. Although permanent noise monitoring systems are becoming common around large airports, it is usually not possible to measure sound pressure levels continuously over a long enough period of time to completely define the environmental noise exposure. In practice, measurements usually only sample some part of the total exposure. Such sampling will introduce uncertainties in the estimates of the total noise exposure.

Traffic noise studies have identified various sampling schemes that can introduce errors of 2-3 dB in estimates of daytime LAeq,T values and even larger errors in night-time sound pressure levels (Vaskor et al. 1979). These errors relate to the statistical distributions of sound pressure levels over time (Bradley et al. 1979). Thus, the sampling errors associated with road traffic noise may be quite different from those associated with other noise, because of the quite different variations of sound pressure levels over time. It is also difficult to give general estimates of sampling errors due to seasonal variations. When making environmental noise measurements it is important that the measurement sample is representative of all of the variations in the noise in question, including variations of the source and variations in sound propagation, such as due to varying atmospheric conditions.

2.4.5. Calibration and quality assurance

Sound pressure meters can be calibrated using small calibrated sound sources. These devices are placed on the measurement microphone and produce a known sound pressure level with a specified accuracy. Such calibrations should be made at least daily, and more often if there is some possibility that handling of the sound pressure meter may have modified its sensitivity. It is also important to have a complete quality assurance plan. This should require annual calibration of all noise measuring equipment to traceable standards and should clearly specify correct measurement and operating procedures (ISO 1994).

2.5. Source Characteristics and Sound Propagation

To make a correct assessment of noise it is important to have some appreciation of the characteristics of environmental noise sources and of how sound propagates from them. One should consider the directionality of noise sources, the variability with time and the frequency content. If these are in some way unusual, the noise may be more disturbing than expected. The most common types of environmental noise sources are directional and include: road-traffic noise, aircraft noise, train noise, industrial noise and outdoor entertainment facilities (*cf.* section 2.2). All of these types of environmental noise are produced by multiple sources, which in many cases are moving. Thus, the characteristics of individual sources, as well as the characteristics of the combined sources, must be considered.

For example, we can consider the radiation of sound from individual vehicles, as well as from a line of vehicles on a particular road. Sound from an ideal point source (i.e. non-directional source) will spread out spherically and sound pressure levels would decrease 6 dB for each doubling of distance from the source. However, for a line of such sources, or for an integration over the complete pass-by of an individual moving source, the combined effect leads to sound that spreads cylindrically and to sound pressure levels that decrease at 3 dB per doubling of distance. Thus, there are distinct differences between the propagation of sound from an ideal point source and from moving sources. In practice one cannot adequately assess the noise from a fixed source with measurements at a single location; it is essential to measure in a number of directions from the source. If the single source is moving, it is necessary to measure over a complete pass-by, to account for sound variation with direction and time.

In most real situations this simple behaviour is considerably modified by reflections from the ground and from other nearby surfaces. One expects that when sound propagates over loose ground, such as grass, that some sound energy will be absorbed and sound pressure levels will actually decrease more rapidly with distance from the source. Although this is approximately true, the propagation of sound between sources and receivers close to the ground is much more complicated than this. The combination of direct and ground-reflected sound can combine in a complex manner which can lead to strong cancellations at some frequencies and not at others (Embleton & Piercy 1976). Even at quite short source-to-receiver distances, these complex interference effects can significantly modify the propagating sound. At larger distances (approximately 100 m or more), the propagation of sound will also be significantly affected by various atmospheric conditions. Temperature and wind gradients as well as atmospheric turbulence can have large effects on more distant sound pressure levels (Daigle et al. 1986). Temperature and wind gradients can cause propagating sound to curve either upwards or downwards, creating either areas of increased or decreased sound pressure levels at points quite distant from the source. Atmospheric turbulence can randomize sound so that the interference effects resulting from combinations of sound paths are reduced. Higher frequency sound is absorbed by air depending on the exact temperature and relative humidity of the air (Crocker &

Price 1975; Ford 1987). Because there are many complex effects, it is not usually possible to accurately predict sound pressure levels at large distances from a source.

Using barriers or screens to block the direct path from the source to the receiver can reduce the propagation of sound. The attenuating effects of the screen are limited by sound energy that diffracts or bends around the screen. Screens are more effective at higher frequencies and when placed either close to the sound source or the receiver; they are less effective when placed far from the receiver. Although higher screens are better, in practice it is difficult to achieve more than about a 10 dB reduction. There should be no gaps in the screen and it must have an adequate mass per unit area. A long building can be an effective screen, but gaps between buildings will reduce the sound attenuation.

In some cases, it may be desirable to estimate environmental sound pressure levels using mathematical models implemented as computer programmes (House 1987). Such computer programmes must first model the characteristics of the source and then estimate the propagation of the sound from the source to some receiver point. Although such prediction schemes have several advantages, there will be some uncertainty as to the accuracy of the predicted sound pressure levels. Such models are particularly useful for road traffic noise and aircraft noise, because it is possible to create data bases of information describing particular sources. For more varied types of noise, such as industrial noise, it would be necessary to first characterize the noise sources. The models then sum up the effects of multiple sources and calculate how the sound will propagate to receiver points. Techniques for estimating sound propagation are improving and the accuracy of these models is also expected to improve. These models can be particularly useful for estimating the combined effect of a large number of sources over an extended period of time. For example, aircraft noise prediction models are typically used to predict average yearly noise exposures, based on the combination of aircraft events over a complete year. Such models can be applied to predict sound pressure level contours around airports for these average yearly conditions. This is of course much less expensive than measuring at many locations over a complete one year-period. However, such models can be quite complex, and require skilled users and accurate data bases. Because environmental noise prediction models are still developing, it is advisable to confirm predictions with measurements.

2.6. Sound transmission Into and Within Buildings

Sources of environmental noise are usually located outdoors; for example, road traffic, aircraft or trains. However, people exposed to these noises are often indoors, inside their home or some other building. It is, therefore, important to understand how environmental noises are transmitted into buildings. Most of the same fundamentals discussed earlier apply to airborne sound propagation between homes in multifamily dwellings, via common walls and floors. However, within buildings we can also consider impact sound sources, such as footsteps, as well as airborne sounds.

The amount of incident sound that is transmitted through a building façade is measured in terms of the sound reduction index. The sound reduction index, or transmission loss, is defined as 10 times the logarithm of the ratio of incident-to-transmitted sound power, and it describes in decibels how much the incident sound is reduced on passing through a particular panel. This index of constructions usually increases with the frequency of the incident sound and with the mass of the construction (Kremer 1950). Thus, heavier or more massive constructions tend to have higher sound reductions. When it is not possible to achieve the desired transmission loss by increasing the mass of a panel, increased sound reduction can be achieved by a double panel construction. The two layers should be isolated with respect to vibrations and there should be sound absorbing material in the cavity. Such double panel constructions can provide much greater sound reduction than a single panel. Because sound reduction is also greater at higher frequencies most problems occur at lower frequencies, where most environmental noise sources produce relatively high sound pressure levels.

The sound reduction of buildings can be measured in standard laboratory tests, where the test panel is constructed in an opening between two reverberant test chambers (ISO 1995; ASTM 1997). In these tests sound fields are quite diffuse in both test chambers and the sound reduction index is calculated as the difference between the average sound pressure levels in the two rooms, plus a correction involving the area of the test panel and the total sound absorption in the receiving room. The sound reduction of a complete building façade can also be measured in the field using either natural environmental noises or test signals from loudspeakers (ISO 1978; ASTM 1992). In either case the noise, as transmitted through the façade, must be greater in level than other sounds in the receiving room. For this outdoor-to-indoor sound propagation case, the measured sound reduction index will also depend on the angle of incidence of the outdoor sound, as well as the position of the outdoor measuring microphone relative to the building façade. Corrections of up to 6 dB must be made to the sound pressure level measured outdoors, to account for the effect of reflections from the façade (see also section 2.4.3).

The sound reduction of most real building façades is determined by a combination of several different elements. For example, a wall might include windows, doors or some other type of element. If the sound reduction index values of each element are known, the values for the combined construction can be calculated from the area-weighted sums of the sound energy transmitted through each separate element. Although parts of the building façade, such as massive wall constructions, can be very effective barriers to sound, the sound reduction index of the complete façade is often greatly reduced by less effective elements such as windows, doors or ventilation openings. Completely open windows as such would have a sound reduction index of 0 dB. If window openings makes up 10% of the area of a wall, the sound reduction index of the combined wall and open window could not exceed 10 dB. Thus it is not enough to specify effective sound reducing façade constructions, without also solving the problem of adequate ventilation that does not compromise the sound transmission reduction by the building façade.

Sound reduction index values are measured at different frequencies and from these, single number ratings are determined. Most common are the ISO weighted sound reduction index (ISO 1996) and the equivalent ASTM sound transmission class (ASTM 1994a). However, in their original form these single number ratings are only appropriate for typical indoor noises that usually do not have strong low frequency components. Thus, they are usually not appropriate single number ratings of the ability of a building façade to block typical environmental noises. More recent additions to the ISO procedure have included source spectrum corrections intended to correct approximately for other types of sources (ISO 1996). Alternatively, the ASTM-Outdoor-Indoor Transmission Class rating calculates the A-weighted level reduction to a standard environmental noise source spectrum (ASTM 1994b). Within buildings the impact sound insulation index can be measured with a standard impact source and determined according to ISO and ASTM standards (ISO 1998; ASTM 1994c 1996)

2.7. More Specialized Noise Measures

2.7.1. Loudness and perceived noise levels

There are procedures to accurately rate the loudness of complex sounds (Zwicker 1960; Stevens 1972; ISO 1975a). These usually start from a 1/3 octave spectrum of the noise. The combination of the loudness contributions of each 1/3 octave band with estimates of mutual masking effects, leads to a single overall loudness rating in sones. A similar system for rating the noisiness of sounds has also been developed (Kryter 1994). Again a 1/3 octave spectrum of the noise is required and the 1/3 octave noise levels are compared with a set of equal-noisiness contours. The individual 1/3 octave band noisiness estimates are combined to give an overall perceived noise level (PNL) that is intended to accurately estimate subjective evaluations of the same sound. The PNL metric was initially developed to rate jet aircraft noise.

PNL values will vary with time, for example when an aircraft flies by a measuring point. The effective perceived noise level measure (EPNL) is derived from PNL values and is intended to provide a complete rating of an aircraft fly-over. EPNL values add both a duration correction and a tone correction to PNL values. The duration correction ensures that longer duration events are rated as more disturbing. Similarly, noise spectra that seem to have prominent tonal components are rated as more disturbing by the tone-correction procedure. There is some evidence that these tone corrections are not always successful in improving predictions of adverse responses to noise events (Scharf & Hellman 1980). EPNL values are used in the certification testing of new aircraft. These more precise measures ensure that the noise from new aircraft is rated as accurately as possible.

2.7.2. Aviation noise measures

There are many measures for evaluating the long-term average sound pressure levels from aircraft near airports (Ford 1987; House 1987). They include different frequency weightings, different summations of levels and numbers of events, as well as different time-of-day weightings. Most measures are based on either A-weighted or PNL-weighted sound pressure levels. Because of the many other large uncertainties in predicting community response to aircraft noise, there seems little justification for using the more complex PNL-weighted sound pressure levels and there is a trend to change to A-weighted measures.

Most aviation noise measures are based on an equal energy approach and hence they sum up the total energy of a number of aircraft fly-overs. However, some older measures were based on different combinations of the level of each event and the number of events. These types of measures are gradually being replaced by measures based on the equal energy hypothesis such as LAeq,T values. There is also a range of time-of-day weightings incorporated into current aircraft noise measures. Night-time weightings of 6–12 dB are currently in use. Some countries also include an intermediate evening weighting.

The day-night sound pressure level L_{dn} (von Gierke 1975; Ford 1987) is an LAeq,T based measure with a 10 dB night-time weighting. It is based on A-weighted sound pressure levels and the equal energy principle. The noise exposure forecast (NEF) (Bishop & Horonjeff 1967) is based on the EPNL values of individual aircraft events and includes a 12 dB night-time weighting. It sums multiple events on an equal energy basis. However, the Australian variation of the NEF measure has a 6 dB evening weighting and a 6 dB night-time weighting (Bullen & Hede 1983). The German airport noise equivalent level (LEQ(FLG)) is based on A-weighted levels, but does not follow the equal energy principle.

The weighted equivalent continuous perceived noise level (WECPNL) measure (Ford 1987) proposed by ICAO is based on the equal energy principle and maximum PNL values of aircraft fly-overs. However, in Japan an approximation to this measure is used and is based on maximum A-weighted levels. The noise and number index (NNI), formerly used in the United Kingdom, was derived from maximum PNL values but was not based on the equal energy principle. An approximation to the original version of the NNI has been used in Switzerland and is based on maximum A-weighted levels of aircraft fly-overs, but its use will soon be discontinued. Changes in these measures are slow because their use is often specified in national legislation. However, several countries have changed to measures that are based on the equal energy principle and A-weighted sound pressure levels.

2.7.3. Impulsive noise measures

Impulsive sounds, such as gun shots, hammer blows, explosions of fireworks or other blasts, are sounds that significantly exceed the background sound pressure level for a very short duration. Typically each impulse lasts less than one second. Measurements with the meter set to 'Fast' response (section 2.1.1) do not accurately represent impulsive sounds. Therefore the meter response time must be shorter to measure such impulse type sounds. C-weighted levels have been found useful for ratings of gun shots (ISO 1987). Currently no mathematical description exists which unequivocally defines impulsive sounds, nor is there a universally accepted procedure for rating the additional annoyance of impulsive sounds (HCN 1997). Future versions of ISO Standard 1996 (present standard in ISO 1987b) are planned to improve this situation.

2.7.4. Measures of speech intelligibility

The intelligibility of speech depends primarily on the speech-to-noise ratio. If the level of the speech sounds are 15 dB or more above the level of the ambient noise, the speech intelligibility at 1 m distance will be close to 100% (Houtgast 1981; Bradley 1986b). This can be most simply rated in terms of the speech-to-noise ratio of the A-weighted speech and noise levels. Alternatively, the speech intelligibility index (formerly the articulation index) can be used if octave or 1/3 octave band spectra of the speech and noise are available (ANSI 1997).

When indoors, speech intelligibility also depends on the acoustical properties of the space. The acoustical properties of spaces have for many years been rated in terms of reverberation times. The reverberation time is approximately the time it takes for a sound in a room to decrease to inaudibility after the source has been stopped. Optimum reverberation times for speech have been specified as a function of the size of the room. In large rooms, such as lecture halls and theaters, a reverberation time for speech of about 1 s is recommended. In smaller rooms such as classrooms, the recommended value for speech is about 0.6 s (Bradley 1986b,c). More modern measures of room acoustics have been found to be better correlates of speech intelligibility, and some combine an assessment of both the speech/noise ratio and room acoustics (Bradley 1986a,c). The most widely known is the speech transmission index (STI) (Houtgast & Steeneken 1983), or the abbreviated version of this measure referred to as RASTI (Houtgast & Steeneken 1985; IEC 1988). In smaller rooms, such as school classrooms, the conventional approach of requiring adequately low ambient noise levels, as well as some optimum reverberation time, is probably adequate to ensure good speech intelligibility (Bradley 1986b). In larger rooms and other more specialized situations, use of the more modern measures may be helpful.

2.7.5. Indoor noise ratings

The simplest procedure for rating levels of indoor noise is to measure them in terms of integrated A-weighted sound pressure levels, as measured by LAeq,T. As discussed earlier, this approach has been criticized as not being the most accurate rating of the negative effects of various types of noises, and is thought to be particularly inadequate when there are strong low-frequency components. Several more complex rating schemes are available based on octave band measurements of indoor noises. In Europe the noise rating system (Burns 1968), and in North America the noise criterion (Beranek 1971), both include sets of equal-disturbance type contours. Measured octave band sound pressure levels are compared with these contours and an overall noise rating is determined. More recently, two new schemes have been proposed: the balanced noise criterion procedure (Beranek 1989) and the room criterion system (Blazier 1998). These schemes are based on a wider range of octave bands extending from 16–8 000 Hz. They provide both a numerical and a letter rating of the noise. The numerical part indicates the level of the central frequencies important for speech communication and the letter indicates whether the quality of the sound is predominantly low-, medium- or high-frequency in nature. Extensive comparisons of these room noise rating procedures have yet to be performed. Because the newer measures include a wider range of frequencies, they can better assess a wider range of noise problems.

2.8. Summary

Where there are no clear reasons for using other measures, it is recommended that LAeq,T be used to evaluate more-or-less continuous environmental noises. LAeq,T should also be used to assess ongoing noises that may be composed of individual events with randomly varying sound pressure levels. Where the noise is principally composed of a small number of discrete events the additional use of LAmax or SEL is recommended. As pointed out in this chapter, there are definite limitations to these simple measures, but there are also many practical advantages, including economy and the benefits of a standardized approach.

The sound pressure level measurements should include all variations over time to provide results that best represent the noise in question. This would include variations in both the source and in propagation of the noise from the source to the receiver. Measurements should normally be made close to typical points of reception. The accuracy of the measurements and the details of the measurement procedure must be adapted to the type of noise and to other details of the noise exposure. Assessment of speech intelligibility, aviation noise or impulse noise may require the use of more specialized methods. Where the exposed people are indoors and noise measurements are made outdoors, the sound attenuating properties of the building façade must also be measured or estimated.

3. Adverse Health Effects Of Noise

3.1. Introduction

The perception of sounds in day-to-day life is of major importance for human well-being. Communication through speech, sounds from playing children, music, natural sounds in parklands, parks and gardens are all examples of sounds essential for satisfaction in every day life. Conversely, this document is related to the adverse effects of sound (noise). According to the International Programme on Chemical Safety (WHO 1994), an adverse effect of noise is defined as a change in the morphology and physiology of an organism that results in impairment of functional capacity, or an impairment of capacity to compensate for additional stress, or increases the susceptibility of an organism to the harmful effects of other environmental influences. This definition includes any temporary or long-term lowering of the physical, psychological or social functioning of humans or human organs. The health significance of noise pollution is given in this chapter under separate headings, according to the specific effects: noise-induced hearing impairment; interference with speech communication; disturbance of rest and sleep; psychophysiological, mental-health and performance effects; effects on residential behaviour and annoyance; as well as interference with intended activities. This chapter also considers vulnerable groups and the combined effects of sounds from different sources. Conclusions based on the details given in this chapter are given in Chapter 4 as they relate to guideline values.

3.2. Noise-Induced Hearing Impairment

Hearing impairment is typically defined as an increase in the threshold of hearing. It is assessed by threshold audiometry. Hearing handicap is the disadvantage imposed by hearing impairment sufficient to affect one's personal efficiency in the activities of daily living. It is usually expressed in terms of understanding conventional speech in common levels of background noise (ISO 1990). Worldwide, noise-induced hearing impairment is the most prevalent irreversible occupational hazard. In the developing countries, not only occupational noise, but also environmental noise is an increasing risk factor for hearing impairment. In 1995, at the World Health Assembly, it was estimated that there are 120 million persons with disabling hearing difficulties worldwide (Smith 1998). It has been shown that men and women are equally at risk of noise-induced hearing impairment (ISO 1990; Berglund & Lindvall 1995).

Apart from noise-induced hearing impairment, hearing damage in populations is also caused by certain diseases; some industrial chemicals; ototoxic drugs; blows to the head; accidents; and hereditary origins. Deterioration of hearing capability is also associated with the aging process *per se* (presbyacusis). Present knowledge of the physiological effects of noise on the auditory system is based primarily on laboratory studies on animals. After noise exposure, the first morphological changes are usually found in the inner and outer hair cells of the cochlea, where the stereocilia become fused and bent. After more prolonged exposure, the outer and inner hair cells related to transmission of high-frequency sounds are missing. See Berglund & Lindvall (1995) for further discussion.

The ISO Standard 1999 (ISO 1990) gives a method for calculating noise-induced hearing impairment in populations exposed to all types of noise (continuous, intermittent, impulse) during working hours. Noise exposure is characterized by LAeq over 8 hours (LAeq,8h). In the Standard, the relationships between LAeq,8h and noise-induced hearing impairment are given for frequencies of 500–6 000 Hz, and for exposure times of up to 40 years. These relations show that noise-induced hearing impairment occurs predominantly in the high-frequency range of 3 000–6 000 Hz, the effect being largest at 4 000 Hz. With increasing LAeq,8h and increasing exposure time, noise-induced hearing impairment also occurs at 2 000 Hz. But at LAeq,8h levels of 75 dBA and lower, even prolonged occupational noise exposure will not result in noise-induced hearing impairment (ISO 1990). This value is equal to that specified in 1980 by the World Health Organization (WHO 1980a).

The ISO Standard 1999 (ISO 1990) specifies hearing impairment in statistical terms (median values, and percentile fractions between 0.05 and 0.95). The extent of noise-induced hearing impairment in populations exposed to occupational noise depends on the value of LAeq,8h and the number of years of noise exposure. However, for high LAeq,8h values, individual susceptibility seems to have a considerable effect on the rate of progression of hearing impairment. For daily exposures of 8–16 h, noise-induced hearing impairment can be reasonably well estimated from LAeq,8h extrapolated to the longer exposure times (Axelsson et al. 1986). In this adaptation of LAeq,8h for daily exposures other than 8 hours, the equal energy principle is assumed to be applicable. For example, the hearing impairment due to a 16 h daily exposure is equivalent to that at LAeq,8h plus 3 dB (LAeq,16h = LAeq,8h + $10*\log_{10}(16/8)$ = LAeq,8h + 3 dB. For a 24 h exposure, LAeq,24h = LAeq,8h + $10*\log_{10}(24/8)$ = LAeq,8h + 5 dB).

Since the calculation method specified in the ISO Standard 1999 (ISO 1990) is the only universally adopted method for estimating occupational noise-induced hearing impairment, attempts have been made to assess whether the method is also applicable to hearing impairment due to environmental noise, including leisure-time noise. There is ample evidence that shooting noise, with LAeq,24h values of up to 80 dB, induces the same hearing impairment as an equivalent occupational noise exposure (Smoorenburg 1998). Moreover, noise-induced hearing impairment studies from motorbikes are also in agreement with results from ISO Standard 1999 (ISO 1990). Hearing impairment in young adults and children 12 years and older has been assessed by LAeq on a 24 h time basis, for a variety of environmental and leisure-time exposure patterns (e.g. Passchier-Vermeer 1993; HCN 1994). These include pop music in discotheques and concerts (Babisch & Ising 1989; ISO 1990); pop music through headphones (Ising et al. 1994; Struwe et al. 1996; Passchier-Vermeer et al. 1998); music played by brass bands and symphony orchestras (van Hees 1992). The results are in agreement with values predicted by the ISO Standard 1999 method on the basis of adjusted time.

In the publications cited above, exposure to noise with known characteristics, such as duration and level, was related to hearing impairment. In addition to these publications, there is also an extensive literature showing hearing impairment in populations exposed to specific types of non-occupational noise, although these exposures are not well characterized. These noises originate from shooting, motorcycling, snowmobile driving, playing in arcades, listening to music at concerts and through headphones, using noisy toys, and fireworks (e.g. Brookhouser et al. 1992; see also Berglund & Lindvall 1995). Although the characteristics of these exposures are to a certain extent unknown, the details in the publications suggest that LAeq,24h values of these exposures exceed 70 dB.

In contrast, epidemiological studies failed to show hearing damage in populations exposed to an LAeq,24h of less than 70 dB (Lindemann et al. 1987). The data imply that even a lifetime exposure to environmental and leisure-time noise with an LAeq,24h <70 dBA would not cause hearing impairment in the large majority of people (over 95%). Overall, the results of many studies strongly suggest that the method from ISO Standard 1999 can also be used to estimate hearing impairment due to environmental and leisure-time noise, in addition to estimating the effects of occupational noise exposure.

Although the evidence suggests that the calculation method from ISO Standard 1999 (ISO 1990) should also be accepted for environmental and leisure time noise exposures, large-scale epidemiological studies of the general population do not exist to support this proposition. Taking into account the limitations of the studies, care should be taken with respect to the following aspects:

a. Data from animal experiments indicate that children may be more vulnerable in acquiring noise-induced hearing impairment than adults.

b. At very high instantaneous sound pressure levels, mechanical damage to the ear may occur (Hanner & Axelsson 1988). Occupational limits are set at peak sound pressure levels of 140 dB (EU 1986a). For adults exposed to environmental and leisure-time noise, this same limit is assumed to be valid. In the case of children, however, taking into account their habits while playing with noisy toys, peak sound pressure levels should never exceed 120 dB.

c. For shooting noise with LAeq,24h over 80 dB, studies on temporary threshold shift suggest the possibility of an increased risk for noise-induced hearing impairment (Smoorenburg 1998).

d. Risk for noise-induced hearing impairment may increase when the noise exposure is combined with exposure to vibrations, the use of ototoxic drugs, or some chemicals (Fechter 1999). In these circumstances, long-term exposure to LAeq,24h of 70 dBA may induce small hearing impairments.

e. It is uncertain whether the relationships between hearing impairment and noise exposure given in ISO Standard 1999 (ISO 1990) are applicable for environmental sounds of short rise time. For example, in the case of military low-altitude flying areas (75–300 m above ground) LAmax values of 110–130 dB occur within seconds after the onset of the sound.

Usually noise-induced hearing impairment is accompanied by an abnormal loudness perception which is known as loudness recruitment (*cf.* Berglund & Lindvall 1995). With a considerable loss of auditory sensitivity, some sounds may be perceived as distorted (paracusis). Another sensory effect that results from noise exposure is tinnitus (ringing in the ears). Commonly, tinnitus is referred to as sounds that are emitted by the inner ear itself (physiological tinnitus). Tinnitus is a common and often disturbing accompaniment of occupational hearing impairment (Vernon and Moller 1995) and has become a risk for teenagers attending pop concerts and discotheques (Hetu & Fortin 1995; Passchier-Vermeer et al. 1998; Axelsson & Prasher 1999). Noise-induced tinnitus may be temporary, lasting up to 24 hours after exposure, or may have a more permanent character, such as after prolonged occupational noise exposure. Sometimes tinnitus is due to the sound produced by the blood flow through structures in the ear.

The main social consequence of hearing impairment is an inability to understand speech in daily living conditions, which is considered a severe social handicap. Even small values of hearing impairment (10 dB averaged over 2 000 and 4 000 Hz, and over both ears) may have an effect on the understanding of speech. When the hearing impairment exceeds 30 dB (again averaged over 2 000 and 4 000 Hz and both ears) a social hearing handicap is noticeable (*cf.* Katz 1994; Berglund & Lindvall 1995).

In the past, hearing protection has mainly emphasized occupational noise exposures at high values of LAeq,8h, or situations with high impulsive sounds. The near-universal adoption of an LAeq,8h value of 85 dB (or lower) as the limit for unprotected occupational noise exposure, together with requirements for personal hearing protection, has made cases of severe unprotected exposures more rare. This is particularly true for developed countries. However, monitoring of compliance and enforcement action for sound pressure levels just over the limits may be weak, especially in non-industrial environments in developed countries (Franks 1998), as well as in occupational and urban environments in developing countries (Smith 1998). Nevertheless, regulations for occupational noise exposure exist almost worldwide and exposures to occupational noise are to a certain extent under control.

On the other hand, environmental noise exposures due to a number of noisy activities, especially those during leisure-time activities of children and young adults, have scarcely been regulated. Given both the increasing number of noisy activities and the increasing exposure duration, such as loud music in cars and the use of Walkmen and Discmen, regulatory activities in this field are to be encouraged. Dose-response data are lacking for the general population. However, judging from the limited data for study groups (teenagers, young adults and women), and the assumption that time of exposure can be equated with sound energy, the risk for hearing impairment would be negligible for LAeq,24h values of 70 dBA over a lifetime. To avoid hearing impairment, impulse noise exposures should never exceed 140 dB peak sound pressure in adults, and 120 dB peak sound pressure in children.

3.3. Interference with Speech Communication

Noise interference with speech comprehension results in a large number of personal disabilities, handicaps and behavioural changes. Problems with concentration, fatigue, uncertainty and lack of self-confidence, irritation, misunderstandings, decreased working capacity, problems in human relations, and a number of stress reactions have all been identified (Lazarus 1998). Particularly vulnerable to these types of effects are the hearing impaired, the elderly, children in the process of language and reading acquisition, and individuals who are not familiar with the spoken language (e.g., Lazarus 1998). Thus, vulnerable persons constitute a substantial proportion of a country's population.

Most of the acoustical energy of speech is in the frequency range 100–6 000 Hz, with the most important cue-bearing energy being between 300–3 000 Hz. Speech interference is basically a masking process in which simultaneous, interfering noise renders speech incapable of being understood. The higher the level of the masking noise, and the more energy it contains at the most important speech frequencies, the greater will be the percentage of speech sounds that become indiscernible to the listener. Environmental noise may also mask many other acoustical signals important for daily life, such as door bells, telephone signals, alarm clocks, fire alarms and other warning signals, and music (e.g., Edworthy & Adams 1996). The masking effect of interfering noise in speech discrimination is more pronounced for hearing-impaired persons than for persons with normal hearing, particularly if the interfering noise is composed of speech or babble.

As the sound pressure level of an interfering noise increases, people automatically raise their voice to overcome the masking effect upon speech (increase of vocal effort). This imposes an additional strain on the speaker. For example, in quiet surroundings, the speech level at 1 m distance averages 45–50 dBA, but is 30 dBA higher when shouting. However, even if the interfering noise is moderately loud, most of the sentences during ordinary conversation can still be understood fairly well. Nevertheless, the interpretation required for compensating the masking effect of the interfering sounds, and for comprehending what was said, imposes an additional strain on the listener. One contributing factor could be that speech spoken loudly is more difficult to understand than speech spoken softly, when compared at a constant speech-to-noise ratio (*cf.* Berglund & Lindvall 1995).

Speech levels vary between individuals because of factors such as gender and vocal effort. Moreover, outdoor speech levels decrease by about 6 dB for a doubling in the distance between talker and listener. Speech intelligibility in everyday living conditions is influenced by speech level, speech pronunciation, talker-to-listener distance, sound pressure levels, and to some extent other characteristics of interfering noise, as well as room characteristics (e.g. reverberation). Individual capabilities of the listener, such as hearing acuity and the level of attention of the listener, are also important for the intelligibility of speech. Speech communication is affected also by the reverberation characteristics of the room. For example, reverberation times greater than 1 s produce loss in speech discrimination. Longer reverberation times, especially when combined with high background interfering noise, make speech perception more difficult. Even in a quiet environment, a reverberation time below 0.6 s is desirable for adequate speech intelligibility by vulnerable groups. For example, for older hearing-handicapped persons, the optimal reverberation time for speech intelligibility is 0.3–0.5 s (Plomp 1986).

For complete sentence intelligibility in listeners with normal hearing, the signal-to-noise ratio (i.e. the difference between the speech level and the sound pressure level of the interfering noise) should be 15–18 dBA (Lazarus 1990). This implies that in smaller rooms, noise levels above 35 dBA interferes with the intelligibility of speech (Bradley 1985). Earlier recommendations suggested that sound pressure levels as high as 45 dBA would be acceptable (US EPA 1974). With raised voice (increased vocal effort) sentences may be 100% intelligible for noise levels of up to 55 dBA; and sentences spoken with straining vocal effort can be 100% intelligible with noise levels of about 65 dBA. For speech to be intelligible when listening to complicated messages (at school, listening to foreign languages, telephone conversation), it is recommended that the signal-to-noise ratio should be at least 15 dBA. Thus, with a speech level of 50 dBA, (at 1 m distance this level corresponds to a casual speech level of both women and men), the sound pressure level of interfering noise should not exceed 35 dBA. For vulnerable groups even lower background levels are needed. If it is not possible to meet the strictest criteria for vulnerable persons in sensitive situations (e.g. in classrooms), one should strive for as low background levels as possible.

3.4. Sleep Disturbance

Uninterrupted sleep is known to be a prerequisite for good physiological and mental functioning of healthy persons (Hobson 1989); sleep disturbance, on the other hand, is considered to be a major environmental noise effect. It is estimated that 80-90% of the reported cases of sleep disturbance in noisy environments are for reasons other than noise originating outdoors. For example, sanitary needs; indoor noises from other occupants; worries; illness; and climate (e.g. Reyner & Horne 1995). Our understanding of the impact of noise exposure on sleep stems mainly from experimental research in controlled environments. Field studies conducted with people in their normal living situations are scarce. Most of the more recent field research on sleep disturbance has been conducted for aircraft noise (Fidell et al. 1994 1995a,b 1998; Horne et al. 1994 1995; Maschke et al. 1995 1996; Ollerhead et al. 1992; Passchier-Vermeer 1999). Other field studies have examined the effects of road traffic and railway noise (Griefahn et al. 1996 1998).

The primary sleep disturbance effects are: difficulty in falling asleep (increased sleep latency time); awakenings; and alterations of sleep stages or depth, especially a reduction in the proportion of REM-sleep (REM = rapid eye movement) (Hobson 1989). Other primary physiological effects can also be induced by noise during sleep, including increased blood pressure; increased heart rate; increased finger pulse amplitude; vasoconstriction; changes in respiration; cardiac arrhythmia; and an increase in body movements (cf. Berglund & Lindvall 1995). For each of these physiological effects, both the noise threshold and the noise-response relationships may be different. Different noises may also have different information content and this also could affect physiological threshold and noise-response relationships (Edworthy 1998).

Exposure to night-time noise also induces secondary effects, or so-called after effects. These are effects that can be measured the day following the night-time exposure, while the individual is awake. The secondary effects include reduced perceived sleep quality; increased fatigue; depressed mood or well-being; and decreased performance (Öhrström 1993a; Passchier-Vermeer 1993; Carter 1996; Pearsons et al. 1995; Pearsons 1998).

Long-term effects on psychosocial well-being have also been related to noise exposure during the night (Öhrström 1991). Noise annoyance during the night-time increased the total noise annoyance expressed by people in the following 24 h. Various studies have also shown that people living in areas exposed to night-time noise have an increased use of sedatives or sleeping pills. Other frequently reported behavioural effects of night-time noise include closed bedroom windows and use of personal hearing protection. Sensitive groups include the elderly, shift workers, persons especially vulnerable to physical or mental disorders and other individuals with sleeping difficulties.

Questionnaire data indicate the importance of night-time noise on the perception of sleep quality. A recent Japanese investigation was conducted for 3 600 women (20–80 years old) living in eight roadside zones with different road traffic noise. The results showed that four measures of perceived sleep quality (difficulty in falling asleep; waking up during sleep; waking up too early; feelings of sleeplessness one or more days a week) correlated significantly with the average traffic volumes during night-time. An in-depth investigation of 19 insomnia cases and their matched controls (age,work) measured outdoor and indoor sound pressure levels during sleep (Kageyama et al. 1997). The study showed that road traffic noise in excess of 30 dB LAeq for nighttime induced sleep disturbance, consistent with the results of Öhrström (1993b).

Meta-analyses of field and laboratory studies have suggested that there is a relationship between the SEL for a single night-time noise event and the percentage of people awakened, or who showed sleep stage changes (e.g. Ollerhead et al. 1992; Passchier-Vermeer 1993; Finegold et al. 1994; Pearsons et al. 1995). All of these studies assumed that the number of awakenings per night for each SEL value is proportional to the number of night-time noise events. However, the results have been criticized for methodological reasons. For example, there were small groups of sleepers; too few original studies; and indoor exposure was estimated from outdoor sound pressure levels (NRC-CNRC 1994; Beersma & Altena 1995; Vallet 1998). The most important result of the meta-analyses is that there is a clear difference in the dose-response curves for laboratory and field studies, and that noise has a lower effect under real-life conditions (Pearsons et al. 1995; Pearsons 1998).

However, this result has been questioned, because the studies were not controlled for such things as the sound insulation of the buildings, and the number of bedrooms with closed windows. Also, only two indicators of sleep disturbance were considered (awakening and sleep stage changes). The meta-analyses thus neglected other important sleep disturbance effects (Öhrström 1993b; Carter et al. 1994a; Carter et al. 1994b; Carter 1996; Kuwano et al. 1998). For example, for road traffic noise, perceived sleep quality is related both to the time needed to fall asleep and the total sleep time (Öhrström & Björkman 1988). Individuals who are more sensitive to noise (as assessed by different questionnaires) report worse sleep quality both in field studies and in laboratory studies.

A further criticism of the meta-analyses is that laboratory experiments have shown that habituation to night-time noise events occurs, and that noise-induced awakening decreases with increasing number of sound exposures per night. This is in contrast to the assumption used in the meta-analyses, that the percentage of awakenings is linearly proportional to the number of night-time noise events. Studies have also shown that the frequency of noise-induced awakenings decreases for at least the first eight consecutive nights. So far, habituation has been shown for awakenings, but not for heart rate and after effects such as perceived sleep quality, mood and performance (Öhrström and Björkman 1988).

Other studies suggest that it is the difference in sound pressure levels between a noise event and background, rather than the absolute sound pressure level of the noise event, that determines the reaction probability. The time interval between two noise events also has an important influence of the probability of obtaining a response (Griefahn 1977; *cf.* Berglund & Lindvall 1995). Another possible factor is the person's age, with older persons having an increased probability of awakening. However, one field study showed that noise-induced awakenings are independent of age (Reyner & Horne 1995).

For a good sleep, it is believed that indoor sound pressure levels should not exceed approximately 45 dB LAmax more than 10–15 times per night (Vallet & Vernet 1991), and most studies show an increase in the percentage of awakenings at SEL values of 55–60 dBA (Passchier-Vermeer 1993; Finegold et al. 1994; Pearsons et al. 1995). For intermittent events that approximate aircraft noise, with an effective duration of 10–30 s, SEL values of 55–60 dBA correspond to a LAmax value of 45 dB. Ten to 15 of these events during an eight-hour night-time implies an LAeq,8h of 20–25 dB. This is 5–10 dB below the LAeq,8h of 30 dB for continuous night-time noise exposure, and shows that the intermittent character of noise has to be taken into account when setting night-time limits for noise exposure. For example, this can be achieved by considering the number of noise events and the difference between the maximum sound pressure level and the background level of these events.

Special attention should also be given to the following considerations:

a. Noise sources in an environment with a low background noise level. For example, night-traffic in suburban residential areas.

b. Environments where a combination of noise and vibrations are produced. For example, railway noise, heavy duty vehicles.

c. Sources with low-frequency components. Disturbances may occur even though the sound pressure level during exposure is below 30 dBA.

If negative effects on sleep are to be avoided the equivalent sound pressure level should not exceed 30 dBA indoors for continuous noise. If the noise is not continuous, sleep disturbance correlates best with LAmax and effects have been observed at 45 dB or less. This is particularly true if the background level is low. Noise events exceeding 45 dBA should therefore be limited if possible. For sensitive people an even lower limit would be preferred. It should be noted that it should be possible to sleep with a bedroom window slightly open (a reduction from outside to inside of 15 dB). To prevent sleep disturbances, one should thus consider the equivalent sound pressure level and the number and level of sound events. Mitigation targeted to the first part of the night is believed to be effective for the ability to fall asleep.

3.5. Cardiovascular and Physiological Effects

Epidemiological and laboratory studies involving workers exposed to occupational noise, and general populations (including children) living in noisy areas around airports, industries and noisy streets, indicate that noise may have both temporary and permanent impacts on physiological functions in humans. It has been postulated that noise acts as an environmental stressor (for a review see Passchier-Vermeer 1993; Berglund & Lindvall 1995). Acute noise exposures activate the autonomic and hormonal systems, leading to temporary changes such as increased blood pressure, increased heart rate and vasoconstriction. After prolonged exposure, susceptible individuals in the general population may develop permanent effects, such as hypertension and ischaemic heart disease associated with exposures to high sound pressure levels (for a review see Passchier-Vermeer 1993; Berglund & Lindvall 1995). The magnitude and duration of the effects are determined in part by individual characteristics, lifestyle behaviours and environmental conditions. Sounds also evoke reflex responses, particularly when they are unfamiliar and have a sudden onset.

Laboratory experiments and field quasi-experiments show that if noise exposure is temporary, the physiological system usually returns - after the exposure terminates - to a normal (pre-exposure) state within a time in the range of the exposure duration. If the exposure is of sufficient intensity and unpredictability, cardiovascular and hormonal responses may appear, including increases in heart rate and peripheral vascular resistance; changes in blood pressure, blood viscosity and blood lipids; and shifts in electrolyte balance (Mg/Ca) and hormonal levels (epinephrine, norepinephrine, cortisol). The first four effects are of interest because of noise-related coronary heart disease (Ising & Günther 1997). Laboratory and clinical data suggest that noise may significantly elevate gastrointestinal motility in humans.

By far the greatest number of occupational and community noise studies have focused on the possibility that noise may be a risk factor for cardiovascular disease. Many studies in occupational settings have indicated that workers exposed to high levels of industrial noise for 5–30 years have increased blood pressure and statistically significant increases in risk for hypertension, compared to workers in control areas (Passchier-Vermeer 1993). In contrast, only a few studies on environmental noise have shown that populations living in noisy areas around airports and on noisy streets have an increased risk for hypertension. The overall evidence suggests a weak association between long-term environmental noise exposure and hypertension (HCN 1994; Berglund & Lindvall 1995; IEH 1997), and no dose-response relationships could be established.

Recently, an updated summary of available studies for ischaemic heart disease has been presented (Babisch 1998a; Babisch 1998b; Babisch et al. 1999; see also Thompson 1996). The studies reviewed include case-control and cross-sectional designs, as well as three longitudinal studies. However, it has not yet been possible to conduct the most advanced quantitative integrated analysis of the available studies. Relative risks and their confidence intervals could be estimated only for the classes of high noise levels (mostly >65 dBA during daytime) and low levels (mostly <55 dBA during daytime), rather than a range of exposure levels. For methodological reasons identified in the meta-analysis, a cautious interpretation of the results is warranted (Lercher et al. 1998).

Prospective studies that controlled for confounding factors suggest an increase in ischaemic heart disease when the noise levels exceed 65–70 dB for LAeq (6–22). (For road traffic noise, the difference between LAeq (6-22h) and LAeq,24h usually is of the order of 1.5 dB). When orientation of the bedroom, window opening habits and years of exposure are taken into account, the risk of heart disease is slightly higher (Babisch et al. 1998; Babisch et al. 1999). However, disposition, behavioural and environmental factors were not sufficiently accounted for in the analyses carried out to date. In epidemiological studies the lowest level at which traffic noise had an effect on ischaemic heart disease was 70 dB for LAeq,24h (HCN 1994).

The overall conclusion is that cardiovascular effects are associated with long-term exposure to LAeq,24h values in the range of 65–70 dB or more, for both air- and road-traffic noise. However, the associations are weak and the effect is somewhat stronger for ischaemic heart disease than for hypertension. Nevertheless, such small risks are potentially important because a large number of persons are currently exposed to these noise levels, or are likely to be exposed in the future. Furthermore, only the average risk is considered and sensitive subgroups of the populations have not been sufficiently characterized. For example, a 10% increase in risk factors (a relative risk of 1.1) may imply an increase of up to 200 cases per 100 000 people at risk per year. Other observed psychophysiological effects, such as changes in stress hormones, magnesium levels, immunological indicators, and gastrointestinal disturbances are too inconsistent for conclusions to be drawn about the influence of noise pollution.

3.6. Mental Health Effects

Mental health is defined as the absence of identifiable psychiatric disorders according to current norms (Freeman 1984). Environmental noise is not believed to be a direct cause of mental illness, but it is assumed that it accelerates and intensifies the development of latent mental disorder. Studies on the adverse effects of environmental noise on mental health cover a variety of symptoms, including anxiety; emotional stress; nervous complaints; nausea; headaches; instability; argumentativeness; sexual impotency; changes in mood; increase in social conflicts, as well as general psychiatric disorders such as neurosis, psychosis and hysteria. Large-scale population studies have suggested associations between noise exposure and a variety of mental health indicators, such as single rating of well-being; standard psychological symptom profiles; the intake of psychotropic drugs; and consumption of tranquilizers and sleeping pills. Early studies showed a weak association between exposure to aircraft noise and psychiatric hospital admissions in the general population surrounding an airport (see also Berglund & Lindvall 1995). However, the studies have been criticized because of problems in selecting variables and in response bias (Halpern 1995).

Exposure to high levels of occupational noise has been associated with development of neurosis and irritability; and exposure to high levels of environmental noise with deteriorated mental health (Stansfeld 1992). However, the findings on environmental noise and mental health effects are inconclusive (HCN 1994; Berglund & Lindvall 1995; IEH 1997). The only longitudinal study in this field (Stansfeld et al. 1996) showed an association between the initial level of road traffic noise and minor psychiatric disorders, although the association for increased anxiety was weak and non-linear. It turned out that psychiatric disorders are associated with noise sensitivity, rather than with noise exposure, and the association was found to disappear after adjustment for baseline trait anxiety. These and other results show the importance of taking vulnerable groups into account, because they may not be able to cope sufficiently with unwanted environmental noise (e.g. Stansfeld 1992). This is particularly true of children, the elderly and people with preexisting illnesses, especially depression (IEH 1997). Despite the weaknesses of the various studies, the possibility that community noise has adverse effects on mental health is suggested by studies on the use of medical drugs, such as tranquilizers and sleeping pills, on psychiatric symptoms and on mental hospital admission rates.

3.7. The Effects of Noise on Performance

It has been documented in both laboratory subjects and in workers exposed to occupational noise, that noise adversely affects cognitive task performance. In children, too, environmental noise impairs a number of cognitive and motivational parameters (Cohen et al. 1980; Evans & Lepore 1993; Evans 1998; Hygge et al. 1998; Haines et al. 1998). However, there are no published studies on whether environmental noise at home also impairs cognitive performance in adults. Accidents may also be an indicator of performance deficits. The few field studies on the effects of noise on performance and safety showed that noise may produce some task impairment and increase the number of errors in work, but the effects depend on the type of noise and the task being performed (Smith 1990).

Laboratory and workplace studies showed that noise can act as a distracting stimulus. Also, impulsive noise events (e.g. sonic booms) may produce disruptive effects as a result of startle responses. In the short term, noise-induced arousal may produce better performance of simple tasks, but cognitive performance deteriorates substantially for more complex tasks (i.e. tasks that require sustained attention to details or to multiple cues; or tasks that demand a large capacity of working memory, such as complex analytical processes). Some of the effects are related to loss in auditory comprehension and language acquisition, but others are not (Evans & Maxwell 1997). Among the cognitive effects, reading, attention, problem solving and memory are most strongly affected by noise. The observed effects on motivation, as measured by persistence with a difficult cognitive task, may either be independent or secondary to the aforementioned cognitive impairments.

Two types of memory deficits have been identified under experimental noise exposure: incidental memory and memory for materials that the observer was not explicitly instructed to focus on during a learning phase. For example, when presenting semantic information to subjects in the presence of noise, recall of the information content was unaffected, but the subjects were significantly less able to recall, for example, in which corner of the slide a word had been located. There is also some evidence that the lack of "helping behavior" that was noted under experimental noise exposure may be related to inattention to incidental cues (Berglund & Lindvall 1995). Subjects appear to process information faster in working memory during noisy performance conditions, but at a cost of available memory capacity. For example, in a running memory task, in which subjects were required to recall in sequence letters that they had just heard, subjects recalled recent items better under noisy conditions, but made more errors farther back into the list.

Experimental noise exposure consistently produces negative after-effects on performance (Glass & Singer 1972). Following exposure to aircraft noise, schoolchildren in the vicinity of Los Angeles airport were found to be deficient in proofreading, and in persistence with challenging puzzles (Cohen et al. 1980). The uncontrollability of noise, rather than the intensity of the noise, appears to be the most critical variable. The only prospective study on noise-exposed schoolchildren, designed around the move of the Munich airport (Hygge et al. 1996; Evans et al. 1998), confirmed the results of laboratory and workplace studies in adults, as well the results of the Los Angeles airport study with children (Cohen et al. 1980). An important finding was that some of the adaptation strategies for dealing with aircraft noise, such as tuning out or ignoring the noise, and the effort necessary to maintain task performance, come at a price. There is heightened sympathetic arousal, as indicated by increased levels of stress hormone, and elevation of resting blood pressure (Evans et al. 1995; Evans et al. 1998). Notably, in the airport studies reported above, the adverse effects were larger in children with lower school achievement.

For aircraft noise, it has been shown that chronic exposure during early childhood appears to impair reading acquisition and reduces motivational capabilities. Of recent concern are concomitant psychophysiological changes (blood pressure and stress hormone levels). Evidence indicates that the longer the exposure, the greater the damage. It seems clear that daycare centers and schools should not be located near major sources of noise, such as highways, airports and industrial sites.

3.8. Effects of Noise on Residential Behaviour and Annoyance

Noise annoyance is a global phenomenon. A definition of annoyance is "a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them" (Lindvall & Radford 1973; Koelega 1987). However, apart from "annoyance", people may feel a variety of negative emotions when exposed to community noise, and may report anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation, or exhaustion (Job 1993; Fields et al. 1997 1998). Thus, although the term annoyance does not cover all the negative reactions, it is used for convenience in this document.

Noise can produce a number of social and behavioural effects in residents, besides annoyance (for review see Berglund & Lindvall 1995). The social and behavioural effects are often complex, subtle and indirect. Many of the effects are assumed to be the result of interactions with a number of non-auditory variables. Social and behavioural effects include changes in overt everyday behaviour patterns (e.g. closing windows, not using balconies, turning TV and radio to louder levels, writing petitions, complaining to authorities); adverse changes in social behaviour (e.g. aggression, unfriendliness, disengagement, non-participation); adverse changes in social indicators (e.g. residential mobility, hospital admissions, drug consumption, accident rates); and changes in mood (e.g. less happy, more depressed).

Although changes in social behaviour, such as a reduction in helpfulness and increased aggressiveness, are associated with noise exposure, noise exposure alone is not believed to be sufficient to produce aggression. However, in combination with provocation or pre-existing anger or hostility, it may trigger aggression. It has also been suspected that people are less willing to help, both during exposure and for a period after exposure. Fairly consistent evidence shows that noise above 80 dBA is associated with reduced helping behaviour and increased aggressive behaviour. Particularly, there is concern that high-level continuous noise exposures may contribute to the susceptibility of schoolchildren to feelings of helplessness (Evans & Lepore 1993)

The effects of community noise can be evaluated by assessing the extent of annoyance (low, moderate, high) among exposed individuals; or by assessing the disturbance of specific activities, such as reading, watching television and communication. The relationship between annoyance and activity disturbances is not necessarily direct and there are examples of situations where the extent of annoyance is low, despite a high level of activity disturbance. For aircraft noise, the most important effects are interference with rest, recreation and watching television. This is in contrast to road traffic noise, where sleep disturbance is the predominant effect (Berglund & Lindvall 1995).

A number of studies have shown that equal levels of traffic and industrial noises result in different magnitudes of annoyance (Hall et al. 1981; Griffiths 1983; Miedema 1993; Bradley 1994a; Miedema & Vos 1998). This has led to criticism (e.g. Kryter 1994; Bradley 1994a) of averaged dose-response curves determined by meta-analysis, which assumed that all traffic noises are the same (Fidell et al. 1991; Fields 1994a; Finegold et al. 1994). Schultz (1978) and Miedema & Vos (1998) have synthesized curves of annoyance associated with three types of traffic noise (road, air, railway). In these curves, the percentage of people highly or moderately annoyed was related to the day and night continuous equivalent sound level, L_{dn}. For each of the three types of traffic noise, the percentage of highly annoyed persons in a population started to increase at an L_{dn} value of 42 dBA, and the percentage of moderately annoyed persons at an L_{dn} value of 37 dBA (Miedema & Vos 1998). Aircraft noise produced a stronger annoyance response than road traffic, for the same L_{dn} exposure, consistent with earlier analyses (Kryter 1994; Bradley 1994a). However, caution should be exercised when interpreting synthesized data from different studies, since five major parameters should be randomly distributed for the analyses to be valid: personal, demographic, and lifestyle factors, as well as the duration of noise exposure and the population experience with noise (Kryter 1994).

Annoyance in populations exposed to environmental noise varies not only with the acoustical characteristics of the noise (source, exposure), but also with many non-acoustical factors of social, psychological, or economic nature (Fields 1993). These factors include fear associated with the noise source, conviction that the noise could be reduced by third parties, individual noise sensitivity, the degree to which an individual feels able to control the noise (coping strategies), and whether the noise originates from an important economic activity. Demographic variables such as age, sex and socioeconomic status, are less strongly associated with annoyance. The correlation between noise exposure and general annoyance is much higher at the group level than at the individual level, as might be expected. Data from 42 surveys showed that at the group level about 70% of the variance in annoyance is explained by noise exposure characteristics, whereas at the individual level it is typically about 20% (Job 1988).

When the type and amount of noise exposure is kept constant in the meta-analyses, differences between communities, regions and countries still exist (Fields 1990; Bradley 1996). This is well demonstrated by a comparison of the dose-response curve determined for road-traffic noise

(Miedema & Vos 1998) and that obtained in a survey along the North-South transportation route through the Austrian Alps (Lercher 1998b). The differences may be explained in terms of the influence of topography and meteorological factors on acoustical measures, as well as the low background noise level on the mountain slopes.

Stronger reactions have been observed when noise is accompanied by vibrations and contains low frequency components (Paulsen & Kastka 1995; Öhrström 1997; for review see Berglund et al. 1996), or when the noise contains impulses, such as shooting noise (Buchta 1996; Vos 1996; Smoorenburg 1998). Stronger, but temporary, reactions also occur when noise exposure is increased over time, in comparison to situations with constant noise exposure (e.g. HCN 1997; Klæboe et al. 1998). Conversely, for road traffic noise, the introduction of noise protection barriers in residential areas resulted in smaller reductions in annoyance than expected for a stationary situation (Kaštka et al. 1995).

To obtain an indicator for annoyance, other methods of combining parameters of noise exposure have been extensively tested, in addition to metrics such as LAeq,24h and L_{dn}. When used for a set of community noises, these indicators correlate well both among themselves and with LAeq,24h or L_{dn} values (e.g. HCN 1997). Although LAeq,24h and L_{dn} are in most cases acceptable approximations, there is a growing concern that all the component parameters of the noise should be individually assessed in noise exposure investigations, at least in the complex cases (Berglund & Lindvall 1995).

3.9. The Effects of Combined Noise Sources

Many acoustical environments consist of sounds from more than one source. For these environments, health effects are associated with the total noise exposure, rather than with the noise from a single source (WHO 1980b). When considering hearing impairment, for example, the total noise exposure can be expressed in terms of LAeq,24h for the combined sources. For other adverse health effects, however, such a simple model most likely will not apply. It is possible that some disturbances (e.g. speech interference, sleep disturbance) may more easily be attributed to specific noises. In cases where one noise source clearly dominates, the magnitude of an effect may be assessed by taking into account the dominant source only (HCN 1997). Furthermore, at a policy level, there may be little need to identify the adverse effect of each specific noise, unless the responsibility for these effects is to be shared among several polluters (*cf.* The Polluter Pays Principle in Chapter 5, UNCED 1992).

There is no consensus on a model for assessing the total annoyance due to a combination of environmental noise sources. This is partly due to a lack of research into the temporal patterns of combined noises. The current approach for assessing the effects of "mixed noise sources" is limited to data on "total annoyance" transformed to mathematical principles or rules of thumb (Ronnebaum et al. 1996; Vos 1992; Miedema 1996; Berglund & Nilsson 1997). Models to assess the total annoyance of combinations of environmental noises may not be applicable to those health effects for which the mechanisms of noise interaction are unknown, and for which different cumulative or synergistic effects cannot be ruled out. When noise is combined with different types of environmental agents, such as vibrations, ototoxic chemicals, or chemical odours, again there is insufficient knowledge to accurately assess the combined effects on health

(Berglund & Lindvall 1995; HCN 1994; Miedema 1996; Zeichart 1998; Passchier-Vermeer & Zeichart 1998). Therefore, caution should be exercised when trying to predict the adverse health effects of combined factors in residential populations.

The evidence on low-frequency noise is sufficiently strong to warrant immediate concern. Various industrial sources emit continuous low-frequency noise (compressors, pumps, diesel engines, fans, public works); and large aircraft, heavy-duty vehicles and railway traffic produce intermittent low-frequency noise. Low-frequency noise may also produce vibrations and rattles as secondary effects. Health effects due to low-frequency components in noise are estimated to be more severe than for community noises in general (Berglund et al. 1996). Since A-weighting underestimates the sound pressure level of noise with low-frequency components, a better assessment of health effects would be to use C-weighting.

In residential populations heavy noise pollution will most certainly be associated with a combination of health effects. For example, cardiovascular disease, annoyance, speech interference at work and at home, and sleep disturbance. Therefore, it is important that the total adverse health load over 24 hours be considered and that the precautionary principle for sustainable development is applied in the management of health effects (see Chapter 5).

3.10. Vulnerable Groups

Protective standards are essentially derived from observations on the health effects of noise on "normal" or "average" populations. The participants of these investigations are selected from the general population and are usually adults. Sometimes, samples of participants are selected because of their easy availability. However, vulnerable groups of people are typically underrepresented. This group includes people with decreased personal abilities (old, ill, or depressed people); people with particular diseases or medical problems; people dealing with complex cognitive tasks, such as reading acquisition; people who are blind or who have hearing impairment; fetuses, babies and young children; and the elderly in general (Jansen 1987; AAP 1997). These people may be less able to cope with the impacts of noise exposure and be at greater risk for harmful effects.

Persons with impaired hearing are the most adversely affected with respect to speech intelligibility. Even slight hearing impairments in the high-frequency range may cause problems with speech perception in a noisy environment. From about 40 years of age, people typically demonstrate an impaired ability to understand difficult, spoken messages with low linguistic redundancy. Therefore, based on interference with speech perception, a majority of the population belongs to the vulnerable group.

Children have also been identified as vulnerable to noise exposure (see Agenda 21: UNCED 1992). The evidence on noise pollution and children's health is strong enough to warrant monitoring programmes at schools and preschools to protect children from the effects of noise. Follow up programmes to study the main health effects of noise on children, including effects on speech perception and reading acquisition, are also warranted in heavily noise polluted areas (Cohen et al. 1986; Evans et al. 1998).

The issue of vulnerable subgroups in the general population should thus be considered when developing regulations or recommendations for the management of community noise. This consideration should take into account the types of effects (communication, recreation, annoyance, etc.), specific environments (*in utero*, incubator, home, school, workplace, public institutions, etc.) and specific lifestyles (listening to loud music through headphones, or at discotheques and festivals; motor cycling, etc.).

4. Guideline Values

4.1. Introduction

The human ear and lower auditory system continuously receive stimuli from the world around us. However, this does not mean that all the acoustical inputs are necessarily disturbing or have harmful effects. This is because the auditory nerve provides activating impulses to the brain that enable us to regulate the vigilance and wakefulness necessary for optimal performance. On the other hand, there are scientific reports that a completely silent world can have harmful effects, because of sensory deprivation. Thus, both too little sound and too much sound can be harmful. For this reason, people should have the right to decide for themselves the quality of the acoustical environment they live in.

Exposure to noise from various sources is most commonly expressed as the average sound pressure level over a specific time period, such as 24 hours. This means that identical average sound levels for a given time period could be derived from either a large number of sound events with relatively low, almost inaudible levels, or from a few events with high sound levels. This technical concept does not fully agree with common experience on how environmental noise is experienced, or with the neurophysiological characteristics of the human receptor system.

Human perception of the environment through vision, hearing, touch, smell and taste is characterized by a good discrimination of stimulus intensity differences, and by a decaying response to a continuous stimulus (adaptation or habituation). Single sound events cannot be discriminated if the interval between events drops below a threshold value; if this occurs, the sound is interpreted as continuous. These characteristics are linked to survival, since new and different stimuli with low probability and high information value indicate warnings. Thus, when assessing the effects of environmental noise on people it is relevant to consider the importance of the background noise level, the number of events, and the noise exposure level independently.

Community noise studies have traditionally considered noise annoyance from single specific sources such as aircraft, road traffic or railways. In recent years, efforts have been made to compare the results from road traffic, aircraft and railway surveys. Data from a number of sources show that aircraft noise is more annoying than road traffic noise, which, in turn, is more annoying than railway noise. However, there is not a clear understanding of the mechanisms that create these differences. Some populations may also be at greater risk for the harmful effects of noise. Young children (especially during language acquisition), the blind, and perhaps fetuses are examples of such populations. There are no definite conclusions on this topic, but the reader should be alerted that guidelines in this report are developed for the population at large; guidelines for potentially more vulnerable groups are addressed only to a limited extent.

In the following, guideline values are summarized with regard to specific environments and effects. For each environment and situation, the guideline values take into consideration the identified health effects and are set, based on the lowest levels of noise that affect health (critical health effect). Guideline values typically correspond to the lowest effect level for general populations, such as those for indoor speech intelligibility. By contrast, guideline values for annoyance have been set at 50 or 55 dBA, representing daytime levels below which a majority of the adult population will be protected from becoming moderately or seriously annoyed, respectively.

In these *Guidelines for Community Noise* only guideline values are presented. These are essentially values for the onset of health effects from noise exposure. It would have been preferred to establish guidelines for exposure-response relationships. Such relationships would indicate the effects to be expected if standards were set above the WHO guideline values and would facilitate the setting of standards for sound pressure levels (noise immission standards). However, exposure-response relationships could not be established as the scientific literature is very limited. The best-studied exposure-response relationship is that between L_{dn} and annoyance (WHO 1995a; Berglund & Lindvall 1995; Miedema & Vos 1998). Even the most recent relationships between integrated noise levels and the percentage of highly or moderately annoyed people are still being scrutinized. The results of a forthcoming meta-analysis are expected to be published in the near future (Miedema, personal communication).

4.2. Specific Effects

4.2.1. Interference with communication

Noise tends to interfere with auditory communication, in which speech is a most important signal. However, it is also vital to be able to hear alarming and informative signals such as door bells, telephone signals, alarm clocks, fire alarms etc., as well as sounds and signals involved in occupational tasks. The effects of noise on speech discrimination have been studied extensively and deal with this problem in lexical terms (mostly words but also sentences). For communication distances beyond a few metres, speech interference starts at sound pressure levels below 50 dB for octave bands centered on the main speech frequencies at 500, 1 000 and 2 000 Hz. It is usually possible to express the relationship between noise levels and speech intelligibility in a single diagram, based on the following assumptions and empirical observations, and for speaker-to-listener distance of about 1 m:

a. Speech in relaxed conversation is 100% intelligible in background noise levels of about 35 dBA, and can be understood fairly well in background levels of 45 dBA.

b. Speech with more vocal effort can be understood when the background sound pressure level is about 65 dBA.

A majority of the population belongs to groups sensitive to interference with speech perception. Most sensitive are the elderly and persons with impaired hearing. Even slight hearing impairments in the high-frequency range may cause problems with speech perception in a noisy environment. From about 40 years of age, people demonstrate impaired ability to interpret difficult, spoken messages with low linguistic redundancy, when compared to people aged 20–30 years. It has also been shown that children, before language acquisition has been completed, have more adverse effects than young adults to high noise levels and long reverberation times.

For speech outdoors and for moderate distances, the sound level drops by approximately 6 dB for a doubling of the distance between speaker and listener. This relationship is also applicable to indoor conditions, but only up to a distance of about 2 m. Speech communication is affected also by the reverberation characteristics of the room, and reverberation times beyond 1 s can produce a loss in speech discrimination. A longer reverberation time combined with background noise makes speech perception still more difficult.

Speech signal perception is of paramount importance, for example, in classrooms or conference rooms. To ensure any speech communication, the signal-to-noise relationship should exceed zero dB. But when listening to complicated messages (at school, listening to foreign languages, telephone conversation) the signal-to-noise ratio should be at least 15 dB. With a voice level of 50 dBA (at 1 m distance this corresponds on average to a casual voice level in both women and men), the background level should not exceed 35 dBA. This means that in classrooms, for example, one should strive for as low background levels as possible. This is particularly true when listeners with impaired hearing are involved, for example, in homes for the elderly. Reverberation times below 1 s are necessary for good speech intelligibility in smaller rooms; and even in a quiet environment a reverberation time below 0.6 s is desirable for adequate speech intelligibility for sensitive groups.

4.2.2. Noise-induced hearing impairment

The ISO Standard 1999 (ISO 1990) gives a method of calculating noise-induced hearing impairment in populations exposed to all types of occupational noise (continuous, intermittent, impulse). However, noise-induced hearing impairment is by no means restricted to occupational situations alone. High noise levels can also occur in open-air concerts, discotheques, motor sports, shooting ranges, and from loudspeakers or other leisure activities in dwellings. Other loud noise sources, such as music played back in headphones and impulse noise from toys and fireworks, are also important. Evidence strongly suggests that the calculation method from ISO Standard 1999 for occupational noise (ISO 1990) should also be used for environmental and leisure time noise exposures. This implies that long term exposure to LAeq,24h of up to 70 dBA will not result in hearing impairment. However, given the limitations of the various underlying studies, care should be taken with respect to the following:

a. Data from animal experiments indicate that children may be more vulnerable in acquiring noise-induced hearing impairment than adults.

b. At very high instantaneous sound pressure levels mechanical damage to the ear may occur (Hanner & Axelsson 1988). Occupational limits are set at peak sound pressure levels of 140 dBA (EU 1986a). For adults, this same limit is assumed to be in order for exposure to environmental and leisure time noise. In the case of children, however, considering their habits while playing with noisy toys, peak sound pressure levels should never exceed 120 dBA.

c. For shooting noise with LAeq,24h over 80 dB, studies on temporary threshold shift suggest there is the possibility of an increased risk for noise-induced hearing impairment (Smoorenburg 1998).

d. The risk for noise-induced hearing impairment increases when noise exposure is combined with vibrations, ototoxic drugs or chemicals (Fechter 1999). In these circumstances, long-term exposure to LAeq,24h of 70 dB may induce small hearing impairments.

e. It is uncertain whether the relationships in ISO Standard 1999 (ISO 1990) are applicable to environmental sounds having a short rise time. For example, in the case of military low-altitude flying areas (75–300 m above ground) LAmax values of 110–130 dB occur within seconds after onset of the sound.

In conclusion, dose-response data are lacking for the general population. However, judging from the limited data for study groups (teenagers, young adults and women), and on the assumption that time of exposure can be equated with sound energy, the risk for hearing impairment would be negligible for LAeq,24h values of 70 dB over a lifetime. To avoid hearing impairment, impulse noise exposures should never exceed a peak sound pressure of 140 dB peak in adults, and 120 dB in children.

4.2.3. Sleep disturbance effects

Electrophysiological and behavioral methods have demonstrated that both continuous and intermittent noise indoors lead to sleep disturbance. The more intense the background noise, the more disturbing is its effect on sleep. Measurable effects on sleep start at background noise levels of about 30 dB LAeq. Physiological effects include changes in the pattern of sleep stages, especially a reduction in the proportion of REM sleep. Subjective effects have also been identified, such as difficulty in falling asleep, perceived sleep quality, and adverse after-effects such as headache and tiredness. Sensitive groups mainly include elderly persons, shift workers and persons with physical or mental disorders.
Where noise is continuous, the equivalent sound pressure level should not exceed 30 dBA indoors, if negative effects on sleep are to be avoided. When the noise is composed of a large proportion of low-frequency sounds a still lower guideline value is recommended, because low-frequency noise (e.g. from ventilation systems) can disturb rest and sleep even at low sound pressure levels. It should be noted that the adverse effect of noise partly depends on the nature of the source. A special situation is for newborns in incubators, for which the noise can cause sleep disturbance and other health effects.

If the noise is not continuous, LAmax or SEL are used to indicate the probability of noise-induced awakenings. Effects have been observed at individual LAmax exposures of 45 dB or less. Consequently, it is important to limit the number of noise events with a LAmax exceeding 45 dB. Therefore, the guidelines should be based on a combination of values of 30 dB LAeq,8h and 45 dB LAmax. To protect sensitive persons, a still lower guideline value would be preferred when the background level is low. Sleep disturbance from intermittent noise events increases with the maximum noise level. Even if the total equivalent noise level is fairly low, a small number of noise events with a high maximum sound pressure level will affect sleep.

Therefore, to avoid sleep disturbance, guidelines for community noise should be expressed in terms of equivalent sound pressure levels, as well as LAmax/SEL and the number of noise events. Measures reducing disturbance during the first part of the night are believed to be the most effective for reducing problems in falling asleep.

4.2.4. Cardiovascular and psychophysiological effects

Epidemiologial studies show that cardiovascular effects occur after long-term exposure to noise (aircraft and road traffic) with LAeq,24h values of 65–70 dB. However, the associations are weak. The association is somewhat stronger for ischaemic heart disease than for hypertension. Such small risks are important, however, because a large number of persons are currently exposed to these noise levels, or are likely to be exposed in the future. Other possible effects, such as changes in stress hormone levels and blood magnesium levels, and changes in the immune system and gastro-intestinal tract, are too inconsistent to draw conclusions. Thus, more research is required to estimate the long-term cardiovascular and psychophysiological risks due to noise. In view of the equivocal findings, no guideline values can be given.

4.2.5. Mental health effects

Studies that have examined the effects of noise on mental health are inconclusive and no guideline values can be given. However, in noisy areas, it has been observed that there is an increased use of prescription drugs such as tranquilizers and sleeping pills, and an increased frequency of psychiatric symptoms and mental hospital admissions. This strongly suggests that adverse mental health effects are associated with community noise.

4.2.6. Effects on performance

The effects of noise on task performance have mainly been studied in the laboratory and to some extent in work situations. But there have been few, if any, detailed studies on the effects of noise on human productivity in community situations. It is evident that when a task involves auditory signals of any kind, noise at an intensity sufficient to mask or interfere with the perception of these signals will also interfere with the performance of the task. A novel event, such as the start of an unfamiliar noise, will also cause distraction and interfere with many kinds of tasks. For example, impulsive noises such as sonic booms can produce disruptive effects as the result of startle responses; and these types of responses are more resistant to habituation.

Mental activities involving high load in working memory, such as sustained attention to multiple cues or complex analysis, are all directly sensitive to noise and performance suffers as a result. Some accidents may also be indicators of noise-related effects on performance. In addition to the direct effects on performance, noise also has consistent after-effects on cognitive performance with tasks such as proof-reading, and on persistence with challenging puzzles. In contrast, the performance of tasks involving either motor or monotonous activities is not always degraded by noise.

Chronic exposure to aircraft noise during early childhood appears to damage reading acquisition. Evidence indicates that the longer the exposure, the greater the damage. Although there is insufficient information on these effects to set specific guideline values, it is clear that day-care centres and schools should not be located near major noise sources, such as highways, airports and industrial sites.

4.2.7. Annoyance responses

The capacity of a noise to induce annoyance depends upon many of its physical characteristics, including its sound pressure level and spectral characteristics, as well as the variations of these properties over time. However, annoyance reactions are sensitive to many non-acoustical factors of social, psychological or economic nature, and there are also considerable differences in individual reactions to the same noise. Dose-response relations for different types of traffic noise (air, road and railway) clearly demonstrate that these noises can cause different annoyance effects at equal LAeq,24h values. And the same type of noise, such as that found in residential areas around airports, can also produce different annoyance responses in different countries.

The annoyance response to noise is affected by several factors, including the equivalent sound pressure level and the highest sound pressure level of the noise, the number of such events, and the time of day. Methods for combining these effects have been extensively studied. The results are not inconsistent with the simple, physically based equivalent energy theory, which is represented by the LAeq noise index.

Annoyance to community noise varies with the type of activity producing the noise. Speech communication, relaxation, listening to radio and TV are all examples of noise-producing activities. During the daytime, few people are seriously annoyed by activities with LAeq levels below 55 dB; or moderately annoyed with LAeq levels below 50 dB. Sound pressure levels during the evening and night should be 5–10 dB lower than during the day. Noise with low-frequency components require even lower levels. It is emphasized that for intermittent noise it is necessary to take into account the maximum sound pressure level as well as the number of noise events. Guidelines or noise abatement measures should also take into account residential outdoor activities.

4.2.8. Effects on social behaviour

The effects of environmental noise may be evaluated by assessing the extent to which it interferes with different activities. For many community noises, interference with rest, recreation and watching television seem to be the most important issues. However, there is evidence that noise has other effects on social behaviour: helping behaviour is reduced by noise in excess of 80 dBA; and loud noise increases aggressive behavior in individuals predisposed to aggressiveness. There is concern that schoolchildren exposed to high levels of chronic noise could be more susceptible to helplessness. Guidelines on these issues must await further research.

4.3. Specific Environments

Noise measures based solely on LAeq values do not adequately characterize most noise environments and do not adequately assess the health impacts of noise on human well-being. It is also important to measure the maximum noise level and the number of noise events when deriving guideline values. If the noise includes a large proportion of low-frequency components, values even lower than the guideline values will be needed, because low-frequency components in noise may increase the adverse effects considerably. When prominent low-frequency components are present, measures based on A-weighting are inappropriate. However, the difference between dBC (or dBlin) and dBA will give crude information about the presence of low-frequency components in noise. If the difference is more than 10 dB, it is recommended that a frequency analysis of the noise be performed.

4.3.1. Dwellings

In dwellings, the critical effects of noise are on sleep, annoyance and speech interference. To avoid sleep disturbance, indoor guideline values for bedrooms are 30 dB LAeq for continuous noise and 45 dB LAmax for single sound events. Lower levels may be annoying, depending on the nature of the noise source. The maximum sound pressure level should be measured with the instrument set at "*Fast*".

To protect the majority of people from being seriously annoyed during the daytime, the sound pressure level on balconies, terraces and outdoor living areas should not exceed 55 dB LAeq for a steady, continuous noise. To protect the majority of people from being moderately annoyed during the daytime, the outdoor sound pressure level should not exceed 50 dB LAeq. These values are based on annoyance studies, but most countries in Europe have adopted 40 dB LAeq as the maximum allowable level for new developments (Gottlob 1995). Indeed, the lower value should be considered the maximum allowable sound pressure level for all new developments whenever feasible.

At night, sound pressure levels at the outside façades of the living spaces should not exceed 45 dB LAeq and 60 dB LAmax, so that people may sleep with bedroom windows open. These values have been obtained by assuming that the noise reduction from outside to inside with the window partly open is 15 dB.

4.3.2. Schools and preschools

For schools, the critical effects of noise are on speech interference, disturbance of information extraction (e.g. comprehension and reading acquisition), message communication and annoyance. To be able to hear and understand spoken messages in classrooms, the background sound pressure level should not exceed 35 dB LAeq during teaching sessions. For hearing impaired children, an even lower sound pressure level may be needed. The reverberation time in the classroom should be about 0.6 s, and preferably lower for hearing-impaired children. For assembly halls and cafeterias in school buildings, the reverberation time should be less than 1 s. For outdoor playgrounds, the sound pressure level of the noise from external sources should not exceed 55 dB LAeq, the same value given for outdoor residential areas in daytime.

For preschools, the same critical effects and guideline values apply as for schools. In bedrooms in preschools during sleeping hours, the guideline values for bedrooms in dwellings should be used.

4.3.3. Hospitals

For most spaces in hospitals, the critical effects of noise are on sleep disturbance, annoyance and communication interference, including interference with warning signals. The LAmax of sound events during the night should not exceed 40 dB indoors. For wardrooms in hospitals, the guideline values indoors are 30 dB LAeq, together with 40 dB LAmax during the night. During the day and evening the guideline value indoors is 30 dB LAeq. The maximum level should be measured with the instrument set at "*Fast*".

Since patients have less ability to cope with stress, the equivalent sound pressure level should not exceed 35 dB LAeq in most rooms in which patients are being treated or observed. Particular attention should be given to the sound pressure levels in intensive care units and operating theatres. Sound inside incubators may result in health problems, including sleep disturbance, and may lead to hearing impairment in neonates. Guideline values for sound pressure levels in incubators must await future research.

4.3.4. Ceremonies, festivals and entertainment events

In many countries, there are regular ceremonies, festivals and other entertainment to celebrate life events. Such events typically produce loud sounds including music and impulsive sounds. There is widespread concern about the effect of loud music and impulse sounds on young people who frequently attend concerts, discotheques, video arcades, cinemas, amusement parks and spectator events, etc. The sound pressure level is typically in excess of 100 dB LAeq. Such a noise exposure could lead to significant hearing impairment after frequent attendance.

Noise exposure for employees of these venues should be controlled by established occupational standards. As a minimum, the same standards should apply to the patrons of these premises. Patrons should not be exposed to sound pressure levels greater than 100 dB LAeq during a 4-h period, for at most four times per year. To avoid acute hearing impairment the LAmax should always be below 110 dB.

4.3.5. Sounds through headphones

To avoid hearing impairment in both adults and children from music and other sounds played back in headphones, the LAeq,24h should not exceed 70 dB. This implies that for a daily one-hour exposure the LAeq should not exceed 85 dB. The exposures are expressed in free-field equivalent sound pressure levels. To avoid acute hearing impairment, the LAmax should always be below 110 dB.

4.3.6. Impulsive sounds from toys, fireworks and firearms

To avoid acute mechanical damage to the inner ear, adults should never be exposed to more than 140 dB peak sound pressure. To account for the vulnerability in children, the peak sound pressure level produced by toys should not surpass 120 dB, measured close to the ears (100 mm). To avoid acute hearing impairment, LAmax should always be below 110 dB.

4.3.7. Parkland and conservation areas

Existing large quiet outdoor areas should be preserved and the signal-to-noise ratio kept low.

4.4. WHO Guideline Values

The WHO guideline values in Table 4.1 are organized according to specific environments. When multiple adverse health effects are identified for a given environment, the guideline values are set at the level of the lowest adverse health effect (the critical health effect). An adverse health effect of noise refers to any temporary or long-term deterioration in physical, psychological or social functioning that is associated with noise exposure. The guideline values represent the sound pressure levels that affect the most exposed receiver in the listed environment.

The time base for LAeq for "daytime" and "night-time" is 16 h and 8 h, respectively. No separate time base is given for evenings alone, but typically, guideline value should be 5 –10 dB lower than for a 12 h daytime period. Other time bases are recommended for schools, preschools and playgrounds, depending on activity.

The available knowledge of the adverse effects of noise on health is sufficient to propose guideline values for community noise for the following:

a. Annoyance.
b. Speech intelligibility and communication interference.
c. Disturbance of information extraction.
d. Sleep disturbance.
e. Hearing impairment.

The different critical health effects are relevant to specific environments, and guideline values for community noise are proposed for each environment. These are:

a. Dwellings, including bedrooms and outdoor living areas.
b. Schools and preschools, including rooms for sleeping and outdoor playgrounds.
c. Hospitals, including ward and treatment rooms.
d. Industrial, commercial shopping and traffic areas, including public addresses, indoors and outdoors.
e. Ceremonies, festivals and entertainment events, indoors and outdoors.
f. Music and other sounds through headphones.
g. Impulse sounds from toys, fireworks and firearms.

h. Outdoors in parkland and conservation areas.

It is not enough to characterize the noise environment in terms of noise measures or indices based only on energy summation (e.g. LAeq), because different critical health effects require different descriptions. Therefore, it is important to display the maximum values of the noise fluctuations, preferably combined with a measure of the number of noise events. A separate characterization of noise exposures during night-time would be required. For indoor environments, reverberation time is also an important factor. If the noise includes a large proportion of low frequency components, still lower guideline values should be applied.

Supplementary to the guideline values given in Table 4.1, precautionary recommendations are given in Section 4.2 and 4.3 for vulnerable groups, and for noise of a certain character (e.g. low-frequency components, low background noise), respectively. In Section 3.10, information is given regarding which critical effects and specific environments are considered relevant for vulnerable groups, and what precautionary noise protection would be needed in comparison to the general population.

Table 4.1: Guideline values for community noise in specific environments.

Specific environment	Critical health effect(s)	LAeq [dB]	Time base [hours]	LAmax, fast [dB]
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50	16 16	- -
Dwelling, indoors Inside bedrooms	Speech intelligibility and moderate annoyance, daytime and evening Sleep disturbance, night-time	35 30	16 8	 45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60
School class rooms and pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35	during class	-
Pre-school bedrooms, indoors	Sleep disturbance	30	sleeping -time	45
School, playground outdoor	Annoyance (external source)	55	during play	-
Hospital, ward rooms, indoors	Sleep disturbance, night-time Sleep disturbance, daytime and evenings	30 30	8 16	40 -
Hospitals, treatment rooms, indoors	Interference with rest and recovery	#1		
Industrial, commercial shopping and traffic areas, indoors and outdoors	Hearing impairment	70	24	110
Ceremonies, festivals and entertainment events	Hearing impairment (patrons:<5 times/year)	100	4	110
Public addresses, indoors and outdoors	Hearing impairment	85	1	110
Music through headphones/ earphones	Hearing impairment (free-field value)	85 #4	1	110
Impulse sounds from toys, fireworks and firearms	Hearing impairment (adults) Hearing impairment (children)	- -	- -	140 #2 120 #2
Outdoors in parkland and conservation areas	Disruption of tranquillity	#3		

#1: as low as possible;
#2: peak sound pressure (not LAmax, fast), measured 100 mm from the ear;
#3: existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low;
#4: under headphones, adapted to free-field values

5. Noise Management

The goal of noise management is to maintain low noise exposures, such that human health and well-being are protected. The specific objectives of noise management are to develop criteria for the maximum safe noise exposure levels, and to promote noise assessment and control as part of environmental health programmes. This is not always achieved (Jansen 1998). The United Nations′ Agenda 21 (UNCED 1992), as well as the European Charter on Transport, Environment and Health (London Charter 1999), both support a number of environmental management principles on which government policies, including noise management policies, can be based. These include:

a. **The precautionary principle**. In all cases, noise should be reduced to the lowest level achievable in a particular situation. Where there is a reasonable possibility that public health will be damaged, action should be taken to protect public health without awaiting full scientific proof.

b. **The polluter pays principle**. The full costs associated with noise pollution (including monitoring, management, lowering levels and supervision) should be met by those responsible for the source of noise.

c. **The prevention principle**. Action should be taken where possible to reduce noise at the source. Land-use planning should be guided by an environmental health impact assessment that considers noise as well as other pollutants.

The government policy framework is the basis of noise management. Without an adequate policy framework and adequate legislation it is difficult to maintain an active or successful noise management programme. A policy framework refers to transport, energy, planning, development and environmental policies. The goals are more readily achieved if the interconnected government policies are compatible, and if issues which cross different areas of government policy are co-ordinated.

5.1. Stages in Noise Management

A legal framework is needed to provide a context for noise management (Finegold 1998; Hede 1998a). While there are many possible models, an example of one is given in Figure 5.1. This model depicts the six stages in the process for developing and implementing policies for community noise management. For each policy stage, there are groups of 'policy players' who ideally would participate in the process.

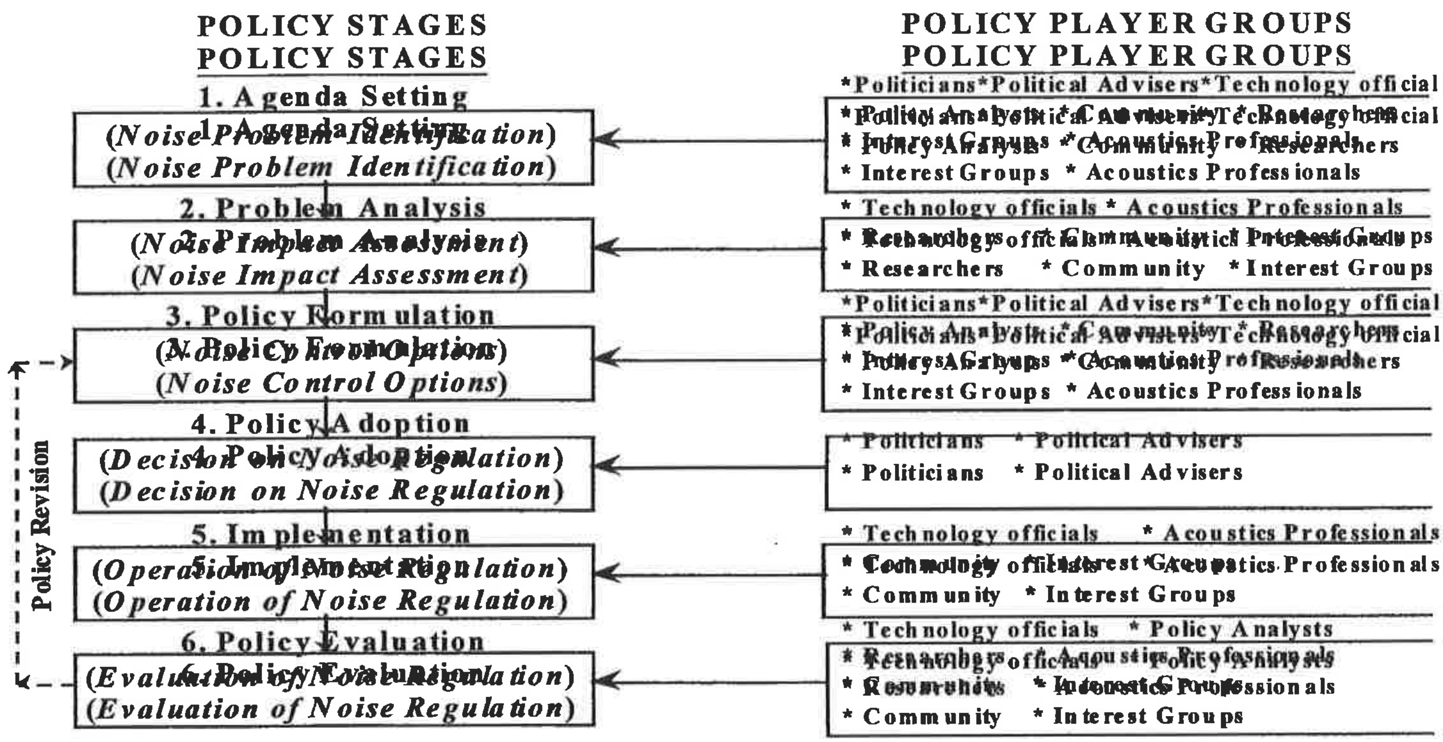

Figure 5.1. A model of the policy process for community noise management (Hede 1998a)

When goals and policies have been developed, the next stage is the development of the strategy or plan. Figure 5.2 summarizes the stages involved in the development of a noise management strategy. Specific abatement measures 19 are listed in Table 5.1.

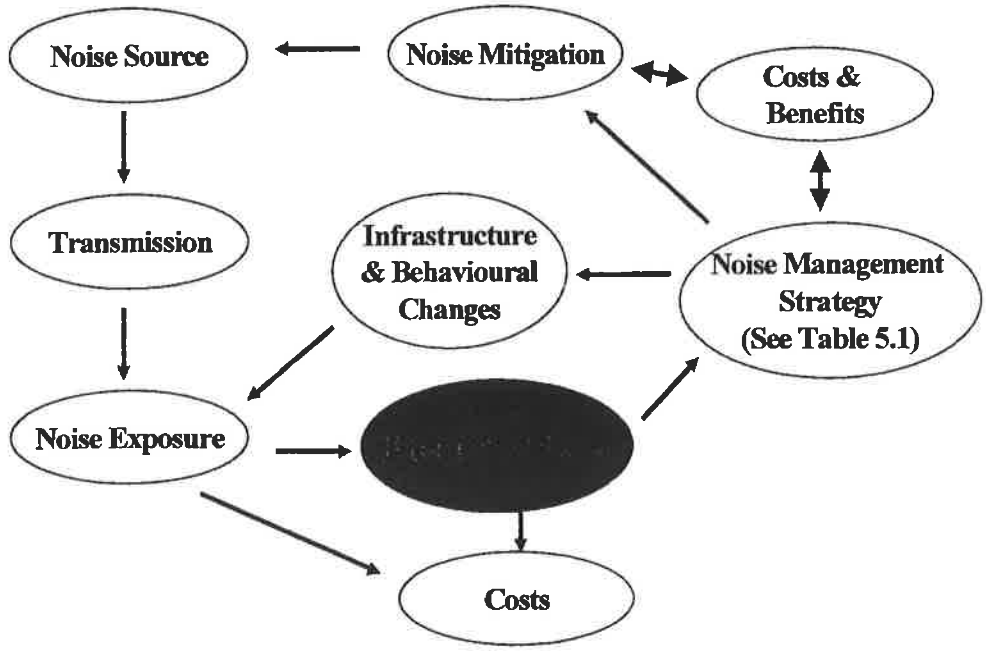

Figure 5.2. Stages involved in the development of a noise abatement strategy.

Table 5.1. Recommended Noise Management Measures (following EEA 1995)

Legal measures	**Examples**
Control of noise emissions	Emission standards for road and off-road vehicles; emission standards for construction equipment; emission standards for plants; national regulations, EU Directives
Control of noise transmission	Regulations on sound-obstructive measures
Noise mapping and zoning around roads, airports, industries	Initiation of monitoring and modeling programmes
Control of noise immissions	Limits for exposure levels such as national immission standards; noise monitoring and modeling; regulations for complex noise situations; regulations for recreational noise
Speed limits	Residential areas; hospitals
Enforcement of regulations	Low Noise Implementation Plan
Minimum requirements for acoustical properties of buildings	Construction codes for sound insulation of building parts
Engineering Measures	
Emission reduction by source modification	Tyre profiles; low-noise road surfaces; changes in engine properties
New engine technology	Road vehicles; aircraft; construction machines
Transmission reduction	Enclosures around machinery; noise screens
Orientation of buildings	Design and structuring of tranquille uses; using buildings for screening purposes
Traffic management	Speed limits; guidance of traffic flow by electronic means
Passive protection	Ear plugs; ear muffs; insulation of dwellings; façade design
Implementation of land-use planning	Minimum distance between industrial, busy roads and residential areas; location of tranquillity areas; by-pass roads for heavy traffic; separating out incompatible functons
Education and information	
Raising public awareness	Informing the public on the health impacts of noise, enforcement action taken, noise levels, complaints
Monitoring and modeling of soundscapes	Publication of results
Sufficient number of noise experts	University or highschool curricula
Initiation of research and development	Funding of information generation according to scientific research needs
Initiation of behaviour changes	Speed reduction when driving; use of horns; use of loudspeakers for advertisements

The process outlined in Figure 5.2 can start with the development of noise standards or guidelines. Ideally, it should also involve the identification and mapping of noise sources and exposed communities. Meteorological conditions and noise levels would also normally be monitored. These data can be used to validate the output of models that estimate noise levels. Noise standards and model outputs may be considered in devising noise control tactics aimed at achieving the noise standards. Before being enforced, current control tactics need to be revised, and if the standards are achieved they need continued enforcement. If the standards are not achieved after a reasonable period of time, the noise control tactics may need to be revised.

National noise standards can usually be based on a consideration of international guidelines, such as these Guidelines for Community Noise, as well as national criteria documents, which consider dose-response relations for the effects of noise on human health. National standards take into account the technological, social, economic, political and other factors specific for the country.

In many cases monitoring may show that noise levels are considerably higher than established guidelines. This may be particularly true in developing countries, and the question has to be raised as to whether national standards should reflect the optimum levels needed to protect human health, when this objective is unlikely to be achieved in the short- or medium-term with available resources. In some countries noise standards are set at levels that are realistically attainable under prevailing technological, social, economic and political conditions, even though they may not be fully consistent with the levels needed to protect human health. In such cases, a staged programme of noise abatement should be implemented to achieve the optimum health protection levels over the long term. Noise standards periodically change after reviews, as conditions in a country change over time, and with improved scientific understanding of the relationship between noise pollution and the health of the population. Noise level monitoring (Chapter 2) is used to assess whether noise levels at particular locations are in compliance with the standards selected.

5.2. Noise Exposure Mapping

A crucial component of a low-noise implementation plan is a reasonably quantitative knowledge of exposure (see Figure 5.2). Exposure should be mapped for all noise sources impacting a community; for example, road traffic, aircraft, railway, industry, construction, festivals and human activity in general. For some components of a noise exposure map or noise exposure inventory, accurate data may be available. In other cases, exposure can be calculated from the characteristics of the mechanical processes. While estimates of noise emissions are needed to develop exposure maps, measurements should be undertaken to confirm the veracity of the assumptions used in the estimates. Sample surveys may be used to provide an overall picture of the noise exposure. Such surveys would take account of all the relevant characteristics of the noise source. For example motor vehicle emissions may be estimated by calculations involving the types of vehicles, their number, their age and the characteristic properties of the road surface.

In developing countries, there is usually a lack of appropriate statistical information to produce noise exposure estimates. However, where action is needed to lower noise levels, the absence of comprehensive information should not prevent the development of provisional noise exposure estimates. Basic information about the exposed population, transport systems, industry and other relevant factors can be used to calculate provisional noise exposures. These can then be used to develop and implement interim noise management plans. The preliminary exposure estimates can be revised as more accurate information becomes available.

5.3. Noise Exposure Modeling

As indicated in Chapter 2 modeling is a powerful tool for the interpolation, prediction and optimization of control strategies. However, models need to be validated by monitoring data. A strength of models is that they enable examination and comparison of the consequences for noise exposure of the implementation of the various options for improving noise. However, the accuracy of the various models available depends on many factors, including the accuracy of the source emissions data and details of the topography (for which a geographical information system may be used). For transportation noise parameters such as the number, type and speed of vehicles, aircraft or trains, and the noise characteristics of each individual event must be known. An example of a model is the annoyance prediction model of the Government of the Netherlands (van den Berg 1996).

5.4. Noise Control Approaches

An integrated noise policy should include several control procedures: measures to limit the noise at the source, noise control within the sound transmission path, protection at the receiver's site, land-use planning, education and raising of public awareness. Ideally, countries should give priority to precautionary measures that prevent noise, but they must also implement measures to mitigate existing noise problems.

5.4.1. Mitigation measures

The most effective mitigation measure is to reduce noise emissions at the source. Therefore, regulations with noise level limits for the main noise sources should be introduced.

Road traffic noise. Limits on the noise emission of vehicles have been introduced in many countries (Sandberg 1995). Such limits, together with the relevant measuring methods, should also be introduced in other regions of the world. Besides these limits a special class of "low-noise trucks" has been introduced in Europe. These trucks follow state-of-the-art noise control and are widely used in Austria and Germany (Lang 1995). Their use is encouraged by economic incentives; for example, low-noise trucks are excepted from a night-time ban on certain routes, and their associated taxes are lower than for other trucks. In Europe, the maximum permissible noise levels range from 69 dBA for motor vehicles to 77 dBA for cars, and 83 dBA for heavy two-wheeled vehicles to 84 dBA for trucks. A number of European Directives give permissible sound levels for motor vehicles and motorcycles (EU 1970; EU 1978; EU 1996a; EU 1997). In addition to noise level limits for new vehicles (type test), noise emissions of vehicles already in use should be controlled regularly. Limits on the sound pressure levels for vehicles reduce the noise emission from the engines.

However, the main noise from traffic on highways is rolling noise. This may be reduced by quiet road surfaces (porous asphalt, "drain asphalt") or by selection of quiet tires. Road traffic noise may also be reduced by speed limits, provided the limits are enforced. For example, reducing the speed of trucks from 90 to 60 km/h on concrete roads would reduce the maximum sound pressure level by 5 dB, and the equivalent sound pressure level by 4 dB. Decreasing the speed of cars from 140 to 100 km/h would result in the same noise reduction (WHO 1995a). In the central parts of cities a speed limit of 30 km/h may be introduced. At 30 km/h cars produce maximum sound pressure levels that are 7 dB lower, and equivalent sound pressure levels that are 5 dB lower, than cars driving at 50 km/h.

Noise emission from road traffic may be further reduced by a night-time ban for all vehicles, or especially for heavy vehicles. Traffic management designed to ensure uniform traffic flow in towns also serves to reduce noise. "Low-noise behaviour" of drivers should be encouraged as well, by advocating defensive driving manners. In some countries, car drivers use their horns frequently, which results in noise with high peak levels. The unnecessary use of horns within cities should be forbidden, especially during night-time, and this rule should be enforced.

Railway noise and noise from trams. The main noise sources are the engine and the wheel-rail contact. Noise at the source can be reduced by well-maintained rails and wheels, and by the use of disc brakes. Sound pressure levels may vary by more than 10 dB, depending on the type of railway material. Replacement of steel wheels by rubber wheels could also reduce noise from railways and trams substantially. Other measures include innovations in engine and track technology (Moehler 1988; Öhrström & Skånberg 1996).

Aircraft noise. The noise emission of aircraft is limited by ICAO Annex 16, Chapter 2 and Chapter 3, which estimates maximum potential sound emissions under certification procedures (ICAO 1993). Aircraft following the norms of Chapter 3 represent the state-of-the-art of noise control of the 1970s. In many countries, non-certified aircraft (i.e. aircraft not fulfilling the ICAO requirements) are not permitted and Chapter 2 aircraft may not be registered again. After the year 2002 only Chapter 3 aircraft will be allowed to operate in many countries.

Similar legislation should be adopted in other countries. The use of low-noise aircraft may also be encouraged by setting noise-related charges (that is, landing charges that are related not only to aircraft weight and capacity, but also to noise emission). Examples of systems for noise-related financial charges are given in OECD 1991 (see also OECD-ECMT 1995). Night-time aircraft movements should be discouraged where they impact residential communities. Particular categories of aircraft (such as helicopters, rotorcraft and supersonic aircraft) pose additional problems that require appropriate controls. For subsonic airplanes two EU Directive give the permissible sound levels (EU 1980; EU 1989).

Machines and Equipment. Noise emission has to be considered a main property of all types of machines and equipment. Control measures include design, insulation, enclosure and maintenance.

Consumers should be encouraged to take noise emission into account when buying a product. Declaring the A-weighted sound power level of a product would assist the consumer in making this decision. The introduction of sound labeling is a major tool for reducing the noise emission of products on the market. For example, within the European Community, "permissible sound levels" and "sound power levels" have to be stated for several groups of machines; for example, lawn mowers, construction machines and household equipment (EU 1984a-f; EU 1986b,c). For other groups of machines sound level data have been compiled and are state-of-the-art with respect to noise control.

A second step would be the introduction of limits on the sound power levels for certain groups of machines, heating and ventilation systems (e.g. construction machines, household appliances). These limits may be set by law, in recommendations and by consumers, using state-of-the-art measurements. There have also been promising developments in the use of active noise control (involving noise cancellation techniques). These are to be encouraged.

Noise control within the sound transmission path. The installation of noise barriers can protect dwellings close to the traffic source. In several European countries noise barrier regulations have been established (WHO 1995b), but in practice they are often not adequately implemented. These regulations must define:

a. Measuring and calculation methods for deriving the equivalent sound pressure level of road or railway traffic, and schemes for determining the effectiveness of the barrier.

b. The sound pressure limits that are to be achieved by installing barriers.

c. The budgetary provisions.

d. The responsible authority.

Noise protection at the receiver's site. This approach is mainly used for existing situations. However, this approach must also be considered for new and, eventually, for old buildings in noisy areas. Residential buildings near main roads with heavy traffic, or near railway lines, may be provided with sound-proofed windows.

5.4.2. Precautionary measures

With careful planning, noise exposure can be avoided or reduced. A sufficient distance between residential areas and an airport will make noise exposure minimal, although the realization of such a situation is not always possible. Additional insulation of houses can help to reduce noise exposure from railroad and road traffic. For new buildings, standards or building codes should describe the positions of houses, as well as the ground plans of houses with respect to noise sources. The required sound insulation of the façades should also be described. Various countries have set standards for the maximum sound pressure levels in front of buildings and for the minimum sound insulation values required for façades.

Land use planning. Land use planning is one of the main tools for noise control and includes:

a. Calculation methods for predicting the noise impact caused by road traffic, railways, to provide suitable comfort conditions and low indoor noise levels. Detailed maintenance logs should be kept for all equipment. A schedule should be developed for routine equipment checks and calibration of control system components. Selection of low-noise domestic products should encouraged as far as is possible.

5.6.4. Resolving indoor noise problems

Addressing occupant complaints and symptoms. When complaints are received from occupants of a building, the cognizant authority should be responsive. The initial investigation into the cause of the complaint may be conducted by the in-house management staff, and they should continue an investigation as far as possible. If necessary, they should be responsible for hiring an outside consultant

Building diagnostic procedures. After receiving complaints related to indoor noise levels, facility personnel or consultants should attempt to identify the cause of the problem through an iterative process of information collection and hypothesis testing. To begin, a walkthrough inspection of the building, including the affected areas and the mechanical systems serving these spaces is required. A walkthrough can provide information on the soundproofing system of the building, the sound pathways and sound sources. Visual indicators of sound sources and soundproofing malfunctions should be evaluated first. Symptom logs and schedules of building activities may provide enough additional information to resolve the problem.

If a walkthrough alone does not provide a solution, measurements of sound pressure levels at various locations should be taken, and indoor and ambient levels of noise pollution should be compared. As part of the investigation, the absorption characteristics of walls and ceilings should be evaluated. Sophisticated sampling methods may be necessary to provide proof of a problem to the building owner or other responsible party. The results may be used to confirm a hypothesis or ascertain the source of the indoor noise problem. Whenever a problem is discovered during the investigation, a remedy to the situation should be attempted and a determination made of whether the complaint has been resolved.

In some cases, it should be recognized that difficulties in interpreting the sampling results may exist. The costs of certain types of testing should also be taken into account. Simple, cost-effective screening methods should be developed to make sampling a more attractive option for both investigators and clients. Finally, it must be remembered that several factors cause symptoms similar to those induced by noise pollution. Examples include air pollutants, ergonomics, lighting, vibration and psychosocial factors. Consequently, any investigation of noise complaints should also evaluate non-noise factors.

5.7. Priority Setting in Noise Management

Priorities in noise management will differ between countries, according to policy objectives, needs and capabilities. Priority setting in noise management refers to prioritizing health risks and concentrating on the most important sources of noise. For effective noise management, the goals, policies and noise control schemes have to be defined. Goals for noise management include eliminating noise, or reducing noise to acceptable levels, and avoiding the adverse health effects of noise on human health. Policies for noise management encompass laws and regulations for setting noise standards and for ensuring compliance. The amount of information to be included in low-noise implementation plans and the use of cost-benefit comparisons also fall within the purview of noise management policies. Techniques for noise control include source control, barriers in noise pathways and receiver protection. Adequate calculation models for noise propagation, as well as programmes for noise monitoring, are part of an overall noise control scheme.

As emphasized above, a framework for a political, regulatory and administrative approach is required to guarantee the consistent and transparent promulgation of noise standards. This ensures a sound and practical framework for risk-reducing measures and for the selection of abatement strategies.

5.7.1. Noise policy and legislation

Noise is both a local and a global problem. Governments in every country have a responsibility to set up policies and legislation for controlling community noise. There is a direct relationship between the level of development in a country and the degree of noise pollution impacting its people. As a society develops, it increases its level of urbanization and industrialization, and the extent of its transportation system. Each of these developments brings an increase in noise load. Without appropriate intervention the noise impact on communities will escalate (see Figure 5.3). If governments implement only weak noise policies and regulations, they will not be able to prevent a continuous increase in noise pollution and associated adverse health effects. Failure to enforce strong regulations is ineffective in combating noise as well.

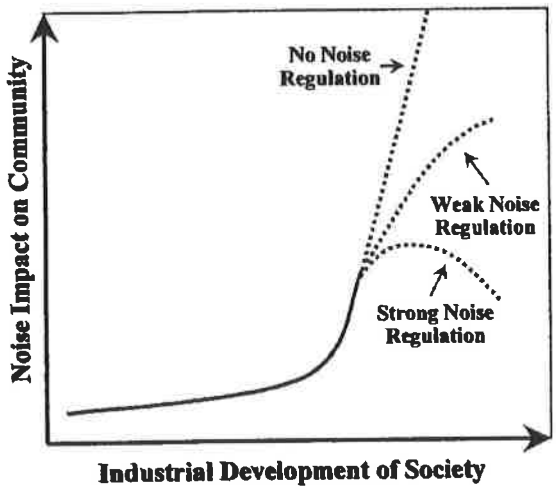

Figure 5.3. Relationship between noise regulation and impact with development (from Hede 1998b)

Policies for noise regulatory standards at the municipal, regional, national and supranational levels are usually determined by the legislatures. The regulatory standards adopted strongly depend on the risk management strategies of the legislatures, and can be influenced by sociopolitical considerations and/or international agreements. Although regulatory standards may be country specific, in general the following issues are taken into consideration:

a. Identification of the adverse public health effects that are to be avoided.

b. Identification of the population to be protected.

c. The type of parameters describing noise and the limit applicable to the parameters.

d. Applicable monitoring methodology and its quality assurance.

e. Enforcement procedures to achieve compliance with noise regulatory standards within a defined time frame.

f. Emission control measures and emission regulatory standards.

g. Immission standards (limits for sound pressure levels).

h. Identification of authorities responsible for enforcement.

i. Resource commitment.

Regulatory standards may be based solely on scientific and technical data showing the adverse effects of noise on public health. But other aspects are usually considered, either when setting standards or when designing appropriate noise abatement measures. These other aspects include the technological feasibility, costs of compliance, prevailing exposure levels, and the social, economic and cultural conditions. Several standards may be set. For example, effect-oriented regulatory standards may be set as a long-term goal, while less-stringent standards are adopted for the short term. As a consequence, noise regulatory standards differ widely from country to country (WHO 1995a; Gottlob 1995).

Noise regulatory standards can set the reference point for emission control and abatement policies at the national, regional or municipal levels, and can thus strongly influence the implementation of noise control policies. In many countries, exceeding regulatory standards is linked to an obligation to develop abatement action plans at the municipal, regional or national levels (low-noise implementation plans). Such plans have to address all relevant sources of noise pollution.

5.7.2. *Examples of noise policies*

Different countries have adopted a range of policies and regulations for noise control. A number of these are outlined in this section as examples.

Argentina. In Argentina, a national law recently limited the daily 8-h exposure to industrial noise to 80 dB, and it has had beneficial effects on hearing impairment and other hearing disorders among workers. In general, industry has responded by introducing constant controls on noise sources, combined with hearing tests and medical follow-ups for workers. Factory owners have recruited permanent health and safety engineers who control noise, supply advice on how to make further improvements, and routinely assess excessive noise levels. The engineers also provide education in personal protection and in the correct use of ear plugs, mufflers etc.

At the municipal level two types of noise have been considered. Unnecessary noise, which is forbidden; and excessive noise, which is defined for neighbourhood activities (zones), and for which both day and night-time maximum limits have been introduced. The results have been relatively successful in mitigating unwanted noise effects. At the provincial level, similar results have been accomplished for many cities in Argentina and Latin America.

Australia. In Australia, the responsibility for noise control is shared primarily by state and local governments. There are nationally-agreed regulatory standards for airport planning and new vehicle noise emissions. The Australian Noise Exposure Forecast (ANEF) index is used to describe how much aircraft noise is received at locations around an airport (DoTRS 1999). Around all airports, planning controls restrict the construction of dwellings within the 25 ANEF exposure contour and require sound insulation for those within 20 ANEF. Road traffic noise limits are set by state governments, but vary considerably in both the exposure metric and in maximum allowable levels. New vehicles are required to comply with stringent design rules for noise and air emissions. For example, new regulation in New South Wales adopts LAeq as the metric and sets noise limits of 60 dBA for daytime, and 55 dBA for night-time, along new roads. Local governments set regulations restricting noise emissions for household equipment, such as air conditioners, and the hours of use for noisy machines such as lawn mowers.

Europe. In Europe, noise legislation is not generally enforced. As a result, environmental noise levels are often higher than the legislated noise limits. Moreover, there is a gap between long-term political goals and what represents a "good acoustical environment". One reason for this gap is that noise pollution is most commonly regulated only for new land use or for the development of transportation systems, whereas enlargements at existing localities may be approved even though noise limits or guideline values are already surpassed (Gottlob 1995). A comprehensive overview of the noise situation in Europe is given in the Green Paper (EU 1996b), which was established to give noise abatement a higher priority in policy making. The Green Paper outlines a new framework for noise policy in Europe with the following options for future action:

a. Harmonizing the methods for assessing noise exposure, and encouraging the exchange of information among member states.

b. Establishing plans to reduce road traffic noise by applying newer technologies and fiscal instruments.

c. Paying more attention to railway noise in view of the future extension of rail networks.

d. Introducing more stringent regulation on air transport and using economic instruments to encourage compliance.

e. Simplifying the existing seven regulations on outdoor equipment by proposing a Framework Directive that covers a wider range of equipment, including construction machines and others.

Pakistan. In Pakistan, the Environmental Protection Agency is responsible for the control of air pollution nationwide. However, only recently have controls been enforced in Sindh in an attempt to raise public awareness and carry out administrative control on road vehicles producing noise (Zaidi, personal communication).

South Africa. In South Africa, noise control is three decades old. It began with codes of practice issued by the South African Bureau of Standards to address noise pollution in various sectors of the country (e.g. see SABS 1994 1996; and the contribution of Grond in Appendix 2). In 1989, the Environment Conservation Act made provision for the Minister of Environmental Affairs and Tourism to make regulations for noise, vibration and shock (DEAT 1989). These regulations were published in 1990 and local authorities could apply to the Minister to make them applicable in their areas. Later, the act was changed to make it obligatory for all authorities to apply the regulations. However, according to the new Constitution of South Africa of 1996, legislative responsibility for noise control rests exclusively with provincial and local authorities. The noise control regulations will apply to local authorities in South Africa as soon as they are published in the provinces. This will not only give local authorities the power to enforce the regulations, but also place an obligation on them to see that the regulations are enforced.

Thailand. In 1996, noise pollution regulations in Thailand stipulated that not more than 70 dBA LAeq,24h should be allowed in residential areas, and the maximum level of noise in industry should be no more than 85 dBA Leq 8h (Prasansuk 1997).

United States of America. Environmental noise was not addressed as a national policy issue in the USA until the implementation of the Noise Control Act of 1972. This congressional act directed the US Environmental Protection Agency to publish scientific information about noise exposure and its effects, and to identify acceptable levels of noise exposure under various conditions. The Noise Control Act was supposed to protect the public health and well-being with an adequate margin of safety. This was accomplished in 1974 with the publication of the US EPA "Levels Document" (US EPA 1974). It addressed issues such as the use of sound descriptions to describe sound exposure, the identification of the most important human effects resulting from noise exposure, and the specification of noise exposure criteria for various effects. Subsequent to the publication of the US EPA "Levels Document", guidelines for conducting environmental impact analysis were developed (Finegold et al. 1998). The day-night average sound level was thus established as the predominant sound descriptor for most environmental noise exposure.

It is evident from these examples that noise policies and regulations vary considerably across countries and regions. Moves towards global noise policies need to be encouraged to ensure that the world population gains the maximum health benefits from new developments in noise control.

5.7.3. Noise emission standards have proven to be inadequate

Much of the progress towards solving the noise pollution problem has come from advanced technology, which in turn has come about mainly as a result of governmental regulations (e.g. OECD-ECMT 1995). So far, however, the introduction of noise emission standards for vehicles has had limited impact on exposure to transportation noise, especially from aircraft and road traffic noise (Sandberg 1995). In part, this is because changes in human behaviour (of polluters, planners and citizens) have tended to offset some of the gains made. For example, mitigation efforts such as developing quieter vehicles, moving people to less noise-exposed areas, improving traffic systems and direct noise abatement and control (sound insulation, barriers etc.), have been counteracted by increases in the number of roads and highways built, by the number of traffic movements, and by higher driving speeds and the number of kilometers driven (OECD 1991; OECD-ECMT 1995).

Traffic planning and correction policies may diminish the number of people exposed to the very high community noise levels (>70 dB LAeq), but the number exposed to moderately high levels (55-65 dB LAeq) continues to increase in industrialized countries (Stanners & Bordeau 1995). In developing countries, exposure to excessive sound pressure levels (>85 dB LAeq), not only from occupational noise but also from urban, environmental noise, is the major avoidable cause of permanent hearing impairment (Smith 1998). Such sound pressure levels can also be reached by leisure activities at concerts, discotheques, motor sports and shooting ranges; by music played back in headphones; and by impulse noises from toys and fireworks.

A substantial growth in air transport is also expected in the future. Over the next 10 years large international airports may have to accommodate a doubling in passenger movements. General aviation noise at regional airports is also expected to increase (Large & House 1989). Although jet aircraft are expected to become less noisy due to regulation of noise emissions (ICAO 1993), the number of passengers is expected to increase. Increased air traffic movement between 1980 and 1990 is considered to be the main reason for the average 22% increase in the number of people exposed to noise above 67 dB LAeq at German airports (OECD 1993).

5.7.4. Unsustainable trends in noise pollution future policy planning

A number of trends are expected to increase environmental noise pollution, and are considered to be unsustainable in the long term. The OECD (1991) identified the following factors to be of increasing importance in the future:

a. The expanding use of increasingly powerful sources of noise.

b. The wider geographical dispersion of noise sources, together with greater individual mobility and spread of leisure activities.

c. The increasing invasion of noise, particularly into the early morning, evenings and weekends.

d. The increasing public expectations that are closely linked to increases in incomes and in education levels.

Apart from these, increased noise pollution is also linked to systemic changes in business practices (OECD-ECMT 1995). By accepting a just-in-time concept in transportation, products and components are stored in heavy-duty vehicles on roads, instead of in warehouses; and workers are recruited as temporary consultants just in time for the work, instead of as long-term employees.

In addition, the OECD (1991) report forecasts:

a. A strengthening of present noise abatement policies and their applications.

b. A further sharpening of emission standards.

c. A co-ordination of noise abatement measures and transport planning, to specifically reduce mobility.

d. A co-ordination of noise abatement measures with urban planning.

Planners need to know the likely effects of introducing a new noise source, or of increasing the level of an existing source, on the noise pollution in a community. Policy makers, when considering applications for new developmental projects, must take into account maximum levels, continuous equivalent sound pressure levels of both the background and the new noise source, the frequency of noise occurrence and the operating times of major noise sources.

5.7.5. Analysis of the impact of environmental noise

The concept of an environmental noise impact analysis (ENIA) is central to the philosophy of managing environmental noise. An ENIA should be required before implementing any project that would significantly increase the level of environmental noise in a community (typically, greater than a 5dB increase). The first step in performing an ENIA is to develop a baseline description of the existing noise environment. Next, the expected level of noise from a new source is added to the baseline exposure level to produce the new overall noise level. If the new total noise level is expected to cause an unacceptable impact on human health, trade-off analyses should then be performed to assess the cost, technical feasibility and community acceptance of noise mitigation measures. It is strongly recommended that countries develop standardized procedures for performing ENIAs (Finegold et al. 1998; SABS 1998).

Assessment of adverse health effects. In setting noise standards (for example on the basis of these guidelines), the adverse health effects from which the population is to be protected need to be defined. Health effects range from hearing impairment to sleep disturbance, speech interference to annoyance. The distinction between adverse and non-adverse effects sometimes poses considerable difficulties. Even the elaborate definition of an adverse health effect given in Chapter 3 incorporates significant subjectivity and uncertainty. More serious noise effects, such as hearing impairment or permanent threshold shift, are generally accepted as adverse. Consideration of health effects that are both temporary and reversible, or that involve functional changes with uncertain clinical significance, requires a judgement on whether these less-serious effects should be considered when deriving guideline values. Judgements as to the adversity of health effects may differ between countries, because of factors such as cultural backgrounds and different levels of health status.

Estimation of the population at risk. The population at risk is that part of the population in a given country or community that is exposed to enhanced levels of noise. Each population has sensitive groups or subpopulations that are at higher risk of developing health effects due to noise exposure. Sensitive groups include individuals impaired by concurrent diseases or other physiological limitations and those with specific characteristics that makes them more vulnerable to noise (e.g. premature babies; see the contribution of Zaidi in Appendix 2). The sensitive groups in a population may vary across countries due to differences in medical care, nutritional status, lifestyle and demographic factors, prevailing genetic factors, and whether endemic or debilitating diseases are prevalent.

Calculation of exposure-response relationships. In developing standards, regulators should consider the degree of uncertainty in the exposure-response relationships provided in the noise guidelines. Differences in the population structure (age, health status), climate (temperature, humidity) and geography (altitude, environment) can influence the prevalence and severity of noise-related health effects. In consequence, modified exposure-response relationships may need to be applied when setting noise standards.

Assessment of risks and their acceptability. In the absence of distinct thresholds for the onset of health effects, regulators must determine what constitutes an acceptable health risk for the population and select an appropriate noise standard to protect public health. This is also true in cases where thresholds are present, but where it would not be feasible to adopt noise guidelines as standards because of economical and/or technical constraints. The acceptability of the risks involved, and hence the standards selected, will depend on several factors. These include the expected incidence and severity of the potential effects, the size of the population at risk, the perception of related risks, and the degree of scientific uncertainty that the effects will occur at any given noise level. For example, if it is suspected that a health effect is severe and the size of the population at risk is large, a more cautious approach would be appropriate than if the effect were less troubling, or if the population were smaller.

Again, the acceptability of risk may vary among countries because of differences in social norms, and the degree of adversity and risk perception by the general population and stakeholders. Risk acceptability is also influenced by how the risks associated with noise compare with risks from other pollution sources or human activities.

5.7.6. Cost-benefit analysis

In the derivation of noise standards from noise guidelines two different approaches for decision making can be applied. Decisions can be based purely on health, cultural and environmental consequences, with little weight to economic efficiency. This approach has the objective of reducing the risk of adverse noise effects to a socially acceptable level. The second approach is based on a formal cost-effectiveness, or cost-benefit analysis (CBA). The objective is to identify control actions that achieve the greatest net economic benefit, or are the most economically efficient. The development of noise standards should account for both extremes, and involve stakeholders and assure social equity to all the parties involved. It should also provide sufficient information to guarantee that stakeholders understand the scientific and economic consequences.

To determine the costs of control action, the abatement measures used to reduce emissions must be known. This is usually the case for direct measures at the source and these measures can be monetarized. Costs of action should include all costs of investment, operation and maintenance. It may not be possible to monetarize indirect measures, such as alternative traffic plans or change in behaviour of individuals.

The steps in a cost-benefit analysis include:

a. The identification and cost analysis of control action (such as emission abatement strategies and tactics).

b. An assessment of noise and population exposure, with and without the control action.

c. The identification of benefit categories, such as improved health and reduced property loss.

d. A comparison of the health effects, with and without control action.

e. A comparison of the estimated costs of control action with the benefits that accrue from such action.

f. A sensitivity and uncertainty analysis.

Action taken to reduce one pollutant may increase or decrease the concentration of other pollutants. These additional effects should be considered, as well as pollutant interactions that may lead to double counting of costs or benefits, or to disregarding some costly but necessary action. Due to different levels of knowledge about the costs of control action and health effects, there is a tendency to overestimate the cost of control action and underestimate the benefits.

CBA is a highly interdisciplinary task. Appropriately applied, it is a legitimate and useful way of providing information for managers who must make decisions that impact health. CBA is also an appropriate tool for drawing the attention of politicians to the benefits of noise control. In any case, however, a CBA should be peer-reviewed and never be used as the sole and overriding determinant of decisions.

5.7.7. Review of standard setting

The setting of standards should involve stakeholders at all levels (industry, local authorities, non-governmental organizations and the general public), and should strive for social equity or fairness to all parties involved. It should also provide sufficient information to guarantee that the scientific and economic consequences of the proposed standards are clearly understood by the stakeholders. The earlier that stakeholders are involved, the more likely is their co-operation. Transparency in moving from noise guidelines to noise standards helps to increase public acceptance of necessary measures. Raising public awareness of noise-induced health effects (changing of risk perception) also leads to a better understanding of the issues involved (risk communication) and serves to obtain public support for necessary control action, such as reducing vehicle emissions. Noise standards should be regularly reviewed, and revised as new scientific evidence emerges.

5.7.8. Enforcement of noise standards: Low-noise implementation plans

The main objective of enforcing noise standards is to achieve compliance with the standards. The instrument used to achieve this goal is a Low-Noise Implementation Plan (LNIP). The outline of such a plan should be defined in the regulatory policies and should use the tactical instruments discussed above. A typical low-noise implementation plan includes:

a. A description of the area to be regulated.

b. An emissions inventory.

c. A monitored or simulated inventory of noise levels.

d. A comparison of the plan with emissions and noise standards or guidelines.

e. An inventory of the health effects.

f. A causal analysis of the health effects and their attribution to individual sources.

g. An analysis of control measures and their costs.

h. An analysis of transportation and land-use planning.

i. Enforcement procedures.

j. An analysis of the effectiveness of the noise management procedures.

k. An analysis of resource commitment.

l. Projections for the future.

As the LNIP also addresses the effectiveness of noise control technologies and policies, it is very much in line with the Noise Control Assessment Programme (NCAP) proposed recently (Finegold et al. 1999).

5.8. Conclusions on Noise Management

Successful noise management should be based on the fundamental principles of precaution, the polluter pays and prevention. The noise abatement strategy typically starts with the development of noise standards or guidelines, and the identification, mapping and monitoring of noise sources and exposed communities. A powerful tool in developing and applying the control strategy is to make use of modeling. These models need to be validated by monitoring data. Noise parameters relevant to the important sources of noise must be known. Indoor noise exposures present specific and complex problems, but the general principles for noise management hold. The main means for noise control in buildings include careful site investigations, adequate building designs and building codes, effective means for addressing occupant complaints and symptoms, and building diagnostic procedures.

Noise control should include measures to limit the noise at the source, to control the sound transmission path, to protect the receiver's site, to plan land use, and to raise public awareness. With careful planning, exposure to noise can be avoided or reduced. Control options should take into account the technical, financial, social, health and environmental factors of concern. Cost-benefit relationships, as well as the cost-effectiveness of the control measures, must be considered in the context of the social and financial situation of each country. A framework for a political, regulatory and administrative approach is required for the consistent and transparent promulgation of noise standards. Examples are given for some countries, which may guide others in their development of noise policies.

Noise management should:

a. Start monitoring human exposures to noise.

b. Have health control require mitigation of noise emissions. The mitigation procedures should take into consideration specific environments such as schools, playgrounds, homes and hospitals; environments with multiple noise sources, or which may amplify the effects of noise; sensitive time periods, such as evenings, nights and holidays; and groups at high risk, such as children and the hearing impaired.

c. Consider noise consequences when making decisions on transport-system and land-use planning.

d. Introduce surveillance systems for noise-related adverse health effects.

e. Assess the effectiveness of noise policies in reducing noise exposure and related adverse health effects, and in improving supportive "soundscapes."

a. Adopt these Guidelines for Community Noise as long-term targets for improving human health.

g. Adopt precautionary actions for sustainable development of acoustical environments.

6. Conclusions And Recommendations

6.1. Implementation of the Guidelines

The potential health effects of community noise include hearing impairment; startle and defense reactions; aural pain; ear discomfort speech interference; sleep disturbance; cardiovascular effects; performance reduction; and annoyance responses. These health effects, in turn, can lead to social handicap; reduced productivity; decreased performance in learning; absenteeism in the workplace and school; increased drug use; and accidents. In addition to health effects of community noise, other impacts are important such as loss of property value. In these guidelines the international literature on the health effects of community noise was reviewed and used to derive guideline values for community noise. Besides the health effects of noise, the issues of noise assessment and noise management were also addressed. Other issues considered were priority setting in noise management; quality assurance plans; and the cost-efficiency of control actions. The aim of the guidelines is to protect populations from the adverse health impacts of noise.

The following recommendations were considered appropriate:

a. Governments should consider the protection of populations from community noise as an integral part of their policy for environmental protection.

b. Governments should consider implementing action plans with short-term, medium-term and long-term objectives for reducing noise levels.

c. Governments should adopt the health guidelines for community noise as targets to be achieved in the long-term.

h. Governments should include noise as an important issue when assessing public health matters and support more research related to the health effects of noise exposure.

f. Legislation should be enacted to reduce sound pressure levels, and existing legislation should be enforced.

g. Municipalities should develop low-noise implementation plans.

h. Cost-effectiveness and cost-benefit analyses should be considered as potential instruments when making management decisions.

i. Governments should support more policy-relevant research into noise pollution (see section 6.3).

6.2. Further WHO Work on Noise

The WHO Expert Task Force proposed several issues for future work in the field of community noise. These are:

a. The WHO should consider updating the guidelines on a regular basis.

b. The WHO should provide leadership and technical direction in defining future research priorities into noise.

c. The WHO should organize workshops on the application of the guidelines.

d. The WHO should provide leadership and co-ordinate international efforts to develop techniques for the design of supportive sound environments (e.g. 'soundscapes").

e. The WHO should provide leadership for programmes to assess the effectiveness of health-related noise policies and regulations.

f. The WHO should provide leadership and technical direction for the development of sound methodologies for EIAP and EHIAP.

g. The WHO should encourage further investigation into using noise exposure as an indicator of environmental deterioration, such as found in black spots in cities.

a. The WHO should provide leadership, technical support and advice to developing countries, to facilitate the development of noise policies and noise management.

6.3. Research Needs

In the publication entitled "Community Noise", examples of essential research and development needs were given (Berglund & Lindvall 1995). In part, the scientific community has already addressed these issues.

A major step forward in raising public awareness and that of decision makers is the recommendation of the present Expert Task Force to concentrate more **on variables which have monetary consequences. This means that research should consider the dose-response relationships between sound pressure levels and politically relevant variables, such as noise-induced social handicap, reduced productivity, decreased performance in learning, workplace and school absenteeism, increased drug use and accidents.**

There is also a need for continued efforts to understand community noise and its effects on the health of the world population. Below is a list of essential research needs in non-prioritized order. Research priorities may vary over time and by place and capabilities. The main goal in suggesting these research activities is to improve the scientific basis for policy-making and noise management. This will protect and improve the public health with regard to the effects of community noise pollution.

Research related to measurement and monitoring systems for health effects

- Development of a global noise impact monitoring study. The study should be designed to obtain longitudinal data across countries on the health effects on communities of various types of environmental noise. A baseline survey could be undertaken in both developed and developing countries and monitoring surveys conducted every 3-5 years. Since a national map of noise exposure from all sources would be prohibitively expensive, periodic surveys of a representative sample of about 1000 people (using standard probability techniques) could be reliably generalized to the whole population of a country with an accuracy of plus-or-minus 3%. A small number of standard questions could be used across countries to obtain comparative data on the impact of all the main types of noise pollution.
- Development of continuous monitoring systems for direct health effects in critical locations.
- Development of standardized methods for low-cost assessment of local sound levels by measurement or model calculations.
- Development of instruments appropriate for local/regional surveys of people's perceptions of their noise/sound environments.
- Protocols for reliable measurements of high-frequency hearing (8000 Hz and above) and for evaluation of such measures as early biomarkers for hearing impairment/deficits.

Research related to combined noise sources and combined health effects

- Research into the combined health effects of traffic noise, with emphasis on the distribution of sound levels over time and over population sub-environments (time-activity pattern).
- Comprehensive studies on combined noise sources and their combinations of health effects in the 3 large areas of transport (road, rail and aircraft).
- Procedures for evaluating the various health effects of complex combined noise exposures over 24 hours on vulnerable groups and on the general population.
- Methods for assessing the total health effect from noise immission (and also other pollution) in sensitive areas (for example, airports, city centers and heavily-trafficked highways)

Research related to direct and/or long-term health effects (sensitive risk groups, sensitive areas and combined exposures)

- Identification of potential risk groups, including identification of sensitive individuals (such as people with particular health problems; people dealing with complex cognitive tasks; the blind; the hearing impaired; young children and the elderly), differences between sexes, discrimination of risk among age groups, and influence of transportation noise on pregnancy course and on fetal development.
- Studies of dose-response relationships for various effects, and for continuous transportation noise at relatively low levels of exposure and low number of noise events per unit time (including traffic flow composition).
- Studies on the perception of control of noise exposure, genetic traits, coping strategies and noise annoyance as modifiers of the effects of noise on the cardiovascular system, and as causes of variability in individual responses to noise.
- Prospective longitudinal studies of transportation noise that examine physiological measures of health, including standardized health status inventory, blood pressure, neuro-endocrine and immune function.
- Knowledge on the health effects of low-frequency components in noise and vibration.
-

Research related to indirect or after-effects of noise exposure

- Field studies on the effects of exposure to specific sounds such as aircraft noise and loud music, including effects such as noise-induced temporary and permanent threshold shifts, speech perception and misperception, tinnitus and information retrieval.
- Studies on the influence of noise-induced sleep disturbance on health, work performance, accident risk and social life.
- Assessment of dose-response relationships between sound levels and politically relevant variables such as noise-induced social handicap, reduced productivity, decreased performance in learning, workplace and school absenteeism, increased drug use and accidents.
- Determination of the causal connection between noise and mental health effects, annoyance and (spontaneous) complaints in areas such as around large airports, heavy-trafficked highways, high-speed rail tracks and heavy vehicles transit routes. The connections could be examined by longitudinal studies, for example.
- Studies on the impact of traffic noise on recovery from noise-related stress, or from nervous system hyperactivity due to work and other noise exposures.

Research on the efficiency of noise abatement policies which are health based

- Determination of the accuracy and effectiveness of modern sound insulation (active noise absorption), especially in residential buildings, in reducing the long-term effects of noise on annoyance/sleep disturbance/speech intelligibility. This can be accomplished by studying sites that provide data on remedial activities and changes in behavioral patterns among occupants.
- Evaluation of environmental (area layout, architecture) and traffic planning (e.g. rerouting) interventions on annoyance, speech interference and sleep disturbance.
- Comparative studies to determine whether children and the hearing impaired have equitable access to healthier lives when compared with normal adults in noise-exposed areas.
- Development of a methodology for the environmental health impact assessment of noise that is applicable in developing as well as developed countries.

Research into positive acoustical needs of the general population and vulnerable groups

- Development of techniques/protocols for the design of supportive acoustical environments for the general population and for vulnerable groups. The protocols should take into account time periods that are sensitive from physiological, psychological and socio-cultural perspectives.
- Studies to characterize good "restoration areas" which provide the possibility for rest without adverse noise load.
- Studies to assess the effectiveness of noise policies in maintaining and improving soundscapes and reducing human exposures.

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Appendix 2 : Examples Of Regional Noise Situations

REGION OF THE AMERICAS

Latin America (Guillermo Fuchs, Argentina).

As more and more cities in Latin America surpass the 20 million inhabitants mark, the noise pollution situation will continue to deteriorate. Most noise pollution in Latin American cities comes from traffic, industry, domestic situations and from the community. Traffic is the main source of outdoor noise in most big cities. The increase in automobile engine power and lack of adequate silencing results in LAeq street levels >70 dB, above acceptable limits. Vehicle noise has strong low-frequency peaks at ~13 Hz, and at driving speeds of 100 Km/h noise levels can exceed 100 dB. The low-frequency (LF) noise is aerodynamic in origin produced, for example, by driving with the car windows open. Little can be done to mitigate these low-frequency noises, except to drive with all the windows closed. Noise exposure due to leisure activities such as carting, motor racing and Walkman use is also growing at a fast rate. Walkman use in the street not only contributes to temporary threshold shifts (TTS) in hearing, but also endangers the user because they may not hear warning signals Construction sites, pavement repairs and advertisements also contribute to street noise, and noise levels of 85–100 dB are common.

The Centro de Investigaciones Acústicas y Luminotécnicas (CIAL) in Córdoba, Argentina has investigated noise pollution in both the field and in the laboratory. The most noticeable effect of excessive urban noise is hearing impairment, but other psychophysiological effects also result. For example, tinnitus resulting from sudden or continuous noise bursts, can produce a TTS of 20–30 dB, and prolonged exposures can result in permanent threshold shifts (PTS). By analyzing sound spectra down to a few Hertz, and at levels of up to 120 dB, discrete frequencies and bands of infrasound were found which damage hearing. With LF sounds at levels of 120 dB, TTS resulted after brief exposure, and PTS after only 30 min of exposure. The effects of noise on hearing can be especially detrimental to children in schools located downtown. Field studies in Córdoba city schools located near streets with high traffic density showed that speech intelligibility was dramatically degraded in classrooms that did not meet international acoustical standards. This is a particularly worrying problem for the younger students, who are in the process of language acquisition, and interferes with their learning process.

In general, community noise in Latin America remains above accepted limits. Particularly at night, sleep and rest are affected by transient noise signals from electronically amplified sounds, music and propaganda. Field research was carried out in four zones of Buenos Aires, to determine the effects of urban noise on the well-being, health and activities of the inhabitants. The effects of confounding variables were taken into consideration. It was concluded that night-time noise levels in downtown Buenos Aires were barely lower than daytime levels. The results showed that sleep, concentration, communication and well-being were affected in most people when noise levels exceeded those permitted by international laws. The reactions of the inhabitants to protect themselves from the effects of noise varied, and included changing rooms, closing windows and complaining to authorities.

Individual responses to noise also vary, and depend on factors such as social, educational and economic levels, individual sensibility, attitudes towards noise, satisfaction with home or neighborhood, and cognitive and affective parameters. For example, at CIAL, two pilot studies were carried out with a group of adolescents to determine the influence of environmental conditions on the perception of noise. When music was played at very high sound levels (with sound peaks of 119 dBA) in a discotheque, judged to be a pleasant environment, the subjects showed less TTS than when exposed to the same music in the laboratory, which was considered to be an unpleasant environment.

At the municipal level Argentinean Ordinances consider two types of noises: unnecessary and excessive. Unnecessary noises are forbidden. Excessive noises are classified according to neighboring activities and are limited by maximum levels allowed for daytime (7 am to 10 pm) and night-time (10 pm to 7 am). This regulation has been relatively successful, but control has to be continuous. Similar actions have been prescribed at the provincial level in many cities of Argentina and Latin America. Control efforts aimed at reducing noise levels from individual vehicles are showing reasonably good improvements. However, many efforts of municipal authorities to mitigate noise pollution have failed because of economic, political and other pressures. For example, although noise control for automobiles has shown some improvement, efforts have been counteracted by the growth in the number and power of automobiles.

CIAL has designed both static and dynamic tests that can be used to set annual noise control limits. For roads and freeways where permitted speeds are above 80 Km/h, CIAL has also designed barriers which protect buildings lining the freeways. Considerable improvements have been obtained using these barriers with noise reductions of over 20 dB at buildings fronts. The most common types of barrier are concrete slabs or wooden structures, made translucent or covered with vegetation. Planted vegetation does not act as an efficient noise shield for freeway noise, except in cases of thick forest strips. In several cities, CIAL also designed ring roads to avoid heavy traffic along sensitive areas such as hospitals, schools and laboratories.

Efforts have not been successful in reducing the noise pollution from popular sports such as carting, motorboating and motocross, where noise levels can exceed 100 dB. In part, this is because individuals do not believe these activities can result in hearing impairment or have other detrimental effects, in spite of the scientific evidence. Argentinean and other Latin American authorities also have not been successful in reducing the sound levels from music centres, such as discotheques, where sound levels can exceed 100 dB between 11 pm and 6 am. However, public protest is increasing and municipal authorities have been applying some control. For instance, in big cities, discotheque owners and others are beginning to seek advice on how to isolate their businesses from apartment buildings and residential areas. Some improvements have been observed, but accepted limits have not yet been generally attained.

United States of America (Larry Finegold)

Noise Exposure.

In the United States, there have only been a few major attempts to describe broad environmental noise exposures. Early estimates for the average daily exposure of various population groups were reported in the U.S. Environmental Protection Agency's *Levels Document* (US EPA 1974), but these were only partially verified by subsequent large-scale measurements. Another EPA publication the same year provided estimates of the national population distribution as a function of outdoor noise level, and established population density as the primary predictor of a community's noise exposure (Galloway et al. 1974). Methodological issues that need be considered when measuring community noise, including both temporal and geographic sampling techniques, have been addressed by Eldred (1975). This paper also provided early quantitative estimates of noise exposure at a variety of sites, from an isolated spot on the North rim of the Grand Canyon to a spot in downtown Harlem in New York City. Another nationwide survey focused on exposure to everyday urban noises, rather than the more traditional approach of measuring exposure to high-level transportation noise from aircraft, traffic and rail (Fidell 1978). This study included noise exposure and human response data from over 2 000 participants at 24 sites.

A comprehensive report, *Noise In America: The Extent of the Problem,* included estimates of occupational noise exposure in the US in standard industrial classification categories (Bolt, Beranek & Newman, Inc. 1981). A more recent paper reviewed the long-term trends of noise exposure in the US and its impact over a 30-year time span, starting in the early 1970's. The focus was primarily on motor vehicle and aircraft noise, and the prediction was for steadily decreasing population-weighted day-night sound exposure (Eldred 1988). However, it remains to be seen whether the technological improvements in noise emission, such as changing from Chapter 2 to Chapter 3 aircraft, will be offset in the long run by the larger carriers and increased operations levels that are forecast for all transportation modes. Although never implemented in its entirety, a comprehensive plan for measuring community environmental noise and associated human responses was proposed over 25 years ago in the US (Sutherland et al. 1973).

Environmental Noise Policy in the United States

One of the first major breakthroughs in developing an environmental noise policy in the United States occurred in 1969 with the adoption of the National Environmental Policy Act (NEPA). This Congressional Act mandated that the environmental effects of any major development project be assessed if federal funds were involved in the project. Through the Noise Control Act (NCA) of 1972, the U.S. Congress directed the US Environmental Protection Agency (EPA) to publish scientific information about the kind and extent of all identifiable effects of different qualities and quantities of noise. The US EPA was also requested to define acceptable noise levels under various conditions that would protect the public health and welfare with an adequate margin of safety. To accomplish this objective, the 1974 US EPA *Levels Document* formally introduced prescribed noise descriptors and prescribed levels of environmental noise exposure. Along with its companion document, *Guidelines for Preparing Environmental Impact Statements on Noise*, which was published by the U.S. National Research Council in 1977, the

Levels Document has been the mainstay of U.S. environmental noise policy for nearly a quarter of a century. These documents were supplemented by additional Public Laws, Presidential Executive Orders, and many-tiered noise exposure guidelines, regulations, and Standards. Important examples include *Guidelines for Considering Noise in Land Use Planning and Control*, published in 1980 by the US Federal Interagency Committee on Urban Noise; and *Guidelines for Noise Impact Analysis*, published in 1982 by the US EPA.

One of the distinctive features of the US EPA *Levels Document* is that it does not establish regulatory goals. This is because the noise exposure levels identified in this document were determined by a negotiated scientific consensus and were chosen without concern for their economic and technological feasibility; they also included an additional margin of safety. For these reasons, an A-weighted Day-Night Average Sound Level (DNL) of 55 dB was selected in the *Levels Document* as that required to totally protect against outdoor activity interference and annoyance. Land use planning guidelines developed since its publication allow for an outdoor DNL exposure in non-sensitive areas of up to 65 dB before sound insulation or other noise mitigation measures must be implemented. Thus, separation of short-, medium- and long-term goals allow noise-exposure goals to be established that are based on human effects research data, yet still allow for the financial and technological constraints within which all countries must work.

The US EPA's Office of Noise Abatement and Control (ONAC) provided a considerable amount of impetus to the development of environmental noise policies for about a decade in the US. During this time, several major US federal agencies, including the US EPA, the Department of Transportation, the Federal Aviation Administration, the Department of Housing and Urban Development, the National Aeronautics and Space Administration, the Department of Defense, and the Federal Interagency Committee on Noise have all published important documents addressing environmental noise and its effects on people. Lack of funding, however, has made the EPA ONAC largely ineffective in the past decade. A new bill, the *Quiet Communities Act* has recently been introduced in the U.S. Congress to re-enact and fund this office (House of Representatives Bill, H.R. 536). However, the passage of this bill is uncertain, because noise in the US, as in Europe, has not received the attention that other environmental issues have, such as air and water quality.

In the USA there is growing debate over whether to continue to rely on the use of DNL (and the A-Weighted Equivalent Continuous Sound Pressure Level upon which DNL is based) as the primary environmental noise exposure metric, or whether to supplement it with other noise descriptors. Because a growing number of researchers believe that "Sound Exposure" is more understandable to the public, the American National Standards Institute has prepared a new Standard, which allows the equivalent use of either DNL or Sound Exposure (ANSI 1996). The primary purpose of this new standard, however, is to provide a methodology for modeling the Combined or Total Noise Environment, by making numerical adjustments to the exposure levels from various noise sources before assessing their predicted impacts on people. A companion standard (ANSI 1998) links DNL and Sound Exposure with the current USA land use planning table. The latter is currently being updated by a team of people from various federal government agencies and when completed should improve the capabilities of environmental and community land-use planners. These documents will complement the newly revised ANSI standard on acoustical terminology (ANSI 1994).

To summarize progress in noise control made in the USA in the nearly 25 years since the initial national environmental noise policy documents were written, the Acoustical Society of America held a special session in Washington, D.C. in 1995. The papers presented in this special session were then published as a collaborative effort between the Acoustical Society of America and the Institute of Noise Control Engineering (von Gierke & Johnson 1996). This document is available from the Acoustical Society of America, as are a wide range of standards related to various environmental noise and bioacoustics topics from the ANSI.

A document from the European Union is now also available, which includes guidelines for addressing noise in environmental assessments (EU 1996). Policy documents from organizations such as ISO, CEN, and ICAO have shown that international cooperation is quite possible in the environmental noise arena. The ISO document, entitled *Acoustics - Description and Measurement of Environmental Noise* (ISO 1996), and other international standards have already proven themselves to be invaluable in moving towards the development of a harmonized environmental noise policy. The best way to move forward in developing a harmonized environmental noise policy is to take a look at the various national policies that have already been adopted in many countries, including those both from the European member states and from the USA, and to decide what improvements need to be made to the existing policy documents. A solid understanding of the progress that has already been achieved around the world would obviously provide the foundation for the development of future noise policies.

Implementation Concepts and Tools

Development of appropriate policies, regulations, and standards, particularly in the noise measurement and impact assessment areas, is a necessary foundation for implementing effective noise abatement policies and noise control programs. A well-trained cadre of environmental planners will be needed in the future to perform land-use planning and environmental impact analysis. These professionals will require both a new generation of standardized noise propagation models to deal with the Total Noise Environment, as well as sophisticated computer-based impact analysis and land-use planning tools.

A more thorough description of the current noise environment in major cities, suburbs, and rural areas is needed to support the noise policy development process. A new generation of noise measurement and monitoring systems, along with standards related to their use, are already providing considerable improvement in our ability to accurately describe complex noise environments. Finally, both active and passive noise control technologies, and other noise mitigation techniques, are rapidly becoming available for addressing local noise problems. Combined with a strong public awareness and education program, land-use planning and noise abatement efforts certainly have the potential to provide us with an environment with acceptable levels of noise exposure.

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AFRICAN REGION

South Africa (Etienne Grond, South Africa)

Introduction

Cultural and developmental levels diverge greatly in South Africa, and the country can be divided into a first world sector, a developing sector and a third world sector. This contributes to huge variations in both the awareness of noise pollution and in population exposure to noise pollution. Noise-related health problems will in all probability show the same large variations.

Legal requirements

Noise control in South Africa has a history dating back about three decades. Noise control began with codes of practice issued by the South African Bureau of Standards (SABS) to address noise pollution in different sectors. Since then, Section 25 of the Environment Conservation Act (Act 73 of 1989) made provision for the Minister of Environmental Affairs and Tourism to regulate noise, vibration and shock at the national level. These regulations were published in 1990 and local authorities could apply to the Minister to make them applicable in their areas of jurisdiction. However, a number of the bigger local authorities did not apply for the regulations since they already had by-laws in place, which they felt were sufficient. By the middle of 1992 only 29 local authorities had applied the regulations and so the act was changed to make it obligatory for all authorities to apply the regulations. However, by the time the regulations were ready to be published, the new Constitution of South Africa came into effect and this listed noise control as an exclusive legislative competence of provincial and local authorities. This meant that the national government could not publish the regulations. However, provincial governments have agreed to publish the regulations in their respective areas. The regulations will apply to all local authorities as soon as they are published in the provinces, and will give local authorities both the power and the obligation to enforce the regulations.

The Department of Environmental Affairs and Tourism also published regulations during 1997 to make Environmental Impact Assessments mandatory for most new developments, as well as for changes in existing developments. This means that any impact that a development might have on its surrounding environment must be evaluated and, where necessary, the impact must be mitigated to acceptable levels. The noise control regulations also state that a local authority may declare a "controlled area," which is an area where the average noise level exceeds 65 dBA over a period of 24 h period. This means that educational and residential buildings, hospitals and churches may not be situated within such areas.

Occupational noise exposure is regulated by the Department of Manpower, under the Occupational Health and Safety Act (Act 85 of 1993). These regulations states that workers may not be exposed to noise levels of higher than 85 dBA and that those exposed to such levels must make use of equipment to protect their hearing. The problem, however, is that most workers tend not to make use of the provided equipment, either because the equipment is not comfortable, or because they are not aware of the risks high noise levels pose to their hearing. A further problem is that small industries often do not supply the workers with the necessary equipment, or supply inferior equipment that is less costly.

Codes of practice

The codes of practice issued by the SABS were for the most part replaced by IEC (International Electrotechnical Commission) standards and adopted as SABS ISO codes of practice. They are still being used in South Africa and are regularly updated. A relevant list can be found in the references. The SABS has also published a number of recommended practices (ARP). These include the ARP 020: "Sound impact investigations for integrated environmental management" that is currently being upgraded to a code of practice. Such codes of practice can be referred to as requirements in legislation and will be known as SABS 0328: "Methods for environmental noise impact assessments." The codes of practice published in South Africa cover hearing protection; measurement of noise; occupational noise; environmental noise; airplane noise; and building acoustics, etc.

Courses

Local authorities responsible for applying regulations published by the Department of Environmental Affairs and Tourism must employ a noise control officer who has at least three years tertiary education in engineering, physical sciences or health sciences, and who is registered with a professional council. Alternatively, a consultant with similar training may be employed. Most of the universities in South Africa provide the relevant training, with at least part of the training in acoustics. Universities and technical colleges also provide a number of special acoustics courses. Over the last couple of years awareness of environmental conservation has expanded dramatically within the academic community, and most universities and colleges now have degree courses in environmental management. At the very least, these courses include a six-month module in acoustics, and usually also include training in basic mathematics; the physics of sound; sound measuring methodologies; and noise pollution.

Community awareness and exposure to noise pollution

This topic should be discussed with respect to three separate population sectors: the first-world sector (developed), the developing sector and the third-world sector (rural).

Developed sector

This sector of the population is more-or-less as developed as their European and American counterparts. They have been exposed to noise pollution for a considerable time and, for the most part, are aware of the health consequences of high noise levels. People in this group are also aware of the existence of legal measures by which noise pollution can be addressed. Not surprisingly, most of the complaints and legal action regarding noise pollution are received from this group. Information about noise-related health problems is very limited, but because this group is highly aware of the risks posed by high noise levels, future studies will probably show that people in this category have the fewest health problems. The majority of people in this group are less exposed to high noise levels at work, and they live in more affluent neighborhoods with large plots and separating walls. Their houses tend to be built with materials that are noise reducing. They also live further away from major noise-producing activities, such as highways, airports and large industries.

Developing sector

This sector of the population has the greatest exposure to high noise levels, both at home and in the workplace. Overall, they are relatively poor and cannot afford to live in quiet areas, or afford large plots or solid building materials. A large component of this sector resides in squatter communities where building are made of any material available, from plastic to corrugated sheets and wood. The buildings are right next to each other and there is almost no noise attenuation between residencies.

People in this category usually live close to major access routes into the cities, because they make use of public transportation and taxis to get to their places of work. Often, too, they live close to their places of work, which are usually big industries with relatively high levels of noise pollution. These people usually work in high noise areas, and because of their lack of awareness of the effects of high noise levels, often do not make use of available hearing protection equipment. Because of a lack of funds, these people also cannot get out of high noise areas and go to recreational areas for relaxation and lower noise levels. Not much information is available on the adverse health problems in this sector. However, workers in this sector should undergo regular medical examinations and the results can be obtained from the industries involved.

Rural sector

As the name suggests, people in this sector live in rural surroundings and for the most part are not subjected to noise levels that could be detrimental to their health. However, they are almost totally unaware of the risks posed by high noise levels. Some of these people work on farms and work with machinery that emits relatively high noise levels, but because of their lack of awareness they do not make use of hearing protection equipment. One advantage they do have is that they return to homes in quiet surroundings and their hearing has a chance to recover. To date, no studies have been carried out to determine the state of their hearing and it would be impossible to state that they have no health problems related to high noise levels.

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EASTERN MEDITERRANEAN REGION (Shabih H. Zaidi)

Scope

In the Eastern Mediterranean region some countries have highly developed industries, while others have none. In other cases, the agricultural economy is inseparably mixed with high-technology industries, such as the oil industry, which can be seen in nearly the whole of the Arabian Peninsula. Other examples of where agriculture and industry are intertwined can be seen in Pakistan, Jordan and Egypt. The main focus of this paper is community noise, but because industry is so widely distributed, some discussion of industrial noise is inevitable. The scope of this paper is to document the available scientific data on community noise in the WHO Regional Office of the Eastern Mediterranean (EMRO) region, including preventive strategies, legislation, compensation and future trends.

Sources of Noise Pollution

Sources of noise pollution in the Eastern Mediterranean region include noise from transportation, social and religious activities, building and civil works, roadside workshops, mechanical floor shops and others. During civil works and building booms, noise levels in all countries of the Eastern Mediterranean region could easily reach 85dBA during the daytime over an 8 h work period. In Pakistan, unprotected construction work goes on at all times of the day and night and uses outdated machinery; and the noise is compounded by workers shouting. On a typical building site noise levels reach 90–100 dBA.

In Karachi, the main artery for daily commuters is a long road that terminates at the harbor. In the densest area of this road there are a hundred small and large mechanical workshops, garages, metal sheet workers, dent removers, painters, welders and repair shops, all of which create a variety of noises. In the middle of this area at the Tibet Centre the LAeq,8h is 90dBA (Zaidi 1989). A similar picture is seen elsewhere in cities like Lahore, Peshawar, etc. Fortunately, the same is not true for other newly built cities in the EMRO region, such as Dubai, or Tripoli, where strict rules separate industrial zones from residential areas.

A special noise problem is Karachi harbour. This port serves the whole of Pakistan as well as Afghanistan and several Asian states, such as Kyrgyzstan, Kazakhstan and Uzbekistan. The noise level at the main wharf of Karachi Port ranges between 90–110 dBA on any given day. Other special sources of noise are the Eastern Mediterranean airports, and indeed most of the airports in the Middle East. Most northbound air traffic originates in Pakistan, Dubai, Sharjah etc. and flights usually depart after midnight so as to arrive in Europe during the daytime. A study is currently underway in Karachi to identify the damage caused by these nocturnal flights to those living under the flight path (SH Zaidi, GH Shaikh & AN Zaidi, personal communication).

Sadly, violence has become part of Eastern culture and is a significant source of noise pollution. Wars generate a lot of noise, and although noise-induced hearing loss is a secondary issue compared with the killing, after the wars many people are hearing impaired. This has been seen following conflicts in Balochistan, Peshawar and Afghanistan, where perforated ear drums, profound hearing loss and stress-related psychosomatic illnesses are common in the refugee camps. The noise levels during a recent mass demonstration in Karachi, which included the firing of automatic weapons, reached 120 dBA at a distance of 50 m from the scene.

The Effects of Noise on Health

There is good evidence that environmental noise causes a range of health effects, including hearing loss, annoyance, cardiovascular changes, sleep disturbance and psychological effects. Although the health effects of noise pollution have not been documented for the entire EMRO region, data are available for Pakistan and can be used to illustrate the general problem. In this report, noise exposure is mainly expressed as LAeq,24h values.

Noise-induced hearing loss (NIHL).

It is believed that exposure to environmental noise in the EMRO countries is directly related to the living habits, economic prosperity and outdoor habits of people. It has been estimated that no more than 5% of the people are exposed to environmental sound levels in excess of 65dBA over a 24-h period. Similarly, for indoor noise, it is believed that the average family is not exposed to sound levels in excess of 70 dBA over a 24-h period. However, it is difficult to generalize for all countries in the EMRO region, because of ancient living styles and different cultural practices, such as taking siestas between 13:00–16:00 and stopping work at 20:00.

Exposure to noise while travelling to schools, offices or workplaces may vary tremendously between cities in the region. In Karachi, for example, traffic flow is undisciplined, erratic and irrational, with LAeq,8h values of 80–85 dBA. In Riyadh, by contrast, traffic flow is orderly with LAeq levels of 70 dBA during a normal working day. In Karachi, noise levels show significant diurnal variation, reaching levels in excess of 140 dB during the peak rush hour at around 5.00 p.m. (Zaidi 1989). At the Tibet Centre, located at a busy downtown junction, noise levels were 60–70 dB at 9 am, but reached levels in excess of 140 dB between 5-7 p.m. A study conducted on a day that transportation workers went on strike established that road traffic is the most significant source of noise pollution in this city: in the absence of buses, rickshaws, trucks and other public vehicles the LAeq level declined from 90dB to 75dB (Zaidi 1990). Motor engines, horns, loud music on public buses and rickshaws generate at least 65% of the noise in Karachi (Zaidi 1997; Shams 1997). Rickshaws can produce noise levels of 100–110 dBA and do not have silencers. On festive occasions, such as national holidays or political rallies, motorbikes running at high speeds along the Clifton beach in Karachi easily make noise exceeding 120 dBA. (Zaidi 1996).

Another study conducted at 14 different sites in Karachi showed that, in 11 of the sites, the average noise level ranged between 79–80 dB (Bosan & Zaidi 1995). The maximum noise levels at all these sites exceeded 100 dB. Speech interference, measured by the Preferred Speech Interference Level and the Articulation Index, was significant (Shaikh & Rizvi 1990). The study results indicated that two people facing each other at a distance of 1.2 m would have to shout to be intelligible; and the Articulation Indexes demonstrated that communication was unsatisfactory. Of perhaps greater concern are the results of a survey of 587 males between the ages of 17 and 45 years old, who worked as shopkeepers, vehicle drivers, builders and office

Effects of noise on sleep and the cardiovascular system.

In the Eastern Mediterranean region no specific data are available on the effects of noise on sleep or the cardiovascular system. However, factory workers, traffic constables, rickshaw drivers and shopkeepers frequently complain about fatigue, irritability and headaches; and one of the most common causes of poor performance in offices is sleep disturbance. The rising incidence of tinnitus in cities like Karachi is also related to noise exposure, and tinnitus itself can lead to sleep deprivation. Although the effects of noise on the cardiovascular system have been well documented for other countries (Berglund & Lindvall 1995), data are lacking for the EMRO region. However, the prevalence of cardiovascular diseases are on the rise in the EMRO countries, particularly hypertension. While most of the increase in these diseases is due to a rich diet and lack of exercise, the relationship between noise and cardiovascular changes is worth investigating.

The risk to unborn babies and newborns.

Although evidence from other countries indicates that noise may damage the hearing of a fetus, there are no data from the EMRO countries to confirm this. With newborn babies, however, noise from incubators is a major cause of hearing loss in the EMRO region, particularly as 20–27% of them are born underweight (Razi et al. 1995). Once exposed to noise in an incubator, the chances of hearing impairment rapidly rises compared with cohorts in developed countries. Several other factors have also been identified as causing deafness and hearing impairment in newborns in the Eastern Mediterranean region (Zaidi 1998; Zakzouk et al. 1994). They are:

a. Discharge from the ears.

b. Communicable infections.

c. Ototoxicity.

d. Noise.

e. Consanguinity.

f. Iodine deficiency.

Noise Control

Although noise control legislation exists in several EMRO countries, it is seldom enforced, particularly in Pakistan and some neighboring countries. Noise control begins with education, public awareness and the appropriate use of media in highlighting the effects of noise. In Calcutta, for instance, public orientation and mass media mobilization have produced tangible results, and this can easily be done in other countries. Three strategies have been devised for noise control, all of which are practicable in EMRO region countries. They are control at the source, control along the path and control at the receiving end.

There are many ways noise can be controlled at the source. For example, most of the equipment and machinery used in EMRO countries is imported from the West. Noise control could begin by importing quieter machinery, built with newer materials like ceramics or frictionless parts. And at the local level, the timely replacement of parts and proper maintenance of the machines should be carried out. Vehicles like the rickshaw should be banned, or at least be compelled to maintain their silencers, and all vehicles must be put to a road worthiness test periodically. This already occurs in some EMRO countries, but not all. Horns, hooters, music players and other noise making factors must also be controlled. The use of amplifiers and public address systems should also be banned, and social, leisure and religious activities should be restricted to specific places and times.

Along the sound path, barriers can be used to control noise. There are three kinds of barriers available, namely, space absorbers made out of porous material, resonant absorbers and panel absorbers. Architects, for example, use hollow blocks of porous material. The air gaps between building walls not only keep the buildings cool in hot weather, but also reduce the effects of noise. Ceilings and roofs are often treated with absorbent material. In large factories, architects use corrugated sheets and prefabricated material, which are helpful in reducing noise levels. In Pakistan, some people use clay pots in closely ranked positions on rooftops to reduce the effect of heat as well as noise. For civic works and buildings, special enclosures, barriers and vibration controlling devices should be used. Public halls, such as cinemas, mosques and meeting places should have their walls and floors carpeted, and covered with hangings, mats etc. An effective material is jute, which is grown in many countries, mainly Bangladesh, and it is quite economical. Some of the old highways and most of the busy expressways need natural noise barriers, such as earth banks, trees and plants.

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SOUTH-EAST ASIAN REGION. (Sudhakar B. Ogale)

Introduction

The ability to hear sound is a sensory function vital for human survival and communication. However, not all sounds are wanted. Unwanted sounds, for which the term "noise" is normally used, often originate from human activities such as road traffic, rail traffic, aircraft, discos, electric power generators, festivals, firecrackers and toys. In general, however, data on noise pollution in South east Asian countries are not available. For example, there are no comprehensive statistical data regarding the incidence and etiology of hearing impairment. Consequently, it is difficult to estimate the exact percentage of the population affected by community noise.

Excessive noise is the major contributor to many stress conditions. It reduces resistance to illness by decreasing the efficiency of the immune system, and is the direct cause of some gastrointestinal problems. Noise also increases the use of drugs, disturbs sleep and increases proneness to accidents. An increased incidence of mental illness and hospital admissions, increases in absenteeism from work and lethargy from sleep disturbance all result from noise pollution and cause considerable loss of industrial production.

Noise Exposure in India

India is rapidly becoming industrialized and more mechanized, which directly affects noise levels. However, no general population study regarding the magnitude of the noise problem in India has been performed.

Road Traffic Noise

Exposure. A study by the Indian Institute of Road Traffic (IRT) reported that Delhi was the noisiest city in India, followed by Calcutta and Bombay (IRT 1996; Santra & Chakrabarty 1996). The survey examined whether road-traffic noise affected people with respect to annoyance, sleep disturbance, interference with communication and hearing impairment. It showed that 35% of the population in four major cities have bilateral sensory neural hearing loss at noise emission levels above 82 dBA. This is of particular concern in light of a second study, showing that $L_{Aeq,24h}$ levels at 24 kerbside locations in Calcutta were 80–92 dBA (Chakrabarty et al. 1997) The mean noise emission levels of four different vehicle categories are presented in Table A2.1.

Table A2.1: Mean noise emission levels of vehicles

Type of vehicle	Mean sound pressure level
2 wheelers (motor cycle)	82 dBA
3 wheelers (auto rickshaw)	87 dBA
Motor car (taxi, private cars)	85 dBA
Heavy vehicles (trucks)	92 dBA

Control Measures. Only recently has noise pollution been considered an offence in India, under the Environmental (Protection) Act 1986. Several measures are being taken to reduce traffic-noise exposure. These include:

a. Planting trees, shrubs and hedges along roadsides.

b. Mandatory, periodic vehicle inspections by road traffic control.

c. Reintroduction of silent zones, such as around schools, nursing homes and hospitals that face main roads.

d. Regulation of traffic discipline, and a ban on the use of pressure horns.

e. Enforcement of exhaust noise standards.

f. Mandating that silencers be effective in three-wheeled vehicles.

g. The use and construction of bypass roads for heavy vehicles.

h. Limiting night-time access of heavy vehicles to roads in residential neighbourhoods

i. Installation of sound-proof windows.

j. Proper planning of new towns and buildings.

Air Traffic Noise

Many airports were originally built at some distance from the towns they served. But due to growing populations and the lack of space, buildings are now commonly constructed alongside airports in India.

Exposure. A survey revealed that aircraft produced a high level of noise during take-off, with sound pressure levels of 97–109 dBA for the Airbus, and 109 dBA for Boeing aircraft (SB Ogale, unpublished observations). During landing, the aircraft produced a sound pressure level of 108 dBA. Although exposure to aircraft noise is considered to be less of a problem than exposure to traffic noise, the effects of air-traffic noise are similar to those of road traffic, and include palpitations and frequent awakenings at night.

Control measures. The use of ear muffs must be made obligatory at the airport. This can reduce noise exposure to a safe level. An air-traffic control act should also enforce the use and introduction of low-noise aircraft, and mandate fewer night-time flights.

Rail Traffic Noise

Very little attention has been paid to the problems of railway noise.

Exposure. In Bombay, where the majority of residential buildings are situated on either side of railway tracks, residents are more prone to suffer from acoustic trauma. More than 14% of the population in Bombay suffer from sleep disturbances during night, due to high-speed trains and their whistling. A study on surface railways (SB Ogale, unpublished observations) revealed that platform noise was 71–73 dBA in the morning and 78–83 dBA in the evening. The noise from loudspeakers mounted in the platform was 87–90 dBA. At a distance of 1 m from the engine, the whistle noise was 105–108 dBA for a train with an electric engine, up to 110 dBA for a train with diesel engine and 118 dBA for steam engine trains. Vacuum brakes produced noise levels as high as 95 dBA. This suggests that unprotected railway staff on platforms are at risk of permanent noise induced hearing loss.

Festival noise

Festival noise in India was first surveyed in Bombay in late 1970, during the Ganpati festival period. A similar study (Santra et al. 1996) was conducted soon after in Calcutta at the Durga Pooja festival during evening hours (18:00–22:00). The music from loudspeakers produces sound pressure levels of more than 112 dBA. During the festival period the residents experienced a noisy environment for 8–10 h at a stretch, with noise level of 85–95 dBA. This level is above the 80 dBA limit set by WHO for industrial workers exposed to noise for a maximum period of 8 hours.

Control measures. In a religious country, it is politically difficult to restrict religious music, even in the interests of public health. A ban on all music from loudspeakers after 22:00 would decrease the sound pressure levels to below the permissible legal limit. A preventive programme is advocated to measure noise levels with sound level metres.

Fire crackers and toy weapons noise

Exposure. A study conducted by Gupta & Vishvakarma (1989) at the time of Deepawali, an Indian festival of fireworks, determined the auditory status of 600 volunteers from various age groups, before and after exposure to firecrackers. The study also measured the acoustical output of representative samples of toy weapons and firecrackers, and the noise intensity level at critical spectator points. The average sound level at a distance of 3 m from the noise source was 150 dBA, exceeding the 130 dBA level at which adults are at risk for hearing damage. On average, 2.5% of the people surveyed during Deepawali had persistent sensory neural hearing loss of 30 dBA, with those in the 9–15 year old age group being most affected.

Control Measures. A judicious approach in the manufacture and use of toy weapons and firecrackers is encouraged, in addition to legal restraints. Fireworks should be more a display of light, rather than sound.

Generator Noise

Diesel generators are often used in India to produce electric power. Big generators produce sound pressure levels exceeding 96 dBA (SB Ogale, unpublished observations).

Conclusions

No comprehensive statistical data are available for community noise in India, however, the main sources of environmental noise are road traffic, air traffic, rail traffic, festivals, firecrackers and diesel generators. The adverse effects of noise are difficult to quantify, since tolerance to noise levels and to different types of noise varies considerably between people. Noise intensity also varies significantly from place to place. It should also be noted that noise data from different countries are often not obtained by the same method, and in general models have been used which are based on data from a limited number of locations. Noise control measures could be taken at several levels, including building design, legal measures, and educating the people on the health dangers of community noise. In India, what is needed now is noise control legislation and its strict enforcement, if a friendly, low-noise environment is to be maintained.

Noise Exposure in Indonesia

According to a report by the WHO, the noise exposure and control situation in Indonesia is as follows (Dickinson 1993).

Exposure. No nationwide data are available for Indonesia. However, during the last three decades there has been rapid growth in transportation, industry and tourism in Indonesia.

Control Measures. With the large majority of people having little income, protection of the physical environment has not been a first-order priority. The following recommendations have been made with respect to community noise (Dickinson 1993):

a. The cities of Indonesia have relatively large populations and each provincial government will need the staff and equipment to monitor and manage the environment.

b. Sound level meters with noise analysis computer programmes should be purchased.

c. Training courses and adequate equipment should be provided.

d. Noise management planning for airports should be promoted.

e. Reduction measures should be taken for road-traffic noise.

Noise Exposure in Bangladesh

Exposure. In Bangladesh no authentic statistical data on the effects of community noise on deafness or hearing impairment are available (Amin 1995).

Control Measures. Governments have meager resources, a vast population to contend with and high illiteracy rates; consequently, priorities are with fighting hunger, malnutrition, diseases and various man-made and natural calamities. The governments are unable to give the necessary attention towards the prevention, early detection and management of noise disabilities in the country. Close cooperation is needed between the national and international organizations, to exchange ideas, skills and knowledge (Amin 1995).

Noise Exposure in Thailand

Exposure. Noise from traffic, construction, and from factories and industry has become a big problem in the Bangkok area. The National Environmental Board of Thailand was set up two decades ago and has been active in studying the pollution problems in Thailand. Indeed, a committee on noise pollution control was set up to study the noise pollution in Bangkok area and its surroundings. Although regulations and recommendations were made for controlling various sources of noise, the problem was not solved due to a lack of public awareness, the difficulty of proving that noise had adverse effects on health and hearing, and the difficulty of getting access to control noise. A general survey revealed that 21.4% of the Bangkok population is suffering from sensory neural hearing loss (Prasanchuk 1997). Noise sources included street noise, traffic noise, industrial noise and leisure noise.

Control Measures. In 1996, regulations for noise pollution control set LAeq,24h levels at 70 dBA for residential areas, and less than 50 dBA to avoid annoyance. The National Committee on Noise Pollution Control has been asked to study the health effects of noise in the Bangkok area and its surroundings, and determine whether these regulations are realistic and feasible.

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WESTERN PACIFIC REGION.

In this section, information on noise pollution and control will be given for three countries in the Western Pacific Region, namely Australia, the People's Republic of China and Japan. From a noise pollution point of view China may be viewed as a developing country, whereas Japan and Australia, with their high level of industrialization, represent developed countries.

Australia (Andrew Hede & Michinori Kabuto)

Exposure. Australia has a population of 18 million with the majority living in cities that have experienced increasing noise pollution from a number of sources. The single most serious source of noise is road traffic, although in major cities such as Sydney, Melbourne and Perth, large communities are exposed to aircraft noise as well. Other important sources of noise pollution are railway noise and neighbourhood noise (including barking dogs, lawn mowers and garbage collection). A particular problem in Australia is that the climate encourages most residents to live with open windows, and few houses have effective noise insulation.

A study of road-traffic noise was conducted at 264 sites in 11 urban centres with populations in excess of 100 000 people (Brown et al. 1994). Noise was measured one metre from the façade of the most exposed windows and at window height. From the results, it was estimated that over 9% of the Australian population is exposed to LA10,18h levels of 68 dB or greater, and 19% of the population is exposed to noise levels of 63 dB or greater. In terms of LAeq values for daytimes, noise exposure in Australia is worse than in the Netherlands, but better than in Germany, France, Switzerland or Japan.

Control. In the mid-1990's, when a third runway was built at Sydney Airport, the government funded noise insulation of high-exposed dwellings. Increasingly, too, major cities are using noise barriers along freeways adjacent to residential communities. In most states barriers are mandatory for new freeways and for new residential developments along existing freeways and major motorways. There has been considerable testing of noise barriers by state agencies, to develop designs and materials that are cost effective.

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China (Chen Ming)

Introduction

Urban noise pollution has become a contemporary world problem. Urban noise influences people's living, learning and working. People exposed to noise feel disagreeable and cannot concentrate on work. Rest and sleep are also disturbed. People exposed to high-intensity noise do not hear alarm signals and cannot communicate with each other. This can result in injury and, indeed, with the modernization of China, construction accidents related to noise are increasing. According to statistics for several cities in China, including Beijing, Shanghai, Tientsin and Fuzhou, the proportion of total accidents that were noise related was 29.7% in 1979, 34.6% in 1980, 44.8% in 1981 and 50% in 1990. It is therefore very important to control noise pollution in China.

Long-term exposure to urban environmental noise can lead to temporary hearing loss (assessed by temporary threshold shift), permanent hearing loss (assessed by permanent threshold shift) or deafness. Microscopy studies have shown that in people exposed to noise for long periods, hair cells, nerve fibers and ganglion cells were absent in the cochleae, especially in the basal turns. The primary lesion is in the 8–10 mm region of the cochlea, which is responsible for detecting sound at a frequency of 4 000 Hz. People chronically exposed to noise may first complain about tinnitus and, later on, about hearing loss. This is especially true for patients who have bilateral hearing loss at 4 000 Hz, but who have relatively good hearing other frequencies. Non-auditory symptoms of noise include effects on the nervous system, cardiovascular system and blood system. These symptoms were rarely observed in China in the past, but today more and more people complain about hearing damage and non-auditory physiological effects.

Urban environmental noise has thus become a common concern of all members of society. A key to resolving the complex noise issue lies in the effective control of urban noise sources. Control measures include reducing noise at its source, changing noise transmission pathways, building design, community planning and the use of personal hearing protection.

Urban environmental noise sources can be divided into industrial noise, traffic noise, building architecture noise and community district noise sources. Only the last three types are of concern here.

Traffic Noise

There are four sources of traffic noise: road traffic, railway transport, civil aviation and water transport; of these, road traffic is the main source of urban noise. The sound emission levels of heavy-duty trucks are 82–92 dBA and 90–100 dBA for electric horns; air horns are even worse, with sound emission levels of 105–110 dBA. Most urban noise from automobiles is in the 70–75 dB range, and it has been estimated that 27% of all complaints are about traffic noise. When a commercial jet takes off, speech communication is interrupted for up to 1 km on both sides of the runway, but people as far away as 4 km are disturbed in their sleep and rest. If a supersonic passenger plane flies at an altitude of 1 500 m, its sound pressure waves can be heard on the ground in a 30–50 km radius.

Building Noise

As a result of urban development in China, construction noise has become an increasingly serious problem. It is estimated that 80% of the houses in Fuzhou were built in the past 20 years. According to statistics, the noise from ramming in posts and supports is about 88 dB and the noise from bulldozers and excavators is about 91 dB, 10 m from the equipment. About 98% of industrial noise is in the 80–105 dB range, and it is estimated that 20% of all noise complaints is about industrial noise.

Community Noise

The main sources of community noise include street noise, noise from electronic equipment (air conditioners, refrigerators, washing machines, televisions), music, clocks, gongs and drums. Trumpets, gongs, drums and firecrackers, in particular, seriously disturb normal life and lead to annoyance complaints.

In conclusion, urban noise pollution in China is serious and is getting worse. To control noise pollution, China has promulgated standard sound values for environmental noise. These are summarized in table A2.2.

Table A2.2: LAeq standard values in dB for environmental noise in urban areas.

Applied area	day	night
Special residential quarters[1]	45	35
Residential and cultural education area[2]	50	40
Type 1 mixed area[3]	55	45
Type 2 mixed area[4] or commercial area	60	50
Industrial area	65	55
Arterial roads[5]	70	55

1 Special residential quarters: quiet residential area
2 Residential and cultural education area: residential quarters, cultural, educational offices
3 Type 1 mixed area: mixture of commercial area and residential quarters
4 Type 2 mixed area: mixture of industrial area, commercial area, residential quarters and others
5 Roads with traffic volume of more than 100 cars per hour

The peak sound levels for frequent noises emitted during the night-time are not allowed to exceed standard values by more than 10 dBA. Single, sudden noises during the night-time are not allowed to exceed standard values by more than 15dBA.

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Japan (Michinori Kabuto)

Environmental Quality Standards

Noise standards for both general and roadside areas were set in Japan in 1967, through the "Basic Law for Environmental Pollution." This law was updated in September 1999. Each standard is classified according to the type of land use and the time of day. In ordinary residential areas, the night-time standard is 45 dB LAeq, but in areas that require even lower noise exposure, such as hospitals, this is lowered to 40 dB LAeq. In contrast, the daytime levels for commercial and industrial areas is as high as 60 dBA. Standards for roadside areas are 70 dB LAeq for daytime and 65 dB LAeq for nighttime. Between 1973–1997 noise standards for aircraft noise, super-express train noise and conventional railway train noise were also implemented. Standards for aircraft noise were set in terms of the weighted equivalent continuous perceived noise level (WECPNL). For residential areas, the WECPNL standard is 70 dBA, and is 75 dBA for areas where it is necessary to maintain a normal daily life.

For super-express trains, the Environmental Agency required noise levels to be below 75 dBA in densely populated residential areas, such as along the Tokaido and Sanyo Shinkansen lines, as well as in increasingly populated areas, such as along the Tohoku and Joetsu Shinkansen lines. The standards were to be met by 1990, but by 1991 this level had been achieved at only 76% of the measuring sites on average. Noise countermeasures included the installation of new types of sound-proof walls, and laying ballast mats along densely populated stretches of the four Shinkansen lines. Noise and vibration problems can also result from conventional trains, such as occurred with the opening of the Tsugaru Strait and Seto Ohashi railway lines in 1988. Various measures have since been taken to address the problems.

Complaints About Community Noise.

In Japan, complaints to local governments about environmental problems have been summarized annually and reported by Japan Environmental Agency. Thirty-seven percent of all complaints was due to factory (machinery) noise; 22% to construction noise; 3% to road traffic noise; 4% to air traffic noise; 0.8% to rail traffic noise; 9% to night-time business; 6% to other commercial activities; 2.5% to loudspeaker announcements; 9% to domestic noise; and 8% was due to miscellaneous complaints.

Sources of Noise Exposure and their Effects

Road-traffic noise. The number of automobiles in Japan has increased from 20 million in 1971 to 70 million in 1994, a 3.5-fold increase. One-third of this increase was due to heavy-duty vehicles. Since 1994, out of a total of 1 150 000 km of roads in Japan, only 29 930 km have been designed according to noise regulations. According to 1998 estimates by the Environmental Agency, 58% of all roads passed through residential areas. Daytime noise limits were exceeded in 92% of all cases, and night-time limits were exceeded in 87% of all cases. The study also estimated that 0.5 million houses within 10 m of the roads were exposed to excessive traffic noise. In a recent lawsuit, the Japanese Supreme Court ruled that people should be compensated when exposed to night-time noise levels exceeding 65 dB Laeq. This would apply to people living alongside 2 000 km of roads in Japan.

A recent epidemiological study examined insomnia in 3 600 women living in eight different roadside areas exposed to night-time traffic. Insomnia was defined as one or more of the following symptoms: difficulty in falling asleep; waking up during sleep; waking up too early; and feelings of sleeplessness one or more days a week over a period of at least a month. The data were adjusted for confounding variables, such as age, medical care, whether the subjects had young children to care for, and sleep apnea symptoms. The results showed that the odds ratio for insomnia was significantly correlated with the average night-time traffic volume for each of the eight areas and suggested that insomnia could be attributed solely to night-time road traffic.

From the most noisy areas in the above study 19 insomnia cases were selected for a further in-depth examination. The insomnia cases were matched in age and work with 19 control subjects. Indoor and outdoor sound levels during sleep were measured simultaneously at 0.6 s intervals. For residences facing roads with average night-time traffic volume of 6 000 vehicles per hour, the highest sound levels observed were 78–93 dBA. The odds ratios for insomnia in each of the quartiles for LAmax,1min; L50,1min; L10,1min and LAeq,1min generally showed a linear trend and ranged between 1 (lowest quartile) and 6–7 (highest quartile). It was concluded that insomnia was likely to result when night-time indoor LAeq, 1min sound levels exceeded 30 dBA.

Air-traffic noise At the larger Japanese airports (Osaka, Tokyo, Fukuoka), jet airplanes have rapidly increased in number and have caused serious complaints and lawsuits from those living nearby. Complaints about jet-fighter noise are also common from residents living in the vicinity of several U.S. airbases located in Japan. In the case of Kadena and Futemma airbases on Okinawa, a recent study by the Okinawa Prefecture Government suggested that hearing loss, child misbehaviour and low birth-weight babies were possible health effects of the noise associated with these bases (RSCANIH 1997). Using measurements taken in 1968 during the Vietnam War, it was estimated that the WECPNL was 99–108 dBA at the Kadena village fire station. Similar WECPNL estimates of 105 dBA were also obtained for Yara (Kadena-cho) and Sunabe (Chatan-cho) bases. These levels correspond to a LAeq,24h value of 83 dB, and are of serious concern in light of recommendations by the Japan Association of Industrial Health that occupational noise exposure levels should not exceed 85 dB for an 8-h work day if hearing loss is to be avoided.

Audiogrammes of subjects living in areas surrounding Kadena airport indicated that they had progressive hearing loss at higher frequencies. Eight subjects had hearing impairment in the 3–6 kHz range, which strongly suggested that the hearing loss was due to excessive noise exposure. Since the examiners confirmed the subjects had not been exposed to repeated intense noise at their residences or workplaces, the most likely cause of their hearing loss was the intense aircraft noise during take-offs, landings and tune-ups at Kadena airport.

The effects of noise were examined in children from nursery schools and kindergartens in towns surrounding Kadena airport. The children were scored with respect to seven variables: cold symptoms, emotional instability, discontentment-anxiety, headache-stomachache, passivity, eating problems and urination problems. Confounding factors, such as sex, age, birth order, the number of parents living together, the mother's age when the child was born, reaction to noise and the extent of noise exposure, were taken into account. The results showed that children exposed to noise had significantly more problems with respect to their behaviour, physical condition, character and reaction to noise, when compared to a control group of children that had not been exposed to airport noise. This was especially true of for children exposed to a WECPNL of 75 or more. Thus, small children acquire both physical and mental disorders from chronic exposure to aircraft noise.

Chronic exposure to aircraft noise also affects the birth-weight of children. The birth-weights of infants were analyzed using records from 1974 to 1993 in the Okinawa Prefecture. Confounding factors such as the mother's age, whether there were single or multiple embryos, the child's sex, and the legitimacy of the child were considered. The results showed that 9.1 % of all infants born in Kadena-cho, located closest to Kadena airport, had low birth-weights. This was significantly higher than the 7.6 % rate seen in other municipalities around Kadena and Futemma airfields, and much higher than the 7 % rate in cities, towns and villages on other parts of Okinawa Island.

Rail-traffic noise. Commuter trains and subway cars expose Tokyo office workers to much higher noise levels than do other daily activities (Kabuto & Suzuki 1976). Exposure to indoor noise may vary according to railway line or season (there are more open windows in good weather), but the levels range from 65–85 dBA. In general, these values exceeded the $L_{Aeq,24h}$ level of 70 dBA for auditory protection (US EPA 1974).

Neighbourhood noise. Neighbourhood noise, including noise from late-night business operations, noise caused by loudspeaker announcements, and noise from everyday activities, have accounted for approximately 39% of all complaints about noise in recent years. At present, noise controls for late-night business operations have been enforced by ordinances in 39 cities and prefectures, and in 42 cities for loudspeaker announcements.

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Appendix 3 : Glossary

Acoustic	Pertaning to sound or to the sense of hearing (CMD 1997)
Acoustic dispersion	Change of speed of sound with frequency (ANSI 1994)
Acoustic trauma	Injury to hearing by noise, especially loud noise (CMD 1997)
Adverse effect	(of noise:) A change in morphology and physiology of an organism which results in impairment of functional capacity or impairment of capacity to compensate for additional stress or increase in susceptibility to the harmful effects of other environmental influences. This definition includes any temporary or long term lowering of physical, psychological or social functioning of humans or human organs (WHO 1994)
Annoyance	A feeling of displeasure associated with any agent or condition known or believed by an individual or a group to be adversely affecting them" (Lindvall and Radford 1973; Koelega 1987). Any sound that is perceived as irritating or a nuisance (ANSI 1995)
Anxiety	A feeling of apprehension, uncertainty, and fear without apparent stimulus, and associated with physiological changes (tachycardia, sweating, tremor, etc.) (DIMD 1985). A vaguer feeling of apprehension, worry, uneasiness, or dread, the source of which is often nonspecific or unknown to the individual (CMD 1997).
Audiometry	Testing of the hearing sense (CMD 1997). Measurement of hearing, including aspects other than hearing sensitivity (ANSI 1995)
Auditory	Pertaining to the sense of hearing (CMD 1997)
Auditory threshold	Minimum audible sound perceived (CMD 1997)
A-weighting	A frequency dependent correction that is applied to a measured or calculated sound of moderate intensity to mimick the varying sensitivity of the ear to sound for different frequencies

Ambient noise	All-encompassing sound at a given place, usually a composite of sounds from many sources near and far (ANSI 1994)
Articulation index	Numerical value indicating the proportion of an average speech signal that is understandable to an individual (ANSI 1995)
Bel	Unit of level when the base of the logarithm is ten, and the quantities concerned are proportional to power; unit symbol B (ANSI 1994)
Cardiovascular	Pertaining to the heart and blood vessels (DIMD 1985)
Cochlea	A winding cone-shaped tube forming a portion of the inner ear. It contains the receptor for hearing (CMD 1997)
Cognitive	Being aware with perception, reasoning, judgement, intuition, and memory (CMD 1997)
Community noise	Noise emitted from all noise sources except noise at the industrial workplace (WHO 1995a)
Cortisol	A glucocortical hormone of the outer layer of the adrenal gland (CMD 1997)
Critical health effect	Health effect with lowest effect level
C-weighting	A frequency dependent correction that is applied to a measured or calculated sound of high intensity to mimick the varying sensitivity of the ear to sound for different frequencies
dB	Decibel, one-tenth of a bel
dBA	A-weighted frequency spectrum in dB, see A-weighting
dBC	C-weighted frequency spectrum in dB, see C-weighting
dBlin	Unweighted frequency spectrum in dB
Decibel	Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power; unit symbol dB (ANSI 1994)

Ear plug	Hearing protector that is inserted into the ear canal (ANSI 1994)
Ear muff	Hearing protector worn over the pinna (external part) of an ear (ANSI 1994)
Effective perceived noise level	Level of the time integral of the antilogarithm of one tenth of tone-corrected perceived noise level over the duration of an aircraft fly-over, the reference duration being 10 s (ANSI 1994)
Emission	(of sounds). Sounds generated from all types of sources
Epinephrine	A hormone secreted by the adrenal medulla (inner or central portion of an organ) in response to stimulation of the sympathetic nervous system (CMD 1997)
Equal energy principle	Hypothesis that states that the total effect of sound is proportional to the total amount of sound energy received by the ear, irrespective of the distribution of that energy in time
Equivalent sound pressure level	Ten times the logarithm to the base ten of the ratio of the time-mean-square instantaneous sound pressure, during a stated time interval T, to the square of the standard reference sound pressure (ANSI 1994)
Exposure-response curve	Graphical representation of exposure-response relationship
Exposure-response relationship	(With respect to noise:) Relationship between specified sound levels and health impacts
Frequency	For a function periodic in time, the reciprocal of the period (ANSI 1994)
Frequency-weighting	A frequency dependent correction that is applied to a measured or calculated sound (ANSI 1994)
Gastro-intestinal	Pertaining to the stomach and intestines (CMD 1997)
Hearing impairment, hearing loss	A decreased ability to perceive sounds as compared which what the individual or examiner would regard as normal (CMD 1997)
Hearing threshold	For a given listener and specified signal, the minimum (a) sound pressure level or (b) force level that is capable of

	evoking an auditory sensation in a specified function of trials (ANSI 1994)
Hertz	Unit of frequency, the number of times a phenomenon repeats itself in a unit of time; abbreviated to Hz
Hysteria	A mental disorder, usually temporary, presenting somatic (pertaining to the body) symptoms, stimulating almost any type of physical disease. Symptoms include emotional instability, various sensory disturbations, and a marked craving for sympathy (CMD 1997)
Immission	Sounds impacting on the human ear.
Impulsive sound	Sound consisting of one or more very brief and rapid increases in sound pressure
Incubator	An enclosed crib, in which the temperature and humidity may be regulated, for care of premature babies (CMD 1997)
Isolation, insulation	(With respect to sound:) Between two rooms in a specified frequency band, difference between the space-time average sound presssure levels in the two enclosed spaces when one or more sound sources operates in one of the rooms (ANSI 1994). (With respect to vibrations:) Reduction in the capacity of a system to respond to excitation, attained by use of resilient support (ANSI 1994).
Ischaemic Heart Disease	Heart disease due to a local and temporary deficiency of blood supply due to obstruction of the circulation to a part (CMD 1997)
Loudness level	Of a sound, the median sound pressure level in a specified number of trials of a free progressive wave having a frequency of 1000 Hz that is judged equally loud as the unknown sound when presented to listeners with normal hearing who are facing the source; unit phon (ANSI 1994)
Level	Logarithm of the ratio of a quantity to a reference quantity of the same kind; unit Bel (ANSI 1994)
Maximum sound level	Greatest fast (125 milliseconds) A-weighted sound level, within a stated time interval (ANSI 1994)

Mental Health	The absence of identifiable psychiatric disorder according to current norms (Freeman 1984). In noise research, mental health covers a variety of symptoms, ranging from anxiety, emotional stress, nervous complaints, nausea, headaches, instability, argumentativeness, sexual impotency, changes in general mood and anxiety, and social conflicts, to more general psychiatric categories like neurosis, phychosis and hysteria (Berglund and Lindvall 1995).
Morphological	Pertaining to the science of structure and form of organisms without regard to function (CMD 1997)
Nausea	An unpleasant sensation usually preceding vomiting (CMD 1997)
Neurosis	An emotional disorder due to unresolved conflicts, anxiety being its chief characteristic (DIMD 1985)
Noise	Undesired sound. By extension, noise is any unwarranted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device (ANSI 1994).
Noise induced temporary threshold shift	Temporary hearing impairment occurring as a result of noise exposure, often phrased temporary threshold shift (adapted from ANSI 1994)
Noise induced permanent threshold shift	Permanent hearing impairment occurring as a result of noise exposure, often phrased permanent threshold shift (adapted from ANSI 1994)
Noise level	Level of undesired sound
Norepinephrine	A hormone produced by the adrenal medulla (inner or central portion of an organ), similar in chemical and pharmacological properties to epinephrine, but chiefly a vasoconstrictor with little effect on cardiac output (CMD 1997)
Oscillation	Variation, usually with time, of the magnitude of a quantity with respect to a specified reference when the magnitude is alternately greater and smaller than the reference (ANSI 1994)

Ototoxic	Having a detrimental effect on the organs of hearing (CMD 1997)
Paracusis	Any abnormality or disorder of the sense of hearing (CMD 1997)
Pascal	Unit of pressure, equal to one newton per square meter, abbreviated to Pa
Peak sound pressure	Greatest absolute instantaneous sound pressure within a specified time interval (ANSI 1994)
Peak sound pressure level	Level of peak sound pressure with stated frequency weighting, within a specified time interval (ANSI 1994)
Perceived noise level	Frequency-weighted sound pressure level obtained by a stated procedure that combines the sound pressure levels in the 24 one-third octave bands with midband frequencies from 50 Hz to 10 kHz (ANSI 1994)
Permanent threshold shift, permanent hearing loss	Permanent increase in the auditory threshold for an ear (adapted from ANSI 1995) (see also: noise induced permanent threshold shift)
Presbyacusia, presbycusis	The progressive loss of hearing ability due to the normal aging process (CMD 1997)
Psychiatric disorders	Mental disorders
Psychosis	Mental disturbance of a magnitude that there is a personality disintegration and loss of contact with reality (CMD 1997)
Psychotropic drug	A drug that affects psychic function, behaviour or experience (CMD 1997)
Reverberation time	Of an enclosure, for a stated frequency or frequency band, time that would be required for the level of time-mean-square sound pressure in the enclosure to decrease by 60 dB, after the source has been stopped (ANSI 1994)
Sensorineural	Of or pertaining to a sensory nerve; pertaining to or affecting a sensory mechanism and/or a sensory nerve (DIMD 1985)

Signal	Information to be conveyed over a communication system (ANSI 1994)
Signal-to-noise ratio	Ratio of a measure of a signal to the same measure of the noise (ANSI 1995) (see also: noise –in its extended meaning)
Silencer	Duct designed to reduce the level of sound; the sound-reducing mechanisms may be either absorptive or reactive, or a combination (ANSI 1994)
Sound absorption	Change in sound energy into some other form, usually heat, in passing through a medium or on striking a surface (ANSI 1994)
Sound energy	Total energy in a given part of a medium minus the energy that would exist at that same part with no sound waves present (ANSI 1994)
Sound exposure	Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event (ANSI 1994)
Sound exposure level	Ten times the logarithm to the base ten of the ratio of a given time integral of squared, instantaneous A-weighted sound pressure, over a stated time interval or event, to the product of the squared reference sound pressure of 20 micropascals and reference duration of one second (ANSI 1994)
Sound intensity	Average rate of sound energy transmitted in a specified direction at a point through a unit area normal to this direction at the point considered (ANSI 1994)
Sound level meter	Device to be used to measure sound pressure level with a standardized frequency weighting and indicated exponential time weighting for measurements of sound level, or without time weighting for measurement of time-average sound pressure level or sound exposure level (ANSI 1994)
Sound pressure	Root-mean-square instantaneous sound pressure at a point, during a given time interval (ANSI 1994), where the *instantaneous* sound pressure is the total instantaneous pressure in that point minus the static pressure (ANSI 1994)

Sound pressure level	Ten times the logarithm to the base ten of the ratio of the time-mean-square pressure of a sound, in a stated frequency band, to the square of the reference sound pressure in gases of 20 μPa (ANSI 1994)
Sound reduction index	Single-number rating of airborne sound insulation of a partition (ANSI 1994)
Sound transmission class	Single-number rating of airborne sound insulation of a building partition (ANSI 1994)
Speech interference level	One-fourth of the the sum of the band sound pressure levels for octave-bands with nominal midband frequencies of 500, 100, 2000 and 4000 Hz (ANSI 1994)
Speech intelligibility	That property which allows units of speech to be identified (ANSI 1995)
Speech perception	Psychological process that relates a sensation caused by a spoken message to a listener's knowledge of speech and language (ANSI 1995)
Speech comprehension	(a) Highest level of speech perception. (b) Knowledge or understanding of a verbal statement (ANSI 1995)
Speech transmission index	Physical methgod for measuring the quality of speech-transmission channels accounting for nonlinear distortions as well as distortions of time (ANSI 1995)
Stereocilia	Nonmotile protoplasmic projections from free surfaces on the hair cells of the receptors of the inner ear (CMD 1997)
Stress	The sum of the biological reactions to any adverse stimulus, physical, mental or emotional, internal or external, that tends to disturb the organism's homeostasis (DIMD 1985)
Temporary threshold shift, temporary hearing loss	Temporary increase in the auditory threshold for an ear caused by exposure to high-intensity acoustic stimuli (adapted from ANSI 1995) (see also: noise induced temporary threshold shift).
Tinnitus	A subjective ringing or tinkling sound in the ear (CMD 1997). Otological condition in which sound is perceived by

	a person without an external auditory stimulation. The sound may be a whistling, ringing, buzzing, or cricket type sounds, but auditory hallucinations of voices are excluded (ANSI 1995).
Vibration	Oscillation of a parameter that defines the motion of a mechanical system (ANSI 1994)

For references see Appendix A.

Appendix 4 : Acronyms

AAP	American Academy of Pediatrics
AI	Articulation Index
AMIS	Air Management Information System (WHO, Healthy Cities)
ANEF	Australian Noise Exposure Forecast
ANSI	American National Standard Institute, Washington DC, USA
ASCII	American Standard Code for Information Interchange
ASHA	American Speech-Language-Hearing Association, Rockville, MD, USA
ASTM	American Society for Testing and Materials, West Conshohocken, PA, USA
CEN	Comité Européen de Normalisation, Brussels, Belgium (European Committee for Standardization)
CFR	Code of Federal Regulations (United States)
CIAL	Centro de Investigaciones Acústicas y Luminotécnicas, Córdoba, Argentina (Centre of acoustical and light-technical investigations)
CMD	Cyclopedic Medical Dictionary
CNRC	Conseil National de Recherches du Canada (National Research Council)
COPD	Chronic Obstructive Pulmonary Disease
CSD	Commission for Sustainable Development
CSIRO	Commonwealth Scientific and Industrial Research Organization
CVS	Cardiovascular System
DNL	Day-Night Average Sound Level (United States)
EC DG	European Commission Directorate General
ECE	Economic Commission for Europe
ECMT	European Conference of Ministers of Transport
EHIAP	Environmental Health Impact Assessment Plan
EIAP	Environmental Impact Assessment Plan
EMRO	WHO Regional Office of the Eastern Mediterranean
ENIA	Environmental Noise Impact Analysis
EPNL	Effective Perceived Noise Level measure
EU	European Union
FAA	Federal Aviation Administration (United States)
FFT	Fast Fourier Transform technique
GIS	Geographic Information System
Hz	Hertz, the unit of frequency
ICAO	International Civil Aviation Organization
ICBEN	International Commission on the Biological Effects of Noise
IEC	International Electrotechnical Commission
ILO	International Labour Office, Geneva, Switzerland
INCE	Institute of Noise Control Engineering of the United States of America
INRETS	Institut National de REcherche sur les Transports et leur Sécurité, Arcueil, France (National Research Institute for Transport and their Safety)
ISO	International Standards Organization
I-INCE	International Institute of Noise Control Engineering
L10	10 percentile of sound pressure level

L50	Median sound pressure level
L90	90-percentile of sound pressure level
LA	Latin America
LAeq,T	A-weighted equivalent sound pressure level for period T
LAmax	Maximum A-weighted sound pressure level in a stated interval
L_{dn}	Day and night continuous equivalent sound pressure level
Leq,T	Equivalent sound pressure level for period T
LEQ(FLG)	Descriptor used for aircraft noise (Germany)
LNIP	Low Noise Implementation Plan
Lp	Sound pressure level
MTF	Modulation Transfer Function
NASA	National Aeronautics and Space Administration (United States)
NC	Noise Criterion
NCA	Noise Control Act (United States)
NCB	Balanced Noise Criterion procedure system
NEF	Noise Exposure Forecast
NEPA	National Environmental Policy Act (United States)
NGO	Non Governmental Organization
NIHL	Noise Induced Hearing Loss
NIPTS	Noise Induced Permanent Threshold Shift
NITTS	Noise Induced Temporary Threshold Shift
NNI	Noise and Number Index
NR	Noise Rating
NRC	National Research Council (United States, Canada)
OECD	Organisation for Economic Co-operation and Development, Paris, France.
ONAC	Office of Noise Abatement and Control of the US EPA
OSHA	Occupational Safety and Health Administration
Pa	Pascal, the unit of pressure
PAHO	Pan American Health Organization
PHE	Department for Protection of the Human Environment, WHO, Geneva
PNL	Perceived Noise Level
PSIL	Preferred Speech Interference Level
PTS	Permanent Threshold Shift
RASTI	Rapid Speech Transmission Index
RC	Room Criterion
SABS	South African Bureau of Standards
SEL	Sound Exposure Level
STC	Sound Transmission Class
STI	Speech Transmission Index
TTS	Temporary Threshold Shift
UK	United Kingdom
UN	United Nations
UNCED	United Nations Conference on Environment and Development (Rio de Janeiro, June 1992)
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe

UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
US EPA	United States Environmental Protection Agency
USA	United States of America
WCED	World Commission on Environment and Development (Brundtland Commission)
WECPNL	Weighted Equivalent Continuous Perceived Noise Level
WHO	World Health Organization
WWF	World Wildlife Fund

Appendix 5 : Equations and other technical information

Basic acoustical measures

Sound Pressure Level

The time-varying sound pressure will completely define a sound in a given location. The sound pressure range is wide within which human listeners can receive (10^{-5} - 10^{2} N/m^2). Therefore, it is practical to measure sound pressure level on a logarithmic scale. Sound intensity level is defined as 10 times the logarithm (to the base 10) of the ratio of the sound intensity of a target sound to the sound intensity of another (reference) sound. Sound intensity is proportional to the squared sound pressure because the static mass density of the sound medium as well as the speed of sound in this medium are invariant. The sound pressure level (L_p) of a sound may be expressed as a function of sound pressure (p) and is, thus, possible to measure:

$$L_p = 10 \log_{10} (p/p_{ref})^2$$

For the purpose of measuring sound pressure level in a comparative way, the reference pressure, p_{ref}, has an internationally agreed value of $2{\cdot}10^{-5}$ N/m^2 (earlier 20 μPa). Sound pressure level is then expressed in decibel (dB) relative to this reference sound.

Sound Pressure Level of Combined Sounds

Whereas sound intensities or energies or pressures are additive, non-correlated time-varying sound pressure levels have first to be expressed as mean square pressure, then added, and then transferred to a sound pressure value again. For example, if two sound sources are combined, each of a sound pressure level of 80 dB, then the sound pressure level of the resulting combined sound will become 83 dB:

$$L_p = 10 * \log_{10} (10^8 + 10^8) = 10 * \log_{10} (2 * 10^8) = 10 * (\log_{10} 2 + \log_{10} 10^8) = 10 * (0.3 + 8) = 83$$

It is only sounds with similar sound pressure levels that when combined will result in a significant increase in sound pressure level relative to the louder sound. In the example given above, a doubling of the sound energy from two sources will only result in a 3-dB increase in sound pressure level. For two sound sources that emit non-correlated time-varying sound pressures, this represents the maximum increase possible. The sound pressure level outcome, resulting from combining two sound pressure levels in dB, is displayed in Figure A.5.1.

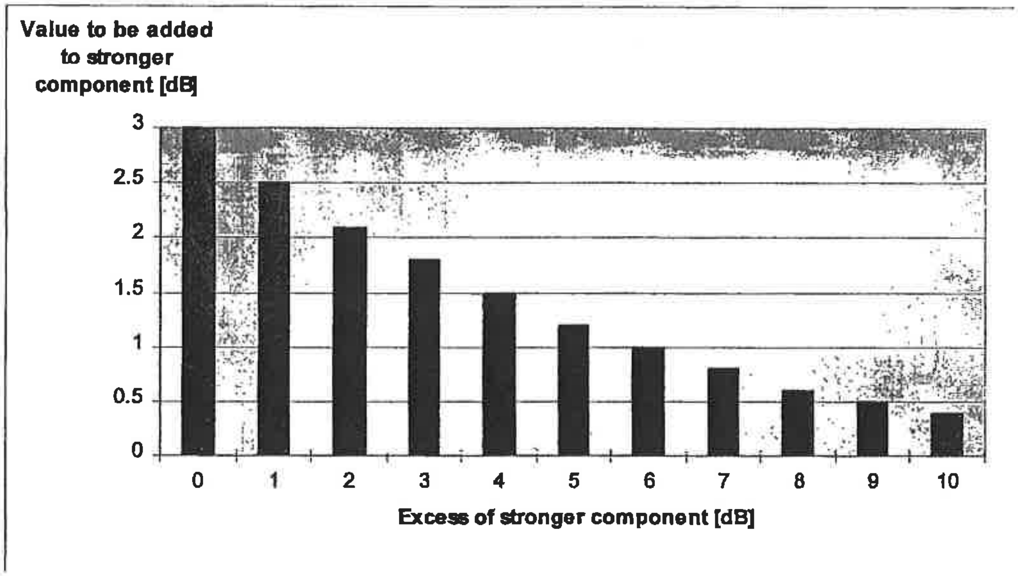

Figure A.5.1: Estimate of combined sound levels

Equivalent Continuous Sound Pressure Level

Average sound pressure level is determined for a time period of interest, T, which may be an interval in seconds, minutes, or hours. This gives a dB-value in Leq that stands for equivalent continuous sound pressure level or simply sound level. It is derived from the following mathematical expression in which A-weighting has been applied:

$$LAeq,T = 10 \log_{10}\{(1/T) \int_0^T 10^{Lp(t)/10}\, dt\} \text{ [dBA]}$$

Because the integral is a measure of the total sound energy during the period T, this process is often called "energy averaging". For similar reasons, the integral term representing the total sound energy may be interpreted as a measure of the total noise dose. Thus, Leq is the level of that steady sound which, over the same interval of time as the fluctuating sound of interest, has the same mean square sound pressure, usually applied as an A-frequency weighting. The interval of time must be stated.

Sound exposure level

Individual noise events can be described in terms of their sound exposure level (SEL). SEL is defined as the constant sound level over a period of 1 s that would have the same amount of energy as the complete noise event (Ford 1987). For a single noise event occurring over a time interval T, the relationship between SEL and LAeq,T is,

$$SEL = LAeq,T + 10 \log_{10} (T/T_0)$$

In this equation T_0 is 1 s.

Day and night continuous sound pressure level

There are different definition in different countries. One definition is (von Gierke 1975; Ford 1987):

L_{dn} = LAeq,16h + LAeq,8h – 10 dBA

Where LAeq,16h is the day equivalent sound pressure level and LAeq,8h is the night equivalent sound pressure level.

Sound Transmission into and within buildings

An approximate relationship between sound reduction index (R), the frequency (f), the mass per unit area of the panel (m) in kg/m^2, and the angle of incidence (θ) is given by

$$R(\theta) = 20 \log\{f\, m\, \mathrm{COS}(\theta)\} - 42.4, \text{ (dB)}$$

This relationship indicates that the sound reduction index will increase with the mass of a panel and with the frequency of the sound as well as varying with the angle of incidence of the sound. It is valid for limp materials but is a good approximation to the behaviour of many real building materials at lower frequencies.

The sound reduction index versus frequency characteristics are usually complicated by a coincidence dip which occurs around the frequency where the wavelength of the incident sound is the same as the wavelength of bending waves in the building façade material. The frequency at which the coincidence dip occurs is influenced by the stiffness of the panel material. Thicker, and hence stiffer materials, will have coincidence dips that are lower in frequency than less stiff materials. Figure A.5.2 plots measured sound reduction index values versus frequency for 4 mm thick glass and illustrates the coincidence dip for this glass at a frequency centered just above 3 kHz.

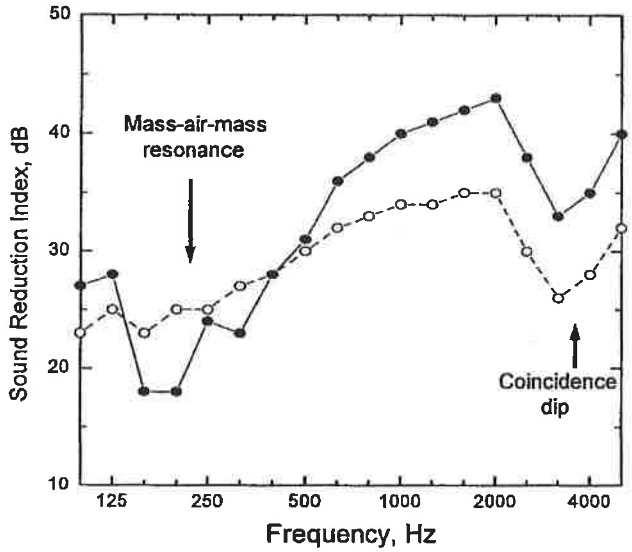

Figure A.5.2: Sound reduction index versus frequency for single and double layers of 4 mm glass (air separation 13 mm).

As also illustrated in Figure A.5.2 for two layers of 4 mm glass, the low frequency sound reduction can be severely limited by the mass-air-mass resonance. This resonance is due to the combination of the masses of the two layers and the stiffness of the enclosed air space. As the Figure A.5.2 example shows, this resonance can often dramatically reduce the low frequency sound reduction of common double window constructions.

The sound reduction of various building constructions can be calculated as the difference between the average sound levels in the two rooms ($L_1 - L_2$) plus a correction involving the area of the test panel (S) in m^2 and the total sound absorption (A) in m^2 in the receiving room,

$$R = L_1 - L_2 + 10\log\{S/A\} \quad \text{[dB]}.$$

For outdoor-to-indoor sound propagation, the measured sound reduction index will also depend on the angle of incidence of the outdoor sound as well as the position of the outdoor measuring microphone relative to the building façade,

$$R = L_1 - L_2 + 10\log\{4S\,COS(\theta)/A\} + k \quad \text{[dB]}.$$

When the outdoor incident sound level L_1 is measured with the outdoor microphone positioned against the external façade surface, measured incident sound pressures will be 6 dB higher due to pressure doubling. This occurs because the incident sound and reflected sound arrive at the microphone at the same time. If the external microphone is located 2 m from the façade, there will not be exact pressure doubling but an approximate doubling of the measured sound energy corresponding to a 3 dB increase in sound level. The table below indicates the appropriate values of k to be used in the above equation, depending on the location of the outdoor microphone, to account for sound reflected from the façade.

k = 0, dB	L_1 does not include reflected sound.
k = -3, dB	L_1 measured 2 m from façade and includes reflected energy.
k = -6, dB	L_1 measured at the façade surface and includes pressure doubling effect.

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Innovation since 1886

Evaluation of the Advanced Locomotive Emissions Control System (ALECS)

ALECS Proof-of-Concept Testing at the Union Pacific J. R. Davis Rail Yard in Roseville, California

Report to
Placer County Air Pollution Control District
3091 County Center Drive, Suite 240
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Date: April 2, 2007

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Executive Summary

The Union Pacific Railroad's J.R. Davis Rail Yard in Roseville, California, is a major center for locomotive maintenance and repair, as well as for assembling and reassembling trains of freight cars. Over 90 percent of all Union Pacific rail traffic in Northern California goes through the yard. Locomotive operations at the rail yard have been determined to be a significant source of emissions of diesel particulate matter (PM) and other pollutants. An agreement between the Placer County Air Pollution Control District (PCAPCD) and the Union Pacific Railroad Company (UPRR) includes a mitigation plan for reducing PM emissions from the rail yard. Part of this plan is an assessment of the use of stationary air pollution control equipment to capture and treat emissions from motionless locomotives while idling or undergoing engine load tests during maintenance.

The Advanced Locomotive Emission Control System (ALECS) comprises a set of stationary emissions control equipment connected to an articulated bonnet. The bonnet is designed to capture locomotive exhaust, delivering it to the ground-based emission control system via ducting. The hood remains attached while the locomotive is moving slowly along the track to the extent of the ducting. The emission control equipment comprises a sodium hydroxide wash to remove sulfur dioxide (SO_2), a triple cloud chamber scrubber for PM removal, and a Selective Catalytic Reduction (SCR) reactor to reduce oxides of nitrogen (NO_x). The ALECS is designed to treat exhaust flows between 2,000 and 12,000 standard cubic feet per minute (scfm). The former is approximately the exhaust flow from a locomotive at idle, while the latter is approximately the exhaust flow from a line-haul locomotive at throttle notch 8 (full power).

The ALECS proof-of-concept was a public-private collaborative project involving the PCAPCD, U.S. Environmental Protection Agency (EPA), Sacramento Metropolitan Air Quality Management District (SMAQMD), UPRR, Advanced Cleanup Technologies Inc. (ACTI), the South Coast Air Quality Management District (SCAQMD), the California Air Resources Board (CARB), and the City of Roseville. Engine, Fuel, and Emissions Engineering, Inc. (EF&EE) was contracted by the SCAQMD to conduct emission measurements before and after the ALECS.

Emission measurements were performed on two locomotives: a General Motors Electro-Motive Division GP38 and a General Electric C39-8 (Dash 8). The GP38 has a 2000 horsepower two-stroke diesel engine, and is typically used for switching and local service. The Dash-8 has a 3900 horsepower four-stroke engine, and is normally used for line-haul freight service. Tests were performed with the locomotives motionless at notch 1, notch 3, notch 5, and notch 8 power settings, and while moving slowing back and forth along a small section of track.

Table 1 summarizes the overall average control efficiencies resulting from the proof-of-concept tests. Using these control efficiencies, estimates were made of the reduction in emissions that may result from use of one ALECS in a rail yard situation. The emission reductions are highly dependent on the specific operation addressed in a rail yard. Table 2 presents the range of emission reductions estimated for two very different applications in a rail yard. One case addresses all idling Tier 2 locomotives; while the other case utilizes Tier 0 locomotives addressing some load and diagnostic testing, with the remainder of the capacity servicing idling locomotives. These cases are meant to define the low and high end of possible emissions for the

ALECS. Actual rail yard installation will most likely yield emission reductions somewhere in between these two assumptions, depending on the specific application.

Table 1. Summary of Pollutant Control Efficiencies

	NO_x	HC	PM	SO_2
Overall Average Control Efficiency[1]	97.8%	62.7%	92.1%	97.3%

[1] ALECS demonstration at Roseville rail yard

Table 2. Range of Estimated Emission Reductions (tons/yr)

	NO_x	HC	PM
Mixed Loads Tier 0 Emissions	83.4	8.44	2.53
Idling Only Tier 2 Emissions	40.0	2.49	1.29

The fully loaded total initial capital cost of the ALECS (for an estimated 12 bonnet system) is $8,680,126 with an annual operational cost of $899,926. The 12 bonnet system is sized to cover an area of the rail yard that allows for at least six locomotives to be connected and running at all times.

Cost effectiveness of the ALECS has been estimated using the total life cycle costs based upon annualizing (and adjusting for the time value of money) the capital investment and the net present value (discounted cash flow) of future operation and maintenance costs for the range of pollutants removed by the two rail yard operating scenarios. The estimated cost effectiveness curve for the total weighted pollutants reduced over the 20 year life of ALECS is illustrated in Figure 1. Pollutants considered in this estimate are NO_x, HC, and PM. Oxides of sulfur (SO_x) emissions that are reduced were not included in this cost effectiveness calculation. The PM emissions were weighted by a factor of 20 as is the practice with the current Carl Moyer Incentive Program guidelines. This weighting was used in calculating cost effectiveness because of the toxicity level of PM. ALECS was estimated to be in full operation 96 percent of the time. The cost effectiveness ranged between $18,437/ton in the all idling mode to $7,297/ton of weighted pollutant reduced in the mixed mode of a combination of locomotives at idle and at loads during maintenance testing.

Noise measurements where made on some high power runs to assess possible noise reductions due to the bonnet attached over the locomotive exhaust stack. Measurements with, and without the bonnet attached yielded noise reductions of 5.3 to 6.8 decibels, representing noise energy reductions of 70 to 79 percent.

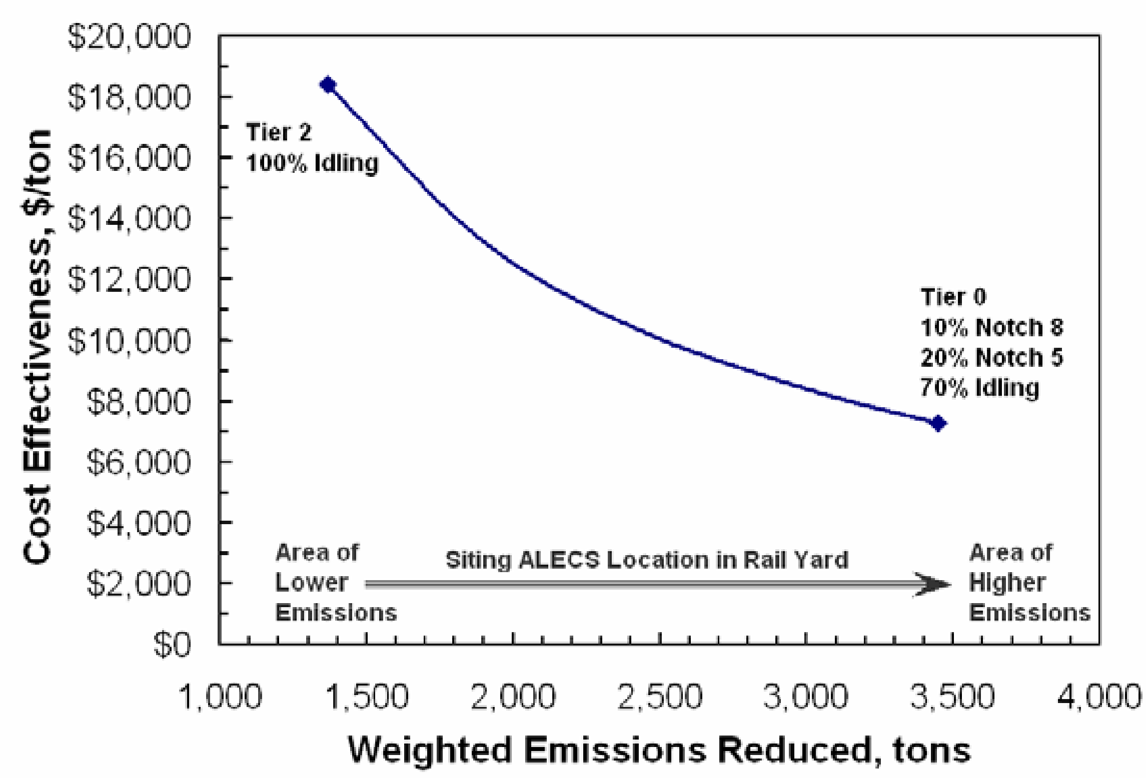

Figure 1. ALECS Cost Effectiveness

While the ALECS proof-of-concept tests met most of the project objectives and yielded valuable information confirming that the system is capable of capturing and treating locomotive emissions, there remains additional work in selected areas in order to support fielding a cost effective system in a rail yard application. The emissions capture subsystem, which includes the bonnet over the locomotive stack and the ducting that routes the exhaust to the emissions control subsystem, was designed to accommodate a single locomotive. The full-scale subsystem capable of capturing and transporting emissions from multiple locomotives was not tested. A number of follow-on actions are recommended, including public policy leadership, internal rail yard analyses with respect to optimal siting situations as well as positive and negative impacts to rail yard operations, demonstrating the emissions capture subsystem for multiple locomotives, developing financial mechanisms for the funding of systems, and community outreach.

1. Introduction

1.1 Project Background and Overview

Placer County Air Pollution Control District (PCAPCD) led a public-private collaborative project in a technology proof-of-concept test of a new concept to clean locomotive diesel exhaust. As a result of public concern over health risk from locomotive diesel emissions emanating from the J. R. Davis Rail Yard in Roseville, California, the PCAPCD arranged for the California Air Resources Board (CARB) to perform a detailed health risk analysis of locomotive diesel exhaust from the rail yard. Diesel exhaust was designated a toxic air contaminant by the CARB in 1998. This yard is one of the largest rail facilities in the western United States and serves as a maintenance and repair hub for locomotives. Over 90 percent of all Union Pacific rail traffic in Northern California moves through the yard (Union Pacific Railroad website, January 2007). The following lists some of the features of the rail yard (see Figure 2 for an aerial overview of the facility).

- Encompasses 915 acres
- 6 miles long
- 55 bowl tracks
- 136 miles of track
- 247 switches
- 2 main lines
- 6,500 rail car capacity
- 1,800-2,300 cars per day classification ability
- Over 30,000 locomotives stop annually
- Additional 15,000 locomotives pass through without stopping
- 21,500 locomotives receive service, maintenance, and/or repair per year
- 9,600 locomotives refueled only for fast turn-around per year
- Locomotives are fueled with 2.8 million gallons of diesel fuel per month

The effort was a public-private collaborative project involving the U.S. Environmental Protection Agency (EPA), California Air Resources Board, three Air Districts, one city government, and two corporations. The purpose of the project was to demonstrate the effectiveness of the stationary control equipment in capturing and treating locomotive exhaust, and to generate the information on capital and operating costs. The CARB Roseville Rail Yard Study (CARB, October 14, 2004) concluded “Computer modeling predicts potential cancer risks greater than 500 in a million (based on 70 years of exposure) northwest of the Service track area and the Hump and Trim area. The area impacted is between 10 to 40 acres.” These are the areas of the rail yard where servicing, fueling, and maintenance testing of locomotives occurs. Subsequent to the health risk findings, the PCAPCD negotiated an agreement with Union Pacific Railroad Company (UPRR) that included a number of measures to reduce diesel emissions. One measure was to investigate the use of stationary control equipment to clean up diesel exhaust captured from motionless or slow moving locomotives in service areas of the rail yard where numbers of locomotives are run for diagnostics and testing.

Figure 2. Aerial View of the J. R. Davis Rail Yard

In response to this measure, the PCAPCD organized and led a technology proof-of-concept test of an innovative new concept to capture locomotive diesel exhaust and remove the air pollutants using conventional stationary source techniques. This project is innovative in that conventional stationary source technology is applied to a mobile source through a novel bonnet type exhaust capture device (see Figure 3). Conventional emissions control equipment includes the Preconditioning Chamber, cloud chamber scrubbers and Selective Catalytic Reduction (SCR) to remove approximately 95 percent of oxides of nitrogen (NO_x), oxides of sulfur (SO_x), and particulate matter (PM). The novel bonnet device consists of a duct structure mounted above the locomotive track and a remotely guided bonnet that fits over the exhaust stack and can move with the locomotive to the extent of the overhead duct structure.

The cost of this collaborative project was covered by direct funding, a grant, in-kind contributions, and corporate product development. The contributing project participants were:

- U.S. Environmental Protection Agency (EPA)
- California Air Resources Board (CARB)
- Placer County Air Pollution Control District (PCAPCD)
- Sacramento Metropolitan Air Quality Management District (SMAQMD)
- South Coast Air Quality Management District (SCAQMD)
- City of Roseville
- Union Pacific Railroad Company (UPRR)
- Advanced Cleanup Technologies, Inc. (ACTI)

Figure 3. Locomotive under the Exhaust Capture Bonnet

1.2 Project Objectives/Motivations

The Advanced Locomotive Emission Control System (ALECS) proof-of-concept test project was a year and a half effort involving the development of locomotive-specific interfaces, temporary installation of emissions control equipment at the Roseville rail yard and testing motionless and slow-moving locomotives to determine the possible effectiveness of the control equipment.

The original objectives of the proof-of-concept test project are listed below (they will be compared to accomplishments later in this report):

> **Objective 1: Demonstrate the Possible Effectiveness of Stationary Control Equipment on Locomotive Exhaust:** This proof-of-concept test of the ALECS equipment should quantify the overall capture and control efficiency of particulate matter (PM), NO_x, SO_x, and total hydrocarbons (THC) with actual locomotive exhaust in a rail yard environment. Locomotive engines in common use come in two distinct technologies; two-stroke and four-stroke. This proof-of-concept test will test one engine of each technology; a GP38 two-stroke locomotive operating on ultra-low sulfur (15 ppmw) fuel, and a Dash-8 four-stroke locomotive operating on a fuel with a sulfur content between 200 ppmw and 500 ppmw. Sound measurements will be taken with and without the control equipment to determine the extent of noise reduction due to the control equipment (sound measurements added during the project).

Emissions testing will be conducted according to a test protocol developed for this project. The test protocol should prescribe accepted test methods appropriate to the pollutants being measured. The protocol will be reviewed by the air districts, CARB, and EPA. The testing will be conducted on the locomotive before the control equipment and upon exit from the control equipment to determine the emissions on a concentration and mass basis.

Objective 2: Demonstrate the Attachment Scheme between the Locomotive and the Stationary Control Equipment: Since a rail yard is a busy place where efficiency of operations is important, the attachment of the emissions control equipment to the locomotive must be quick, simple, and safe to the operating personnel. The operation of the ALECS must absolutely not impede the fluidity of normal railroad operations in any manner. Attachment, detachment, and capture efficiency will be demonstrated on locomotives with one and two emission stacks. During the emissions testing phase of this project, multiple attachments and disconnects shall be performed to demonstrate this capability. Rail yard personnel shall be given a chance to operate the attachment controls.

Objective 3: Demonstrate the Capability of Some Locomotive Movement While Connected to the Control Equipment: One of the design features of the ALECS is to allow movement of the locomotive along the track for a prescribed distance while connected to the emissions control equipment. During emissions testing, some portion of the testing on each locomotive shall be conducted with the locomotive connected to the stationary control equipment and the locomotive moving to demonstrate this capability while fully capturing the exhaust from the engine in the locomotive.

Objective 4: Develop Improved Information on Capital Cost, Operating Procedures, and Operating Costs: The underlying purpose of this proof-of-concept test project is to provide information on performance, operation and cost of using stationary emissions control equipment to treat locomotive exhaust in rail yards that will enable the railroad and equipment suppliers to make business decisions on moving forward in deploying this type of equipment. During the installation and operation of the ALECS, information shall be collected and recorded that will enable capital and life cycle costs to be generated. Rail yard facility requirements for infrastructure and support utilities will be defined. These cost estimates shall be documented in the final report. Railroad personnel shall be instructed on operation and maintenance of the ALECS during the proof-of-concept project, and will provide to the PCAPCD estimates for all costs for impacts to yard or system operations (either capital or operating) are included in the final accounting. These cost estimates will be included in the project final report.

The ALECS to be used for this proof-of-concept test is borrowed from another project where the equipment size was optimized for another application. As part of this objective, the cost of equipment appropriately sized and ALECS designed to serve the J. R. Davis Rail Yard will be estimated.

Objective 5: Document Test Results and Project Findings in a Final Report: Since this proof-of-concept test project has, as one purpose, the generation of information on performance and operation of the ALECS sufficient to allow railroads to make business decisions on use of this stationary control equipment on their rail yards, the project results will be documented in a final report. The final report will include, as a minimum, details of the locomotives tested, configuration of the test setup, test equipment, test conditions, and test methods, logistic and operation issues identified during project implementation, and emission (and noise) test results before and after the control equipment.

2. Description of Technology

2.1 Overall Description

ACTI's ALECS is designed to capture railroad locomotive exhaust emissions and direct them to an emissions treatment system for removal of harmful pollutants.

ALECS is comprised of two major subassemblies, the Emissions Capture Subsystem (ECS) and the Emissions Treatment Subsystem (ETS). The Emissions Capture Subsystem is the system used to capture the exhaust emissions from the locomotive and transport the captured exhaust to the Emissions Treatment Subsystem where a substantial amount of the harmful pollutants are removed.

2.2 Emissions Capture Subsystem

The Emissions Capture Subsystem (ECS) is designed to capture the exhaust emissions from locomotives while motionless or moving slowly within designated areas within a rail yard. The system is designed to capture the exhaust emissions from multiple locomotives. Locomotive exhaust is captured at the exhaust stack and directed through an Overhead Manifold to an emissions treatment system for removal of harmful pollutants.

The ECS is comprised of four major components: the Support Structure, Overhead Manifold, Emissions Intake Bonnet (EIB) and Control Software. The ECS is designed to provide the railroad with the maximum flexibility practical without interfering or impacting railroad operations.

System backpressure on the locomotive engine is controlled by a pressure sensor located within the bonnet, which in turn controls a damper located at the top of the bonnet. Backpressure is controlled between atmospheric and minus 0.25 inch of water gauge pressure, which puts the exhaust system under a slight vacuum. This vacuum essentially captures all of the locomotive's exhaust and may also add some dilution air from the surrounding atmosphere into the capture system.

2.2.1 Proof-of-Concept Test Configuration

For the proof-of-concept test, a scaled down version of the ECS was designed to show that exhaust emissions can be captured from various types of railroad locomotives with different exhaust flows and temperatures, stack configurations, and while immobile or moving within a designated area. Figure 4 shows the proof-of-concept test configuration. Capturing locomotive exhaust emissions was accomplished with the EIB located over the targeted locomotive and lowered around the locomotive exhaust stack (Figure 5 shows two bonnets lowered onto a locomotive).

The captured exhaust was then directed through an overhead manifold to the Emissions Treatment Subsystem. The proof-of-concept test overhead structure and intake manifold can be seen in Figure 6.

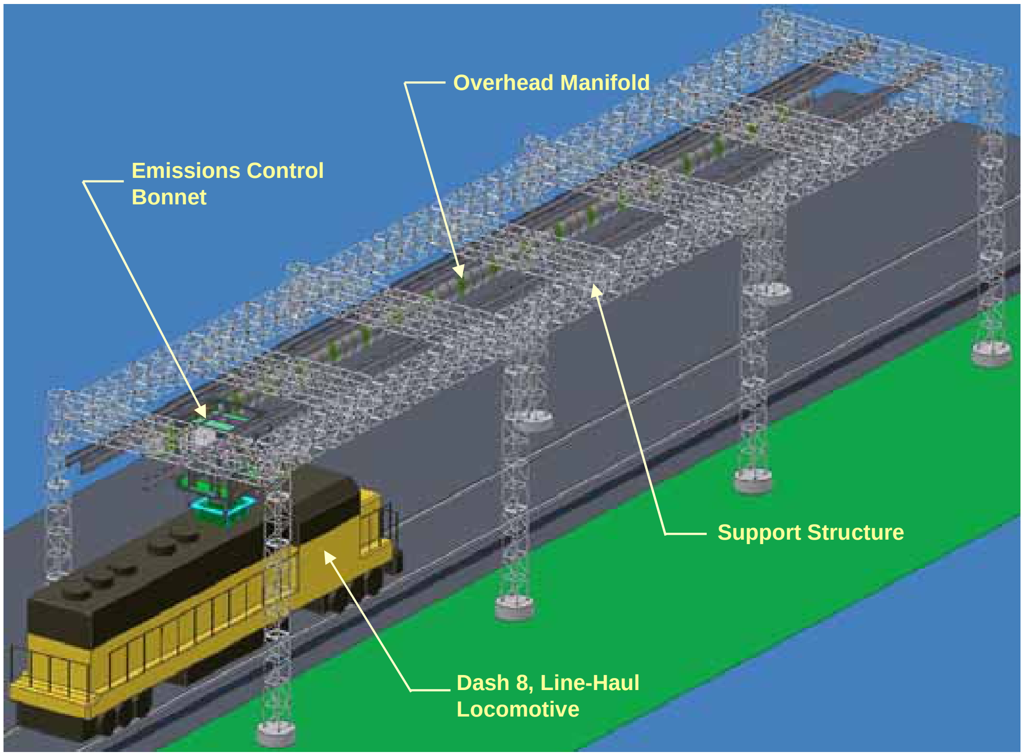

Figure 4. Proof-of-Concept Test Configuration of Emissions Capture Subsystem

Figure 5. Emissions Intake Bonnets Lowered onto a Locomotive

Figure 6. Overhead Structure and Intake Manifold

The short-term proof-of-concept test design of this project could only process the emissions from a single locomotive at a time. The full scale deployment design will need to cover multiple tracks and be able to receive emissions from multiple locomotives and direct the captured exhaust emissions to the Emissions Treatment Subsystem.

One of the functions of the ECS is to reduce or eliminate emissions of locomotives that may require maintenance. Figure 7 shows the visible smoke for a locomotive with high PM emissions. On occasion, visible exhaust emissions as shown in this figure have been observed from the stack of locomotives during engine startup, full power testing, and engine malfunction (invisible emissions can depend upon the atmospheric conditions, cold start of the engine, or throttle notch changes and may become less visible as equilibrium of the engine is attained).

2.2.2 Future Full Scale Deployment Concept

The future full scale deployment concept of the ECS was designed (for costing purposes) to be a versatile system that can be arranged to accommodate many rail yard configurations using common components. These components can be used to tailor a system to an area of the rail yard with varying numbers of parallel tracks of different lengths For the economic analysis, an ECS covering an estimated 1,200 feet of track was selected. The track can be three 400 foot sections side-by side, two 600 foot sections side-by-side or one continuous track at 1,200 feet in length, servicing 12 locomotives.

Figure 7. Visible Locomotive Exhaust Emissions

Shown in Figure 8 is an example of a future typical deployment of the ECS. Figure 9 depicts the system connected to the ETS, with arrows showing the path of the captured exhaust. Note that the system is designed to handle consist (multiple locomotives attached together to power a train) and standalone locomotives. However, the system that was tested in this project used only a single locomotive design.

The Support Structure is the metal framework that supports the Overhead Manifold and Emissions Intake Bonnets. It is comprised of steel Support Piers, Transverse Support and Longitudinal Support Beams.

The Overhead Manifold is the medium that directs the captured exhaust emissions to the ETS. It is comprised of an Intake Outer (Stainless Steel) Tube, an EIB Interface Inner-Connection (Stainless Steel) Tube, a Trolley Support Rail and Power Strip, and Control Cable Harness.

The EIB Interface Connection tube slides within the Intake Outer Tube to allow for automatic positioning of the bonnet over the selected locomotive exhaust stack.

The ECS will monitor exhaust flow rates from multiple locomotives and the exhaust from those locomotives producing the highest exhaust flow will be directed to the treatment system. This will selectively process the exhaust from the locomotives having the highest emissions (operating at the highest throttle notch), thereby optimizing the treatment systems effectiveness and efficiency in reducing the amount of harmful pollutants introduced into the surrounding atmosphere.

Figure 10 is a depiction of the Overhead Manifold, and shown in Figure 11 is a transparent view of the EIB Interface Connection Tube for the full scale, conceptual ECS design.

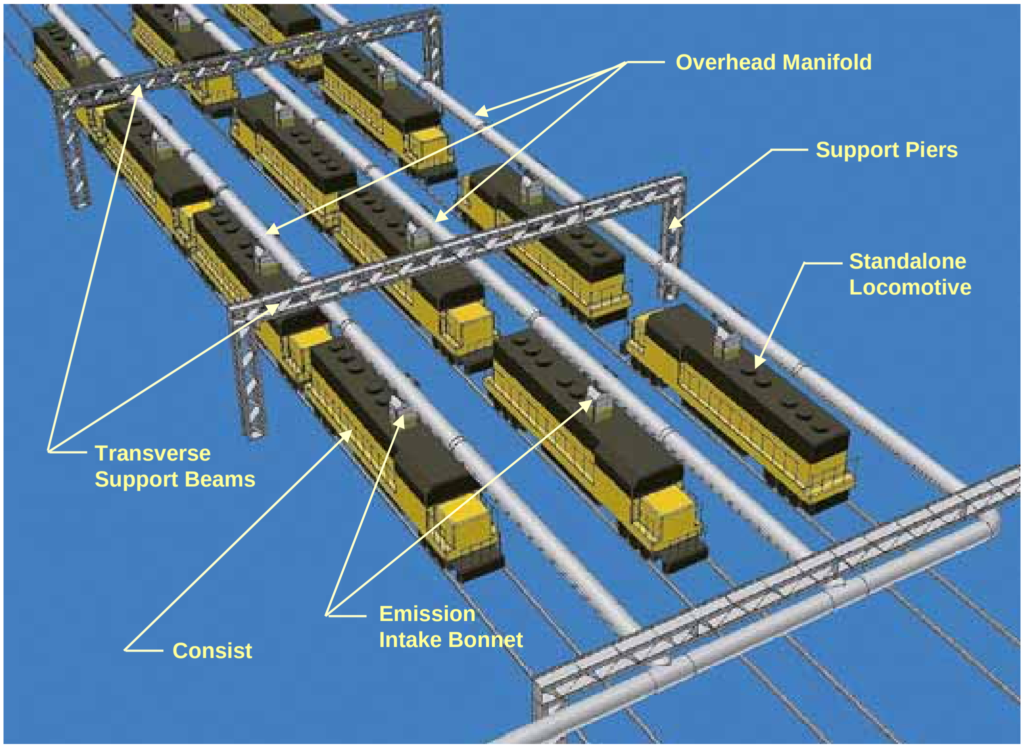

Figure 8. Conceptual Example Deployment of Emissions Capture Subsystem

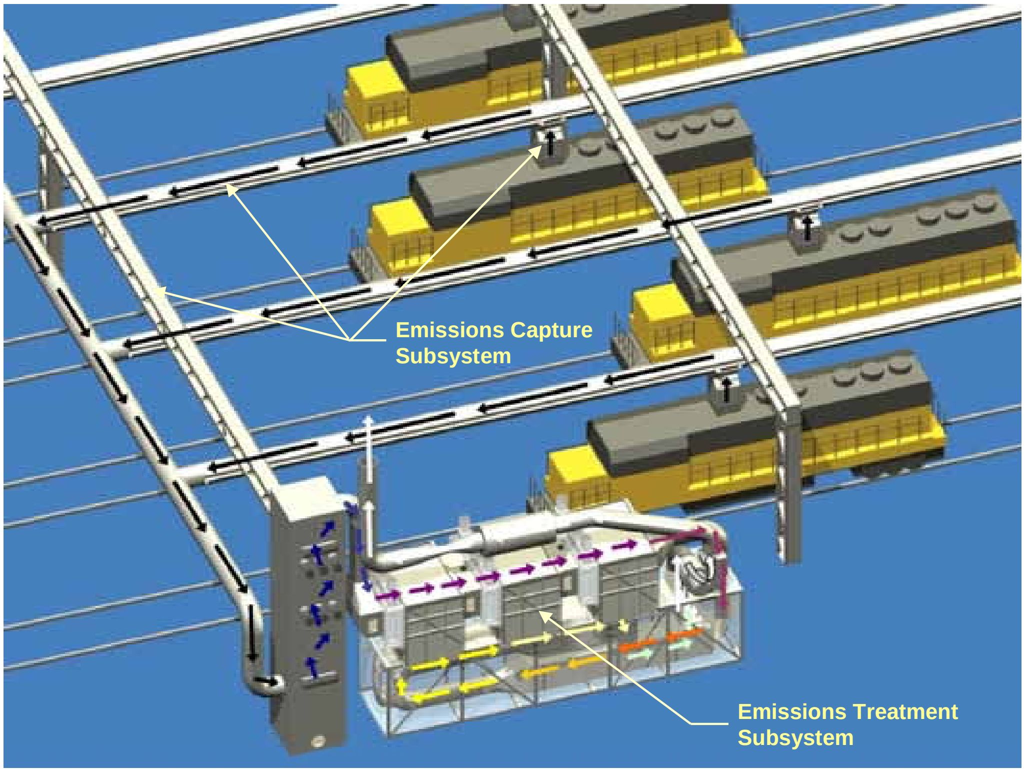

Figure 9. Conceptual Emissions Capture Subsystem Attached to the ETS

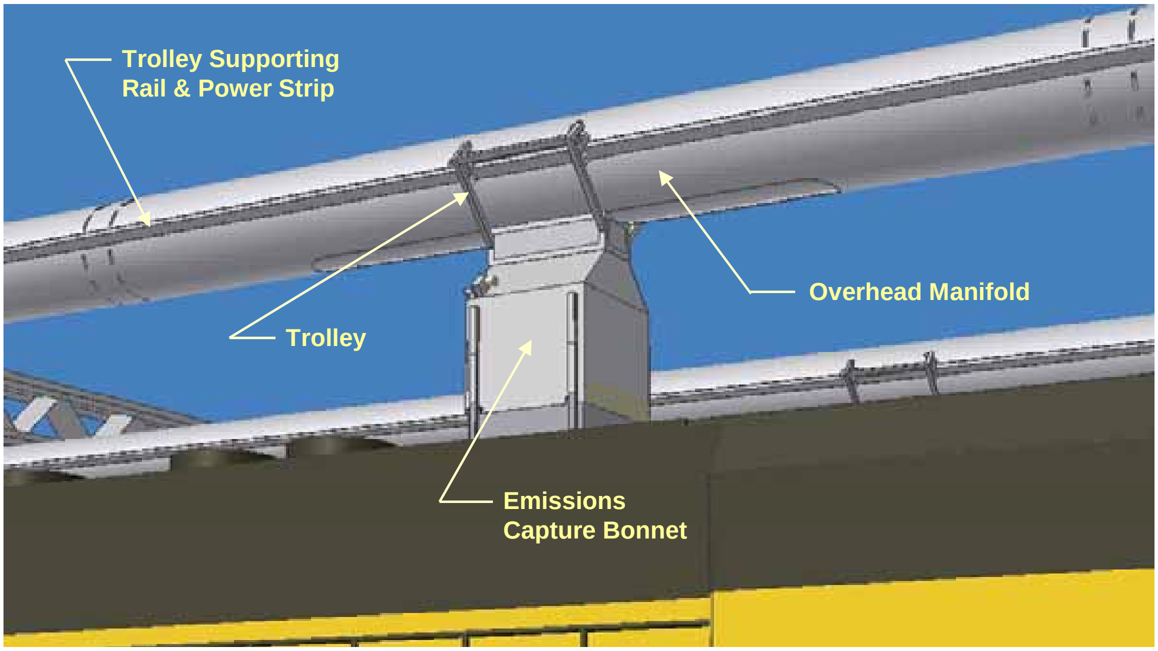

Figure 10. Conceptual Overhead Manifold and Emissions Control Bonnet

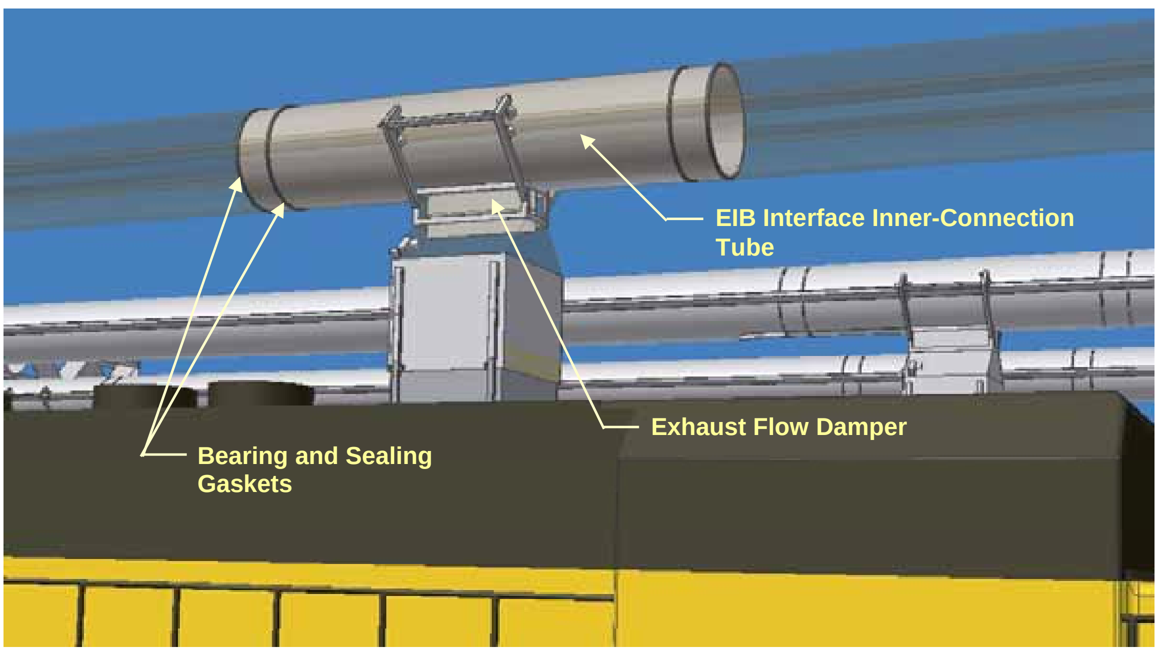

Figure 11. Conceptual Emissions Intake Bonnet and Interface Connection Tube

The EIB is the component that captures the exhaust emissions from locomotives by enclosing the exhaust stack and directing the exhaust emissions into the Overhead Manifold. The EIB is comprised of two components, the Intake Bonnet and the Trolley. The Trolley positions the Intake Bonnet over the locomotive's stack, and the stack lowering mechanism lowers the bonnet around the stack. For a conceptual depiction of the EIB Trolley see Figure 12.

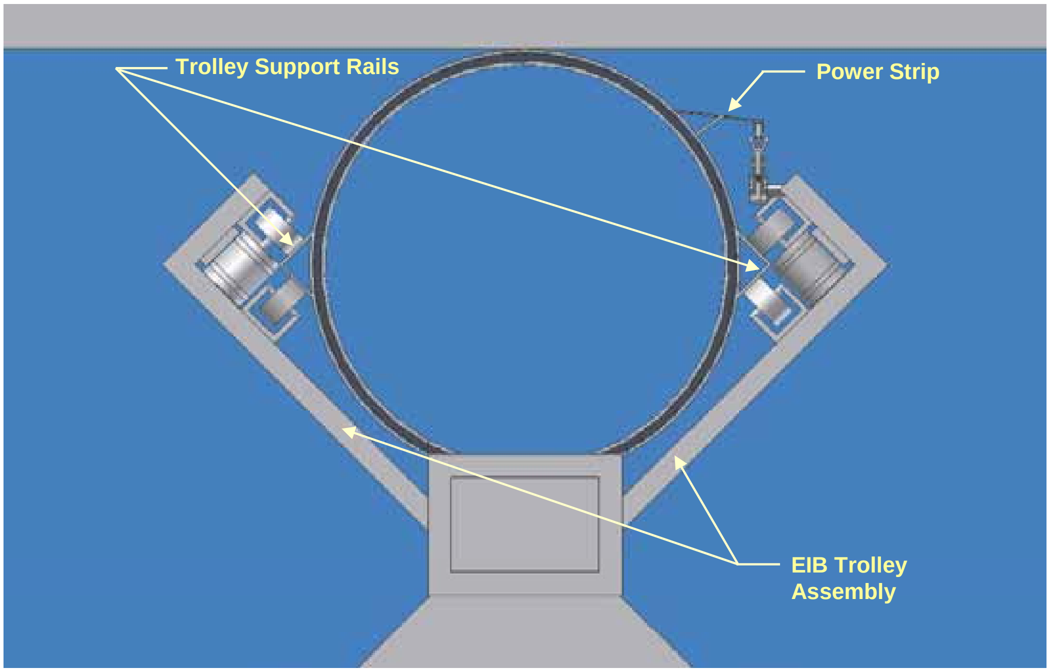

Figure 12. Conceptual Emissions Intake Bonnet Trolley

The ECS Control System will be programmed to automatically locate and connect to the locomotive stack. The system will detect when a locomotive enters the zone of operation. When the system determines that the locomotive has stopped, then a bonnet will be deployed. When the locomotive begins to move out of the zone, then the bonnet will automatically be retracted.

The ECS control system will also work to maximize the capture efficiency by prioritizing higher throttle notch levels over idling locomotives. As previously stated, each bonnet is connected through a control damper to the intake manifold. When a bonnet disconnects from a locomotive, the damper is completely closed to airflow. When a bonnet is connected to the locomotive, the damper is used to modulate the flow to keep the pressure within a negative ¼ inch of water pressure. When a higher exhaust flow rate of one or more of the locomotives is detected, the higher flow locomotive is prioritized over the lower notch and/or idling locomotives, which are temporarily disconnected from the system. The system also automatically connects as many locomotives as required to maintain the maximum flow rate of the ETS.

The bonnets are programmed to failsafe to the disengaged mode. Under any fault condition (e.g. loss of power, over/under pressure, over temperature) the system will disconnect from the locomotives and notify the technician on duty both locally in the Operational Control Unit (OCU) of the ETS and remotely by pager. In the event of an emergency or a failure, emergency stop pushbuttons can disconnect all bonnets, and bring the system to a safe operating condition.

2.3 Emissions Treatment Subsystem

The ETS consists of six major components: a Preconditioning Chamber (PCC) that removes SO_x and an amount of hydrocarbons (THC), a Cloud Chamber Scrubber (CCS) that removes PM, a Thermal Management System to increase operating efficiency, a Selective Catalytic Reduction

(SCR) Reactor for removal of NO_x, a Control System and the Continuous Emissions Measuring System (CEMS).

The ETS and the relative location of its components are shown in Figure 13 and are described further below. The Control system and CEMS descriptions follow these ETS major component descriptions.

The first component the exhaust gas encounters as it enters the system is the Preconditioning Chamber (PCC) which serves several functions. First, it cools the gas adiabatically through a counterflow water spray and in the process increases the water vapor content to near saturation. This feature is required by the following stage, which cannot accept hot gas. Secondly, it removes most of the soluble hydrocarbons and other water soluble compounds. Third, the water is rendered caustic by means of a metered injection of sodium hydroxide to remove 95 to 99 percent of the SO_2, depending on the inlet concentration. The fourth function of the PCC is to cause the nanometer size PM particles to agglomerate into larger particulate globules, which facilitates their removal in the next stage

The path of the exhaust emissions flow through the ETS, along with the relative positions of the major components is shown in Figure 14.

The gas exits the PCC at a temperature of about 140°F. This gas is directed to the first of three Cloud Chamber Scrubbers (CCS). These vessels are empty, except that they are filled with a fog of minute water droplets generated by an array of spray nozzles collinear with the exhaust gas stream. Each droplet is charged to a high voltage immediately after leaving its nozzle. This charge causes particulate matter in the gas stream to be attracted to and adhere to the water droplets, with each of the billions of water droplets collecting many particles. The droplets fall to the bottom of the CCS to a collection reservoir. Droplets entrained in the gas stream are removed by a mist eliminator.

The particles thus collected in the water reservoir are flushed through a solids removal system where they are collected for subsequent removal from the premises and disposal using approved regulatory means. The removal system consists of a solids separation device for inline solids removal, water extraction, and compaction.

The Selective Catalytic Reduction (SCR) Reactor requires a temperature of approximately 600°F to operate. The exhaust gas exiting the CCS is cooled to about 140°F and stripped of SO_2, PM, soluble hydrocarbons, and condensed (particulate) hydrocarbons and sulfates. This clean but cool gas must then be reheated. This is accomplished by a Thermal Management System (Burner & Heat-Exchanger) that is connected to the system in a wraparound arrangement. In this scheme, the hot exhaust from the SCR Reactor is used to heat the cold gas entering the SCR Reactor. Approximately 80 percent of the available heat is recovered from the hot gas leaving the SCR Reactor by this heat exchanger. The additional heat increment required to bring the gas stream up to 600°F is provided by a natural gas or propane-fired burner.

The exhaust emissions flow through the Thermal Management System with the relative positions of the components shown below in Figure 15.

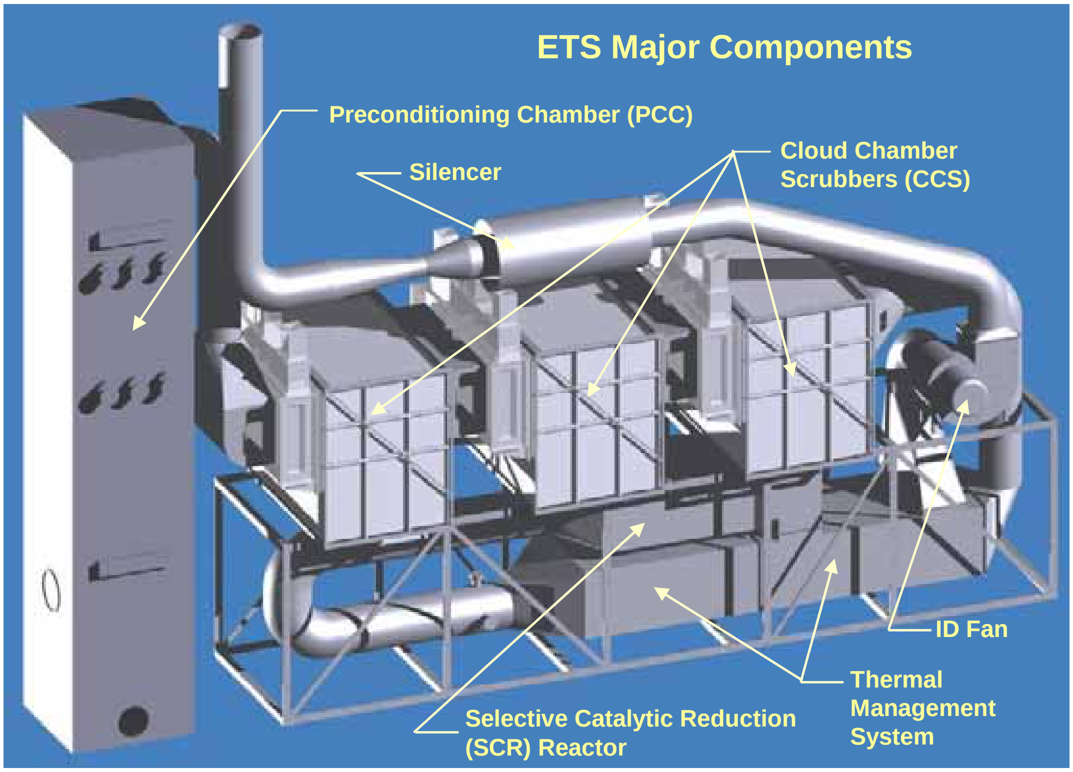

Figure 13. ETS with Relative Locations of Its Components

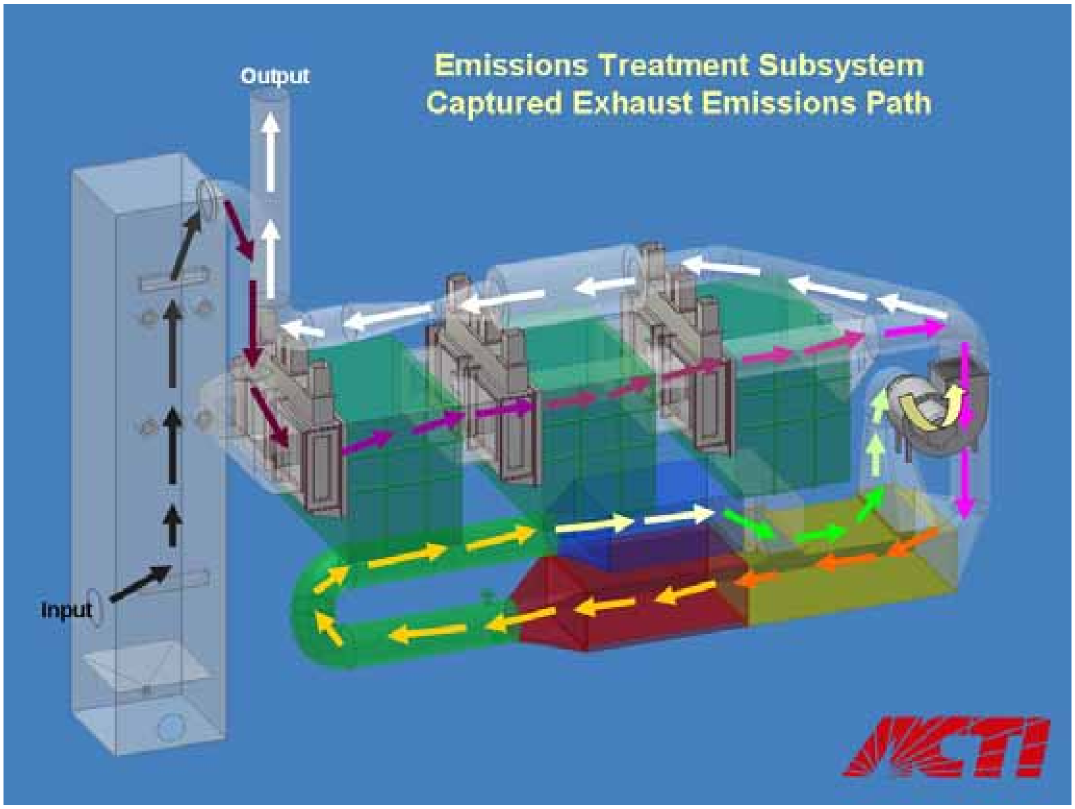

Figure 14. Emissions Treatment Subsystem Captured Exhaust Emissions Path

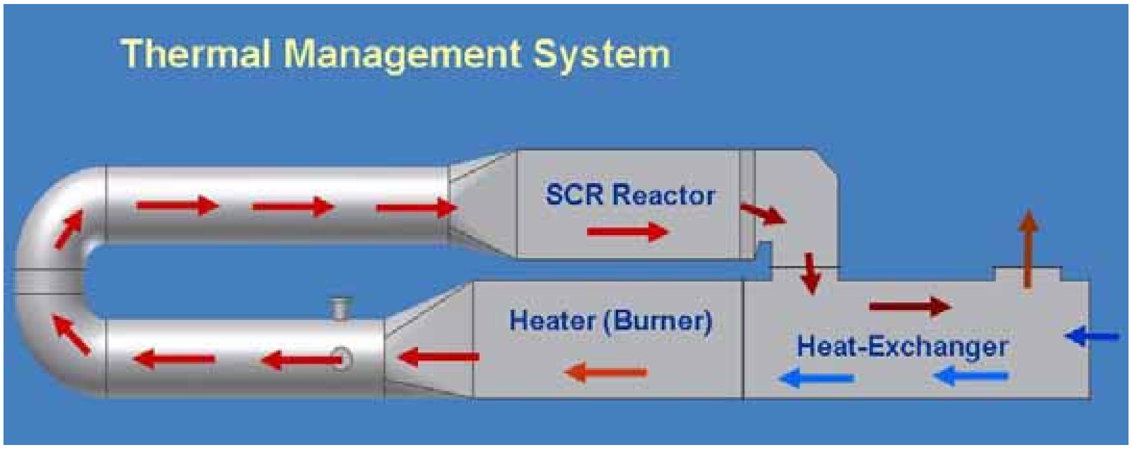

Figure 15. ETS Thermal Management System

The reheated gas at 600°F is passed through the SCR Reactor for NO_x removal. In the SCR Reactor, ammonia combines chemically with NO in the presence of the catalyst, converting the NO and ammonia (NH_3) into water vapor and nitrogen gas. Urea is the reagent this system uses as the source of ammonia. The urea is injected into the system immediately after the burner. Special atomizer nozzles and flow modification devices ensure uniform distribution, and a long mixing duct assures complete conversion of urea to ammonia.

An Induced Draft (ID) fan is located downstream of the SCR Reactor and Thermal Management System, and a silencer is located downstream of the ID fan. This fan draws the exhaust gas from the locomotive through the ducting into the ETS. The flow and pressures are controlled by dampers and the fan's variable speed drive motor.

In addition to the silencer, which acts as a muffler, the downstream ducting and fan housing are acoustically insulated to ensure that the systems operating noise level is reduced to an acceptable level.

Figure 16 shows the ETS in Roseville, California (it was not connected to the ECS yet).

Control System Description

The ALECS Control System is an integrated network which automatically operates and monitors all aspects of the ALECS operation. The ETS has its own Operational Control Unit (OCU), which controls all the ETS processes including any attached ECS. The ETS can be monitored and controlled locally (in the OCU) and remotely. The OCU houses all sensing, monitoring, recording and control system functions for ALECS. These systems acquire, monitor, store and transmit the data required to maintain efficient emissions control operations as well as to document emissions reduction performance during acceptance testing and certification. The OCU operates automatically, adjusting for the wide range of variables in the number of locomotives and their operating characteristics, compensating for changes in real-time.

Figure 16. Emissions Treatment Subsystem in Roseville Rail Yard

Failsafe strategies are built into the control system. This system keeps all ECS and ETS operational parameters within design limits, makes automatic adjustments where appropriate, switches to redundant components or systems in the event of a malfunction or out-of-spec condition, and records significant parameters to verify performance.

As part of the control system, measured data will be recorded in a Microsoft SQL relational database by locomotive identification number.

Continuous Emissions Monitoring System (CEMS)

The CEMS measures the following parameters:

- At the ETS inlet (source measurement)
  - NO_x
  - SO_x
  - O_2
  - PM (time shared with the outlet)
  - Flow
  - Temperature

- At the ETS outlet (discharge to atmosphere)
  - NO_x
  - SO_x
  - O_2
  - THC
  - NH_3 (ammonia)
  - PM (time shared with the inlet)

- Flow
- Temperature

PM is measured at the inlet and outlet using a Dekati Mass Measuring system with a single instrument. This arrangement uses a three-way valve to allow time sharing between the inlet and the outlet by switching the instrument input between sample lines.

Instrumentation Description

The gaseous instrumentation is a Horiba Instruments model ENDA-4000 stack gas analysis system. It uses chemiluminescent analysis for NO_x, non-dispersive infrared (NDIR) for SO_x, and magnetopneumatic analysis for the oxygen (O_2) measurements. A Horiba FIA-236 flame ionization analyzer is used to measure total hydrocarbons. NH_3 is measured by converting the NH_3 to NO in dual stream heated probes with an electrically heated filter chamber in the probe heated to 320°C. NH_3 is determined by measuring the NO thus produced and comparing it to the level without the NH_3 contribution to NO. The NH_3 system includes a built-in Horiba CLA-510 chemiluminescent NO_x analyzer for the NH_3 measurement.

The sample conditioning system includes a solid state thermoelectric pre-cooler with stainless steel impingers, a solid state thermoelectric sample cooler, primary and secondary particulate filters, an acid mist catcher, magnetically coupled sample pump and booster pump, temperature controller for the heated sample line, temperature controller for the sample probe primary filter, automatic temperature and pressure control, and automatic system calibration.

The sampling system consists of a stainless steel sample probe with heated primary filter and automatic blowback, and a heat traced multiple tube sample umbilical. The probe assembly consists of a probe pipe, heated primary filter and NEMA 4X enclosure. Connections route calibration gas upstream of the primary filter. The sampling system on the downstream side of the ETS adds dual stream heated probe heads with integral NH_3 converters and a 2 micron ceramic filter element heated to 320°C.

The sample system is shown in simplified form in Figure 17. Figure 18 is a picture of the CEMS utilized in the proof-of-concept testing.

PM is measured with the Dekati DMM-230 Mass Monitor manufactured by Dekati, Ltd. in Finland. This instrument gives one second data points of particle size as well as other particle statistics. The DMM operation principle is based on measuring particle electrical mobility and aerodynamic size. These two parameters are compared in real time to determine total mass.

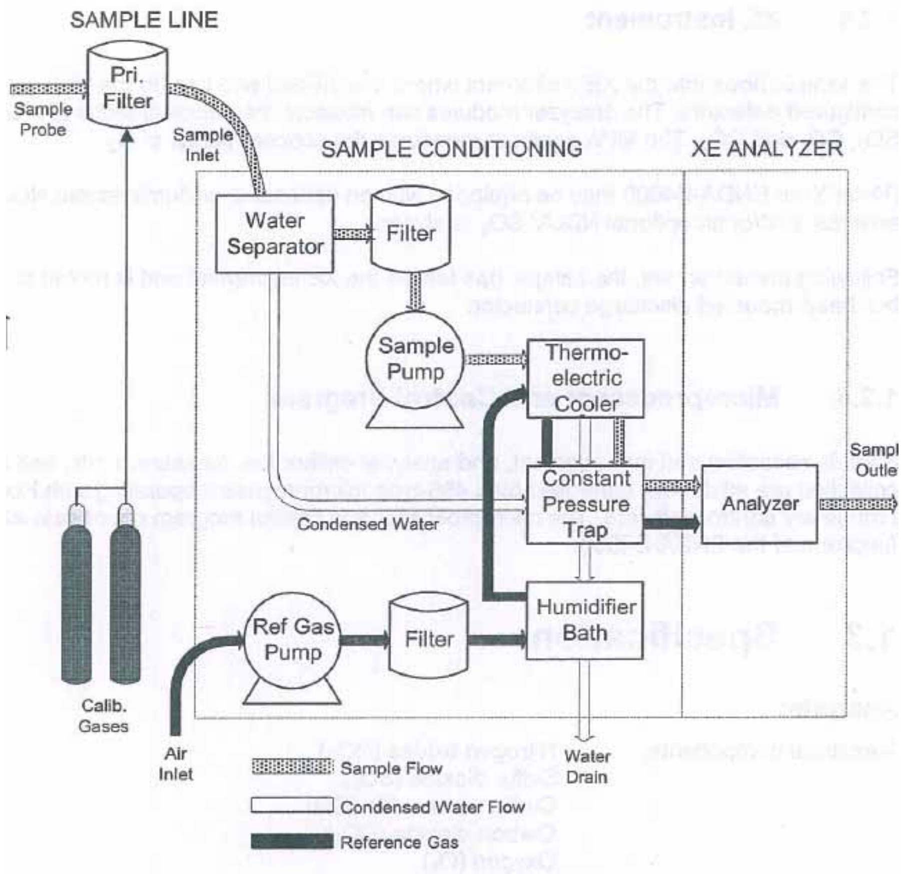

Figure 17. Simplified Diagram of the CEMS Sample System

Figure 18. ALECS CEMS

2.4 Site Preparation and System Installation for Proof-of-Concept Tests at Roseville

Prior to the system being shipped to Roseville, a site was selected that would not interfere with railroad operations and that was safe for operational personnel and visitors. Figure 19 shows an aerial view of the approximate location of the ALECS proof-of-concept test site in the Roseville rail yard. The site was readied by pouring a concrete pad, and as the location did not have easy access to electrical power lines or natural gas, a temporary diesel generator using a Tier 2 engine and a propane engine driven generator were bought in to supply electricity and temporary propane tanks were installed to provide fuel for the burner and propane generator.

Figure 19. Aerial View of the Site Where the ALECS was Installed

The entire system was shipped to the site on flatbed trucks from the various fabrication locations where the components were manufactured and tested. The system was then assembled, tested and readied for demonstration and testing.

With the exception of visitors, all non-railroad personnel underwent rail yard safety training.

3. Testing of System

3.1 Overall Test Plan/Matrix

The test program consisted of testing two locomotives made available by the Union Pacific Railroad that are representative of common high-use locomotives at the Roseville rail yard; one a line-haul locomotive and the other a switcher locomotive. These two locomotives were carefully selected to provide a range of design parameters seen in the locomotive technologies prevalent at Roseville.

Development of the proof-of-concept test plan was a collaborative effort by members of the project team and the emissions testing contractor. Organizations active in this plan development were PCAPCD, ACTI, EPA, CARB, SCAQMD, UPRR's consultant Sierra Research, TIAX, and EF&EE. The goal of the plan development was to demonstrate the ALECS performance over a range of locomotive variations with limited funding available for the testing. A challenge was to come up with test methods suitable for a system that contained a stationary source and a mobile source. Table 3 summarizes the conditions and the number of tests listed in the test plan for the two locomotives to be used with the ALECS.

The resulting test protocol defined the exhaust parameters to be measured and recorded, the sampling locations, the test methods, and the locomotive configurations and throttle settings to be tested. The complete test protocol is included as Appendix A.

Table 3. Summary of Planned Tests

Locomotive	Throttle Notch	Number of Tests per Location	Location of Tests		
			Locomotive Stack	ALECS Inlet	ALECS Outlet
Dash-8	8	3	X	X	X
	5	3	X	X	X
	1	3	X	X	X
	3 (soup baseline)	3	X	X	X
	3 (souping test)	3	X	X	X
	Moving	3	X	X	X
GP38	8	3	X	X	X
	5	3	X	X	X
	1	3	X	X	X
	3 (soup baseline)	3	X	X	X
	3 (souping test)	3	X	X	X
	Moving	3	X	X	X

Each locomotive was tested in a motionless condition and also moving slowly over a 50-foot section of track. The immobile locomotive testing was conducted at four throttle settings; notch 1, notch 3, notch 5 and notch 8. The moving test was conducted at low throttle settings to continuously move the locomotive back and forth along 50 feet of track while connected to the overhead ducting. Three tests were conducted for each individual condition.

The test program included emission measurements at three locations; in the locomotive stack(s), in the inlet ducting to the ground-mounted emission treatment system (Figure 20 shows the ducting between the emissions capture system and the emissions treatment system where measurements were taken), and at the outlet from the emission treatment system (Figure 21 shows the exhaust stack outlet measurement location as well as the inlet measurement location).

Pollutants measured included PM, NO_x, CO, SO_2, and THC. Test procedures for these pollutants conformed to ISO standard 8178. Ammonia (NH_3) was measured only at the inlet and outlet of the emission control system, following EPA Method 320.

Noise measurements were made for each locomotive at notch 8, both with and without the bonnet attached to the exhaust stack. These tests were conducted to evaluate the level of noise reduction that can be attributed to use of the ALECS.

Figure 20. Ducting between the ECS and the ETS

Figure 21. Exhaust Stack of the Emissions Treatment Subsystem

3.2 Locomotives Tested (GP38 and Dash-8)

The larger of the two locomotives tested was a General Electric (GE) C39-8 locomotive (representative of the Dash-8 series) used primarily for line-haul freight service and was equipped with a four-stroke, turbocharged, GE FDL-16 engine. This 16 cylinder engine produces 3,900 tractive horsepower, and discharges exhaust through a single rectangular stack connected directly to the turbocharger outlet. The maximum exhaust flow rate at full power is approximately 12,000 scfm. The test locomotive was identified with the serial number 9143 (see Figure 22).

The smaller locomotive tested was a General Electric Electro-Motive Division (EMD) GP38 (Figure 23). At Roseville, this type of locomotive is used primarily for switching and local service. It was equipped with a two-stroke, Roots-blown, EMD 16-645E engine. The engine has 16 cylinders and is rated at 2,000 tractive horsepower. It is equipped with two exhaust stacks, fed by the front eight and rear eight cylinders, respectively. The maximum exhaust flow rate at full power is approximately 6,000 scfm. The test locomotive was identified with the serial number 604. Table 4 summarizes the locomotive characteristics.

Immobile locomotive tests consisted of triplicate tests of each locomotive running at throttle notch 1, notch 5, notch 8, souping baseline at notch 3, and the souping test at notch 3. “Souping” is the term used for material buildup (such as oils and PM) in the exhaust system at light loads which burns off at higher loads. The souping baseline test is a test run at a throttle setting that is high enough where souping does not occur (notch 3) in order to evaluate steady state emissions. The souping test is run immediately after the notch 1 test to measure the soup that accumulated during the notch 1 test and is burned off in a higher notch run, and then compared to the souping baseline emissions rate.

Figure 22. Single Stack Line-haul Dash-8 Locomotive

Figure 23. Double Stack Switcher GP38 Locomotive

Table 4. Locomotive Characteristics

	Locomotive	
	Dash-8	GP38
Locomotive Service Class	Line-haul	Switcher
Locomotive Model	GE C39-8	EMD GP38
Locomotive Identification Number	9143	604
Engine Model	GE FDL-16	EMD 16-645E
Engine Type	Four-stroke	Two-stroke
Number of Cylinders	16	16
Rated Power Output (horsepower)	3,900	2,000
Number of Exhaust Stacks	1	2
Maximum Exhaust Flow Rate	12,000 scfm	6,000 scfm

Locomotive noise measurements were performed using a hand-held noise meter. Measurements were made at a point 30 meters away from the locomotive along a line passing through the center of the locomotive perpendicular to the track. Noise measurements were taken at the throttle notch 8 operating condition with the bonnet attached and unattached. Noise measurements on a moving locomotive were deemed not necessary due to the low throttle notch settings.

The triplicate moving tests were conducted with the bonnet(s) attached to the locomotive stack(s) and each locomotive moved back and forth under its own power within the 50 feet of test section. The moving tests were conducted for 30 minutes of continuous back and forth motion in which the locomotive throttle was set at notch 1 and the drive was engaged to move and then disengaged from the drive using the brakes to stop.

Additional information on the test conditions can be found in Appendix A and B which contains the test plan and emission test report respectively.

3.3 Emission Measurements

The emissions testing contractor, Engine, Fuel, and Emissions Engineering (EF&EE), used their patented Ride-Along Vehicle Emissions Measurement (RAVEM) sampling system to perform the PM emissions measurements. The RAVEM uses the isokinetic partial flow dilution method specified as one option under ISO 8178. Separate RAVEM samplers were used to sample the exhaust at the locomotive stack, at the inlet to the ALECS (see Figure 24), and in the outlet stack from the ALECS.

The RAVEM system located at the ALECS inlet was configured to measure NO_x, CO, and CO_2 continuously, as well as collecting integrated bag samples of the dilute gas to be analyzed after the end of each test. The RAVEM samplers at the outlet and at the locomotive stack collected integrated bag samples only. These were analyzed at the end of each test by the analyzers of the first RAVEM system.

Figure 24. RAVEM Setup at the Inlet to the Emissions Treatment Subsystem

The ALECS system itself includes continuous emission monitoring systems (CEMS) for NO_x, SO_2, and O_2 at both the inlet and the outlet, and for THC and NH_3 at the outlet only. For these tests, EF&EE provided another THC analyzer for the inlet. Table 5 shows the equipment (EF&EE or ALECS CEM) used to measure emissions by sampling location.

Table 5. Source of Measurements by Sampling Location

	Locomotive Stack	ALECS Inlet	ALECS Outlet
NO_x	E	A, E	A, E
THC	—	E	A
CO	E	E	E
CO_2	E	E	E
SO_2	—	A	A
NH_3	—	E	A, E
N_2O	—	E	E
PM	E	E	E

A = ALECS CEM system equipment
E = EF&EE system equipment

4. Test Results

All of the data taken at the ETS inlet and outlet locations by EF&EE with their RAVEM are presented here (PM, NO_x, CO, and CO_2). NO_x data taken by the ALECS' CEMS will not be presented here because only the NO_x data taken by EF&EE will be used. Although the NO_x data from ALECS's CEMS were not used, there was a good correlation with the RAVEM NO_x data (see the emission test report in Appendix B for comparisons of the two sets of data). However, the SO_2, THC, and NH_3 data taken by the ALECS' CEMS will be presented (EF&EE did not perform these measurements).

The original intent of sampling and analyzing the exhaust at the locomotive stack location was to see if the ducting to the inlet of the ALECS changed any of the results. Unfortunately, the measures at the locomotive stack were influenced by non uniform flow which introduced uncertainties that rendered these data unusable. Also, the nitrous oxide (N_2O) data were too low to be reported by EF&EE. Therefore the data for the locomotive stack location and N_2O data will not be addressed in this report (see the emission test report in Appendix B for a more thorough explanation of the details).

4.1 Emissions Results

Table 6, Table 7, and Table 8 presents the inlet and outlet emission results to the Emission Treatment System (ETS) measurements performed by EF&EE's RAVEM system for the motionless Dash-8, motionless GP38, and moving locomotives respectively.

Table 9, Table 10, and Table 11 are the inlet and outlet emissions results from ALECS' CEMS for the pollutants not measured by EF&EE. They are for the immobile Dash-8, immobile GP38, and moving locomotive tests respectively. The ammonia slip from the use of urea in the SCR system was very low. The average ammonia slip ranged from 0 up to 1.3 g/min (around 3 ppm for an exhaust flow rate of 12,000 scfm).

The CO_2 and CO results show that there are more of these pollutants coming out of the system than what entered (this is reflected in the negative control efficiency values). The increase in CO and CO_2 are attributed to the propane fuel burned to reheat the exhaust gas before the SCR system.

The overall emission control efficiency of the major pollutants of interest is presented in Table 12.

Table 6. ALECS Inlet/Outlet Emissions — RAVEM Data for the Motionless Dash-8

	Inlet Emissions				Outlet Emissions[1]			
	CO_2	CO	NO_x	PM	CO_2	CO	NO_x	PM
Notch 8 Average (g/min)	30,207	119	648	25.5	33,808	146	20.4	2.9
Coefficient Of Deviation	2.5%	6.5%	3.9%	7.9%	5.0%	8.0%	25.9%	6.2%
Control Efficiency					**-11.9%**	**-22.0%**	**96.8%**	**88.8%**
Notch 5 Average (g/min)	18,111	128	427	6.4	21,073	151	6.7	1.2
Coefficient Of Deviation	3.7%	10.8%	2.7%	8.9%	8.2%	18.0%	71.9%	12.9%
Control Efficiency					**-16.4%**	**-18.1%**	**98.4%**	**80.9%**
Notch 1 Average (g/min)	3,785	17	97	4.6	3,623	18	1.9	0.1
Coefficient Of Deviation	6.0%	45.6%	8.4%	6.5%	3.8%	6.0%	107%	2.9%
Control Efficiency					**4.3%**	**-3.0%**	**98.1%**	**98.6%**
Souping Baseline Ave. (g/min)	11,020	37	267	3.8	12,069	48	0.0	0.4
Coefficient Of Deviation	1.6%	11.6%	1.6%	18%	12.0%	29.5%	141%	22.0%
Control Efficiency					**-9.5%**	**-28.5%**	**100%**	**90.7%**
Souping Test Average (g/min)	10,841	41	257	18.2	12,509	58	7.7	0.5
Coefficient Of Deviation	8.0%	19.8%	5.3%	64%	7.0%	8.7%	101%	65.4%
Control Efficiency					**-15.4%**	**-42.6%**	**97.0%**	**97.0%**

[1] Negative control efficiencies are due to the increase of CO_2 and CO from burning propane fuel to reheat the exhaust before entering the SCR.

Table 7. ALECS Inlet/Outlet Emissions — RAVEM Data for the Motionless GP38

	Inlet Emissions				Outlet Emissions[1]			
	CO_2	CO	NO_x	PM	CO_2	CO	NO_x	PM
Notch 8 Average (g/min)	19,411	37	466	6.6	21,466	45	6.8	0.6
Coefficient Of Deviation	6.0%	18.2%	0.8%	16%	3.5%	6.5%	129%	27.8%
Control Efficiency					**-10.6%**	**-24.0%**	**98.6%**	**90.7%**
Notch 5 Average (g/min)	9,869	3	205	4.7	11,150	14	1.4	0.4
Coefficient Of Deviation	1.5%	77.3%	2.0%	16%	2.6%	32.3%	101%	6.2%
Control Efficiency					**-13.0%**	**-324%**	**99.3%**	**90.7%**
Notch 1 Average (g/min)	1,518	(1)	27	0.32	2,257	4	0.8	0.03
Coefficient Of Deviation	11.0%	638%	2.6%	34%	1.5%	31.7%	194%	9.4%
Control Efficiency					**-48.7%**	**#N/A**	**97.0%**	**89.6%**
Souping Baseline Ave. (g/min)	5,630	1	106	1.7	6,347	8	1.6	0.2
Coefficient Of Deviation	7.2%	159%	7.1%	14%	6.4%	18.9%	79.8%	6.4%
Control Efficiency					**-12.7%**	**-474%**	**98.4%**	**90.8%**
Souping Test Average (g/min)	5,327	(2)	99	2.9	5,817	8	4.8	0.1
Coefficient Of Deviation	15.0%	55.5%	8.4%	17%	11.5%	13.7%	133%	14.0%
Control Efficiency					**-9.2%**	**#N/A**	**95.2%**	**94.9%**

[1] Negative control efficiencies are due to the increase of CO_2 and CO from burning fuel to reheat the exhaust before entering the SCR.

Table 8. ALECS Inlet/Outlet Emissions — RAVEM Data for the Moving Tests

	Inlet Emissions				Outlet Emissions[1]			
	CO_2	CO	NO_x	PM	CO_2	CO	NO_x	PM
Dash-8 Moving Test Average (g/min)	1,797	6	43	3.2	2,303	12	0.6	0.0
Coefficient Of Deviation	40.3%	97.6%	35.4%	71%	13.9%	38.9%	129%	16.8%
Control Efficiency					**-28.2%**	**-99.4%**	**98.7%**	**98.5%**
GP38 Moving Test Average (g/min)	898	2	22	0.2	1,661	3	0.8	0.0
Coefficient Of Deviation	18.6%	70.9%	6.5%	116%	8.2%	20.1%	158%	66.8%
Control Efficiency					**-84.9%**	**-47.7%**	**96.3%**	**93.5%**

[1] Negative control efficiencies are due to the increase of CO_2 and CO from burning fuel to reheat the exhaust before entering the SCR.

Table 9. ALECS Inlet/Outlet Emissions — CEMS data for the Motionless Dash-8

	Inlet		Outlet		
	SO_2	THC	SO_2	THC	NH_3
Notch 8 Average (g/min)	27.34	9.90	0.07	6.64	1.3
Coefficient Of Deviation	10.4%	24.0%	198.7%	8.7%	17.8%
Control Efficiency			**99.7%**	**32.9%**	
Notch 5 Average (g/min)	18.16	4.06	0.00	2.79	0.8
Coefficient Of Deviation	8.3%	1.3%	173.2%	37.7%	103.9%
Control Efficiency			**100%**	**31.4%**	
Notch 1 Average (g/min)	1.44	1.39	0.01	0.59	0.3
Coefficient Of Deviation	4.3%	31.5%	97.4%	33.4%	136.0%
Control Efficiency			**99.1%**	**57.6%**	
Souping Baseline Ave. (g/min)	10.87	3.90	0.00	2.60	0.0
Coefficient Of Deviation	14.4%	2.1%	0.0%	13.5%	115.2%
Control Efficiency			**100.0%**	**33.2%**	
Souping Test Average (g/min)	9.42	4.61	0.07	2.24	0.1
Coefficient Of Deviation	6.6%	8.7%	104.9%	37.0%	75.5%
Control Efficiency			**99.2%**	**51.4%**	

Table 10. ALECS Inlet/Outlet Emissions — CEMS Data for the Motionless GP38

	Inlet		Outlet		
	SO_2	THC	SO_2	THC	NH_3
Notch 8 Average (g/min)	16.23	3.38	0.00	0.90	0.1
Coefficient Of Deviation	0.2%	9.3%	0.00	1.7%	173.1%
Control Efficiency			**100.0%**	**73.2%**	
Notch 5 Average (g/min)	4.70	1.62	0.00	0.23	0.0
Coefficient Of Deviation	1.4%	7.8%	0.00	2.4%	99.0%
Control Efficiency			**100.0%**	**85.7%**	
Notch 1 Average (g/min)	0.17	0.52	0.02	0.09	0.6
Coefficient Of Deviation	52.4%	13.9%	173.2%	11.2%	169.1%
Control Efficiency			**88.4%**	**83.1%**	
Souping Baseline Ave. (g/min)	1.35	0.95	0.00	0.14	0.0
Coefficient Of Deviation	20.9%	9.7%	0.00	10.6%	157.3%
Control Efficiency			**100.0%**	**84.9%**	
Souping Test Average (g/min)	1.14	0.97	0.05	0.15	0.2
Coefficient Of Deviation	22.2%	5.3%	173.2%	7.4%	87.6%
Control Efficiency			**96.0%**	**84.2%**	

Table 11. ALECS Inlet/Outlet Emissions — CEMS Data for the Moving Tests

	Inlet		Outlet		
	SO_2	THC	SO_2	THC	NH_3
Dash-8 Moving Test Average (g/min)	0.75	1.27	0.00	0.56	0.000
Coefficient Of Deviation	36.6%	35.3%	0.0%	60.9%	100.2%
Control Efficiency			**100.0%**	**56.0%**	
GP38 Moving Test Average (g/min)	0.24	0.46	0.04	0.10	0.000
Coefficient Of Deviation	9.1%	1.1%	173.2%	9.6%	139.2%
Control Efficiency			**84.9%**	**78.6%**	

Table 12. Average Control Efficiencies of the Major Pollutants

Locomotive	Throttle Notch	NO_x	THC	PM	SO_2
Dash-8	8	96.8%	32.9%	88.8%	99.7%
	5	98.4%	31.4%	80.9%[1]	100.0%
	1	98.1%	57.6%	98.6%	99.1%
	3 (soup baseline)	100.0%	33.2%	90.7%	100.0%
	3 (souping test)	97.0%	51.4%	97.0%	99.2%
	Moving	98.7%	56.0%	98.5%	100.0%
GP38	8	98.6%	73.2%	90.7%	100.0%
	5	99.3%	85.7%	90.7%	100.0%
	1	97.0%	83.1%	89.6%	88.4%
	3 (soup baseline)	98.4%	84.9%	90.8%	100.0%
	3 (souping test)	95.2%	84.2%	94.9%	96.0%
	Moving	96.3%	78.6%	93.5%	84.9%
Overall Average Control Efficiency		**97.8%**	**62.7%**	**92.1%**	**97.3%**

[1] The anomalous low average PM value (in comparison to the other PM control efficiencies) has been investigated by ACTI, but it could not be explained. The data is included in the overall average calculation for completeness.

4.2 Utility, Energy, and Chemical Consumption Rates

ACTI collected operating process data on the ALECS and provided the estimates shown in Table 13 on the utility, energy, and chemical consumption rates per hour of operation. Propane was the fuel used for reheating the exhaust prior to the SCR, but natural gas is the fuel expected to be used in normal operation. The amount of natural gas required to heat the 12,000 scfm of exhaust is 2.60 MMBtu/hr (based upon the measured propane usage during testing, then adjusted using 2,500 Btu/ft^3 propane with 1,031 Btu/ft^3 natural gas to calculate the natural gas usage). Also, in the proof-of-concept test, diesel engine generators were used to produce the electricity needed, but electricity from the local utility is expected to be used in normal operation. The diesel engine generators and propane were used due to the ALECS installation being temporary only for this proof-of-concept test and being located in a remote area of the rail yard.

Table 13. Utility, Energy, and Chemical Consumption Rates

Consumables	Quantity	Units
Electricity	328	kWh/hr
Natural Gas	2.60	MMBtu/hr
Water	180	gal/hr
Aqueous Urea (40%)	0.54	gal/hr
Sodium Hydroxide (30%)	0.0095	gal/hr

4.3 Waste Characterization

The solid waste produced by the ALECS and collected from the Preconditioning Chamber and the Cloud Chamber discharge was analyzed. The toxic chemicals and Title 22 metal compounds were below the detection limit of the laboratory. The only detectable compounds are shown in Table 14. The complete lab report is included in Appendix D.

Table 14. Solid Waste Analysis

	Units	Sample #1	Sample #2
Oil & Grease	mg/Kg	85,000	78,000
Total Recoverable Petroleum Hydrocarbons	mg/Kg	88,000	80,000
Zinc	mg/Kg	92	22

Solid waste accumulated from the ETS was estimated to be produced at a peak rate of 2.2 lb/hr. This estimate is based upon data collected by ACTI during the testing. Captured solid waste was stored in drums that hold around 400 pounds of material each. The filled drums were transported by an ACTI truck to an approved disposal site

The liquid wastewater was analyzed and the results are provided (as well as the solid waste analysis) in Appendix D. Liquid wastewater was being produced at a rate of 0.9 gal/hr. Analysis of the wastewater shows it could be considered safe enough to be discharged to a publicly owned treatment works, but local policies specific to each location will need to be identified.

4.4 Diesel Fuel Analysis

The test fuel for the GP38 was ultra-low sulfur diesel fuel meeting ARB regulations for sulfur and aromatic content. The sulfur limit is 15 ppm, and the limit on aromatic content is 10 percent unless the fuel is produced according to an approved alternative formulation. The test fuel for the Dash-8 was a diesel fuel that is actually supplied to Union Pacific line-haul locomotives outside California. This fuel was specified with sulfur content between 200 and 500 ppm.

Table 15 shows the results of analyses performed on each fuel sample. EF&EE collected fuel samples from each locomotive's fuel tank during the test program. The fuel tanks were sealed and labeled to ensure that fuel was not added to the tanks by mistake.

Table 15. Fuel Analyses

	Method	Dash 8	GP38
Carbon Content	D-5291	86.00%	86.10%
Hydrogen Content	D-5291	13.33%	13.73%
Nitrogen Content	D-5291	0.05%	0.06%
Sulfur Content (ppm)	D-4294	500	<150[1]

[1] This test did not have the resolution to verify 15 ppm sulfur content. However, the fuel was taken from the Roseville rail yard fueling system and all fuel dispensed in Roseville at the time met CARB diesel with a sulfur content of 15 ppm or less.

4.5 Noise Measurements

The locomotive noise measurements were measured at a point 30 meters perpendicularly away from the side of the locomotive with and without the bonnet attached to the stack(s). The decibel scale is logarithmic rather than linear. Hence a small reduction in decibels results in a fairly large percent reduction in sound energy. Table 16 shows the results of the noise measurements taken.

Table 16. Noise Measurements with and without the Bonnet in Place

	Average Sound Level (decibels)			Percent Reduction In Sound Energy
	w/o Bonnet	w/Bonnet	Reduction	
DASH-8: Notch 8	87.0	81.7	5.3	70%
DASH-8: Notch 5	84.5	77.7	6.8	79%
GP38: Notch 8	91.6	84.8	6.8	79%

4.6 Overall System Evaluation

Conventional stationary emission control technology has been demonstrated to be very effective in treating emissions from locomotive sources. The ECS demonstrated the ability to capture emissions from a single locomotive (at a time) while motionless and while moving. The proof–of-concept test utilized a system that was installed to handle a single locomotive at a time; a full-sized emissions capture system (ECS) with multiple locomotives was not tested.

5. Life Cycle Cost Analysis

5.1 Methodology

The life cycle cost analysis estimates the total cost of the ALECS incurred over the life of the system and is used along with the emission estimates to determine the system cost effectiveness per ton of pollutant reduced. The life cycle cost analysis entails Cost Element Definition, Data Collection, and Evaluation.

5.2 Cost Element Definition

Cost elements are broken down into Initial Capital Costs, Operating and Maintenance Costs including Utility/Energy Costs, Repair and Replacement Costs, Downtime Costs, Environmental Costs, and Salvage Value.

A) Initial Capital Costs include engineering and design (drawings and regulatory issues), bidding process, purchase order administration, hardware capital costs, testing and inspection, inventory of spare parts, foundations (design, preparation, concrete and reinforcing), installation of equipment, connection of process piping, connection of electrical wiring and instrumentation, one-time licensing/permitting fees, and the start up (check out) costs.

B) Operating and Maintenance Costs include items such as labor costs of operators, inspections, insurance, warranties, recurring licensing/permitting fees, and all maintenance (corrective and preventive maintenance). Also included are yearly costs of consumables such as the utility/energy costs (electricity, natural gas, and water) and chemical costs (such as sodium hydroxide and urea).

C) Repair and Replacement Costs are the costs of repairing and replacing equipment over the life of the ALECS. This would also include catalyst material replacement.

D) Rail yard impact costs include estimates of costs incurred by the Union Pacific Railroad. An example would be if the ALECS was shut down for repairs and locomotives that normally would be serviced or stored in a specific area needed to be relocated and serviced/stored elsewhere. Rail yard impact costs would also include the costs to change rail yard operations that are different from what is practiced today (including structural changes, if needed, to accommodate ALECS). For example, the additional time and costs (including labor) of rerouting locomotives to the ALECS area if the locomotives may not have been normally required to be moved. Locomotive downtimes can be very expensive to the rail yard and may result in loss of revenue. Costs may also be negative (a benefit to the rail yard) if the implementation of ALECS produced increased efficiencies such as decreased dwell time (time a locomotive is in the rail yard). At the current time, Union Pacific Railroad does not have an estimate (positive or negative) as to the effect ALECS would have on rail yard operations.

E) Environmental Costs are associated with the disposal of wastewater, solid waste, used chemicals, and used parts.

F) The Salvage Value of the system would be the net worth of the ALECS in its final year of the life cycle period. If the system can be moved and salvaged for useful parts/purposes, there would be a reduction in life cycle costs.

The estimates in this report are based upon data and observations taken during the operation and proof-of-concept testing of the ALECS.

5.3 Data Collection and Assumptions

Accuracy of input data is important to improve the certainty of the life cycle cost prediction. Data was obtained from stakeholders in this project (such as ACTI, UPRR, EF&EE, and the PCAPCD) to provide the most accurate information available. Where actual data were not available from the stakeholders, literature searches, theoretical calculations, and engineering estimates were utilized. The ETS would be common among installations at different rail yards, however, the ECS would need to be tailored to each specific installation dependent upon the size and activity of locomotives at each rail yard. However, the main ECS components would be common, just arranged to cover a different length or width of the section of rail yard being addressed. For estimating costs, an installation for the Western United States is assumed.

ACTI provided information on the initial capital costs (see Table 17). The costs include burden, markup, and taxes. Taxes do not include provisions for property taxes. The ECS is based upon the full scale deployment design of the concentric tube manifold subsystem shown Section 2.2. The estimates are based upon 12 bonnets installed for an ETS installed at the rail yard. The ETS equipment costs include a semi-automatic solid waste removal system that will replace the bag filter system that was used in the proof-of-concept test. A boost blower has been added to the Roseville proof-of-concept test design in order to compensate for the length of the full-scale ECS design.

The costs are based upon the assumption of reduced prices from multiple production runs of around 20 units, split between rail and marine applications

The Indirect Installation Costs were adjusted based on ACTI's experience in Roseville. As this system is duplicated in many locations, the required Engineering Support will become considerably less on each succeeding application, and most of the non-recurring engineering will only be needed for the first application. This also applies to some extent to the rest of the indirect installation costs as well. The construction, field expenses, and contractor fees are mostly included as part of the Equipment Costs, although a portion of these costs is still required for final placement and integration of these items.

The proof-of-concept test design utilized a filtration system to separate the particulate from the Preconditioning Chamber and Cloud Chamber Scrubber water for disposal. Figure 25 shows the originally white filters (Figure 26) that have turned black with use in the proof-of-concept testing.

The full scale deployment design would incorporate the Solid Waste Semi-Automatic Removal System shown in Figure 27 that would be able to process higher volumes of particulate with less labor and filter material/changes.

Table 17. ALECS Initial Capital Costs

	Qty	Units	Cost/Unit	Subtotal	Total
Equipment Costs					
ECS: Overhead Structure	1,200	feet	$ 933	$1,119,901	
ECS: Overhead Manifold	1,200	feet	$ 1,077	$1,292,193	
ECS: Bonnets	12	each	$ 57,431	$ 689,170	
ECS: Boost Blower	1	each	$ 19,383	$ 19,383	
ETS	1	each	$3,625,319	$3,625,319	
Emissions Monitoring	1	each	$ 518,378	$ 518,378	
Total Equipment Costs (Cp):				**$7,264,343**	
Shipping	3%	Cp	$7,264,343	**$ 217,930**	
Purchased Equipment Cost (PEC):					**$7,482,273**
Direct Installation Costs					
ECS: Piers	24	each	$ 1,436	$ 34,458	
ECS: Assembly & Erection	1,200	feet	$ 144	$ 172,292	
ECS: Electrical	1	each	$ 43,073	$ 43,073	
ETS: Pads & Foundations	1	each	$ 107,683	$ 107,683	
ETS: Electrical	1	each	$ 93,325	$ 93,325	
ETS: Natural Gas/Propane/CNG	1	each	$ 43,073	$ 43,073	
ETS: Water	1	each	$ 1,436	$ 1,436	
ETS: Sewer (Industrial)	1	each	$ 8,615	$ 8,615	
Permits	1	each	$ 50,970	$ 50,970	
Infrastructure Design & Construction	1	each	$ 78,967	$ 78,967	
Trenching and Coring	1	each	$ 8,615	$ 8,615	
Consumables for Commissioning	1	each	$ 31,587	$ 31,587	
Total Direct Costs (TDC):					**$ 674,094**
Indirect Installation Costs					
Engineering Support	0.5%	PEC	$7,482,273	$ 37,411	
Construction & Field Expenses	1.0%	PEC	$7,482,273	$ 74,823	
Contractor Fees	2.0%	PEC	$7,482,273	$ 149,645	
Start-up	0.5%	PEC	$7,482,273	$ 37,411	
Performance Test	0.5%	PEC	$7,482,273	$ 37,411	
Contingencies	2.5%	PEC	$7,482,273	$ 187,057	
Total Indirect Costs (TIC):					**$ 523,759**
Total Initial Capital Investment (TICI):					**$8,680,126**

Figure 25. Some Solid Waste Filters Used During the Demonstrating Testing

Figure 26. Clean Solid Waste Filter

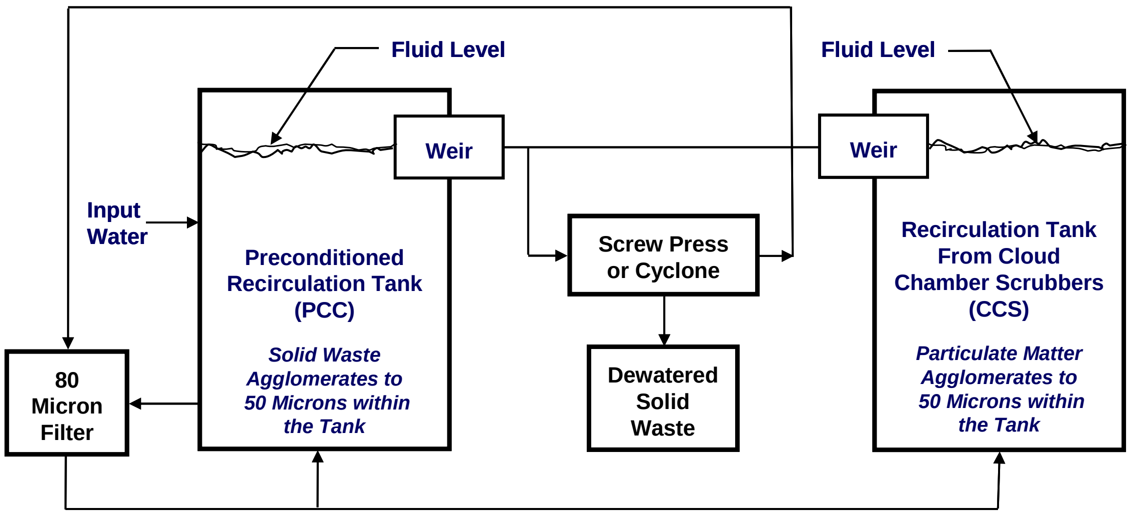

Figure 27. Solid Waste Semi-Automatic Removal System

The solid waste and particulate matter collected within the PCC and CCS recirculation tanks are removed (skimmed) from the surface using a Weir. ACTI experience has shown that the solid waste and particulate matter agglomerates within the tanks to a size of approximately 50 microns. Since the water in the tanks is turbulent, material does not tend to accumulate on the bottom.

The removed material is then sent to a screw press or cyclone which automatically removes much of the water. The removed water is returned to the appropriate recirculation tank, the solid material is then deposited into roll bins for removal and disposal. Analysis has shown the solid waste material to be non-hazardous.

The removed water is then filtered through an 80 micron filter prior to being returned to the appropriate recirculation tank. Filters are disposable and will be replaced every other month.

The annually recurring operation and maintenance costs are presented in Table 18. The consumables and utilities are based upon ALECS operating 96 percent of the maximum annual hours (ACTI estimate). The electricity and natural gas prices are based upon the Energy Information Administration's forecasted 2007 Industrial prices for the Pacific region. The SCR catalyst is estimated to be replaced every five years at a cost (fully loaded) of $86,146. The 5 year life of the catalyst is based upon the removal of sulfur and PM prior to the SCR which extends the life of the catalyst. The catalyst is assumed to not be replaced in the 20th year of the ALECS operation due to the end of its projected 20 year life. This catalyst replacement cost is annualized in the recurring operation and maintenance costs. It is assumed that there will not be a salvage value of the ALECS at the end of its useful life and any salvage value would be offset by any costs associated with shutting down the ALECS.

Burden and profit are not applied to the "Utilities" line items (e.g. electricity, natural gas, and water), as these will be supplied by the rail yard. However, maintenance and labor will be supplied by a third party operator/owner. ALECS will be staffed 24 hours a day, 365 days a year as shown in Table 18.

Table 18. ALECS Annually Recurring Operation and Maintenance Costs

	Usage Rate		Unit Cost		$/hr	$/year
Consumables/Utilities/Fees						
Sodium Hydroxide (30%)	0.0095	gal/hr	$ 1.65	/gal	$ 0.02	$ 132
Aqueous Urea (40%)	0.54	gal/hr	$ 1.86	/gal	$ 1.01	$ 8,462
Electricity	328	kWh/hr	$ 0.0747	/kWh	$ 24.50	$ 206,049
Natural Gas	2.60	MMBtu/hr	$ 7.20	/MMBtu	$ 18.69	$ 157,213
Natural Gas Meter Charge	1	meter	$ 11.51	/meter-day	$ 0.48	$ 4,201
Water	180	gal/hr	$ 1.66	/1000 gal	$ 0.30	$ 2,513
Liquid Waste	0.90	gal/hr	$ 0.34	/gal	$ 0.30	$ 2,563
Solid Waste	2.19	lb/hr	$ 0.051	/lb	$ 0.11	$ 935
Insurance	1	premium/yr	$ 33,863	/site	$ 3.87	$ 33,863
Labor						
Technician	1	Technician	$ 84,114	/year	$ 40.44	$ 84,114
Operator	4	Operators	$ 56,570	/year	$ 27.20	$ 226,279
Maintenance	2.0%	TICI	$ 8,680,126	/TICI	$ 19.82	$ 173,603
Total Annual Recurring Operating Costs[1]:						**$ 899,926**

[1] An additional catalyst replacement cost (not included in the annual costs above) of $86,146 also occurs every 5 years. Cost is annualized in the economic analysis.

5.4 Evaluation

The total life cycle cost of the ALECS is based upon the discounted cash flow of costs in the future (which brings the costs to their present value), and the annualized payments of initial capital costs to account for the time value of money. The costs are summed to produce the total life cycle cost of the ALECS. The interest (discount rate) is assumed to be 4 percent based upon the value used in the Carl Moyer program (CARB, January 6, 2006). The system is designed and projected to have a life of 20 years (the EPA Air Pollution Control Cost Manual uses a 20 year economic lifetime for a SCR system) (EPA, January 2002).

The Initial Capital Investment of $8,593,980 (without the catalyst cost) is annualized with an adjustment for the time value of money (4 percent interest for 20 years) to be $632,360/year. The cumulative 20 year cost is $12,647,202.

The catalyst cost of $86,146 is annualized with an adjustment for time value of money (4 percent interest for 5 years) for the first 5 years. Each subsequent 5 year increment has a catalyst replacement cost reduced to the present value (from the year the catalyst is replaced) before adjusting for the time value of money. This results in a total catalyst cost of $287,727 over the 20 year life of ALECS. The summary of the components used to build up the catalyst costs are presented in Table 19.

Table 19. Summary of Catalyst Costs for ALECS

	Years 1 - 5	Years 6 – 10	Years 11 - 15	Years 16 - 20	Total
Catalyst Cost (2007$)	86,146	86,146	86,146	86,146	344,585
Year of Replacement		6	11	16	
Present (discounted) Value (2007$)	86,146	68,083	55,959	45,994	256,182
Adjusted for Time Value of Money (2007$)	96,754	76,466	62,849	51,658	287,727
Annualized Cost/year (2007$)	19,351	15,293	12,570	10,332	

The net present value (which accounts for the changes in value of money over time) of the operation and maintenance cost ($899,926/year) over the life of ALECS is $12,230,292.

The ALECS total life cycle cost over a 20 year period is $25,165,221. The summary of the annual costs (fully loaded with the burden, markup, and taxes) adjusted for the time value of money is shown in Table 20 and Figure 28.

Table 20. Summary of Annual Costs (2007$)

Year	Initial Capital Cost (w/o catalyst)	Catalyst Cost	Operation and Maintenance Cost	Total Cost
1	632,360	19,351	865,314	1,517,025
2	632,360	19,351	832,032	1,483,743
3	632,360	19,351	800,031	1,451,742
4	632,360	19,351	769,261	1,420,972
5	632,360	19,351	739,674	1,391,385
6	632,360	15,293	711,225	1,358,878
7	632,360	15,293	683,870	1,331,523
8	632,360	15,293	657,567	1,305,221
9	632,360	15,293	632,276	1,279,930
10	632,360	15,293	607,958	1,255,611
11	632,360	12,570	584,575	1,229,505
12	632,360	12,570	562,091	1,207,021
13	632,360	12,570	540,472	1,185,402
14	632,360	12,570	519,685	1,164,615
15	632,360	12,570	499,697	1,144,627
16	632,360	10,332	480,478	1,123,170
17	632,360	10,332	461,998	1,104,690
18	632,360	10,332	444,229	1,086,921
19	632,360	10,332	427,143	1,069,835
20	632,360	10,332	410,715	1,053,406
Total Cost	12,647,202	287,727	12,230,292	**$ 25,165,221**

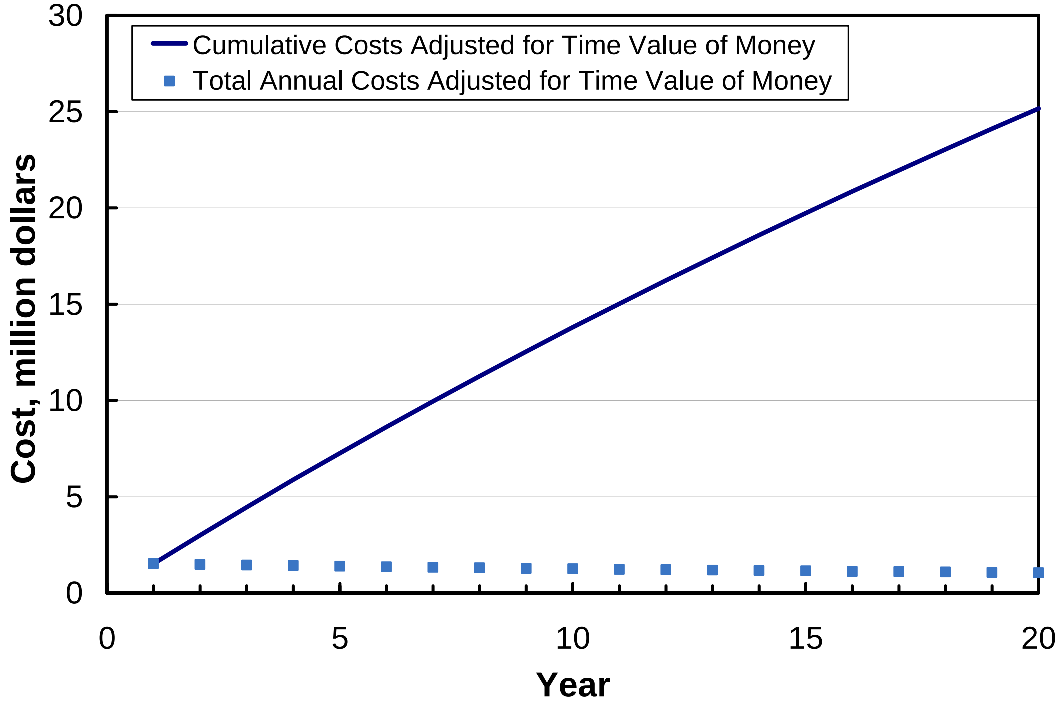

Figure 28. ALECS Annual Cash Flow and Cumulative Costs (2007$)

6. Cost Effectiveness

The cost effectiveness of ALECS is determined by dividing the total ALECS life cycle cost by the total weighted emissions reduced by ALECS over the life of the system. The use of weighted reduced emissions is based upon the Carl Moyer Memorial Air Quality Standards Program (CARB, January 6, 2006). The Carl Moyer program considers NO_x, THC and PM_{10} emission reductions in one calculation where weighting factors are applied. For NO_x and THC emission reductions, a weighting factor of one is used. CARB has identified particulate emissions from diesel-fueled engines as toxic air contaminants, and believes emission reductions of PM_{10} should carry additional weight in the calculation because, for an equivalent weight, these emissions are more harmful to human health. CARB uses a PM10 weighting factor of 20. The Carl Moyer method utilizes the Annualized Cash Flow method which multiplies the initial capital cost by a capital recovery factor to obtain an equivalent end of year annual capital cost payment.[1] This report utilizes the annualized capital costs adjusted for the time value of money and the Discount Cash Flow method for future costs which calculates the cost by determining the present value of the costs of buying, operating, and maintaining the equipment over the life of the equipment (see life cycle costs analysis above).

The weighted cost effectiveness formula for ALECS analysis is:

$$\frac{\text{Total Life Cycle Cost (2007\$)}}{(NO_x + THC + 20{*}PM_{10})\text{ (tons reduced over life of equipment)}}$$

The emissions measurements from this proof-of-concept test are based upon just two locomotives (the Dash-8 and the GP38) and may not be representative of all Dash-8 (line-haul) or all GP38 (switcher) locomotives. The emissions reduced in the rail yard application will be highly dependent on the specific details of each application. In an attempt to bound the possible uses in a rail yard, two examples using only two locomotives are presented. One example case utilizes all idling, Tier 2 locomotives that will produce the lowest emissions for treatment by the ALECS. The other example case, representing high emissions, assumes Tier 0 locomotives operating at various conditions.

Tier 0 Dash-8 emissions data were obtained from CARB (based upon GE certification data for C40-8) as compiled for the Roseville rail yard health risk assessment study (CARB, October 14, 2004) and should be more representative of the locomotives operating at the rail yard. Tier 2 emissions data were estimated based upon EPA engine certification data for the GE engine family "6getg0958efb" (EPA website, March 2007). These emission factors are presented in Table 21. SO_x emission factors were not used because Tier 0 data were not available

Without further information on the estimated number of locomotives and their throttle settings in a specific area of the rail yard, the following 4 scenarios (the first 3 scenarios apply to the Tier 0 locomotives) in Table 22 were created. All of these scenarios were designed to fully use the

[1] The Moyer method does not consider annual operating and maintenance costs.

12,000 scfm capability of ALECS. For example, 6 Tier 2 engines at idle would fully use the systems capability or only 1 Tier 0 locomotive at notch 8.

Table 21. Locomotive Emission Factors

Locomotive	Throttle	Exhaust (scfm)[1]	PM (g/hr)	NO_x (g/hr)	THC (g/hr)
Tier 0	8	12,077	615	29,527	861.21
	5	7,176	327.68	14,746	655.36
	idle	2,000	36.95	746.49	268.65
Tier 2	idle	2,000	25.1	747.2	71.5

[1] Exhaust flow rate for Tier 0 at throttle notch 8 and 5 are from proof-of-concept testing. The idle exhaust flow rates are estimated.

Table 22. Locomotive Scenarios

Scenario #	Locomotive	Number of Locomotives			Total Exhaust (scfm)
		Notch 8	Notch 5	Idle	
1	Tier 0	1	-	-	12,077
2	Tier 0	-	1	2	11,176
3	Tier 0	-	-	6	12,000
4	Tier 2	-	-	6	12,000

Applying the emission factors from Table 21 and this proof-of-concept's overall control efficiencies from Table 12 (the NO_x control efficiency was reduced 1.5 percent, from 97.8 to 96.3 percent, to account for catalyst degradation over time) to the scenarios produced the total emissions controlled in Table 23 if each scenarios were individually running 100 percent of the time.

Table 24 shows the maximum available controlled emissions if ALECS was able to run at full capability (12,000 scfm) 100 percent of the time for each of the bounding cases (Tier 0 and Tier 2). The Tier 0 example case utilizes all GE Dash-8 locomotives with a mix of notch 8 (10 percent), notch 5 (20 percent) and idling (70 percent) operating conditions. The higher notch running of the locomotives represents a situation where the ALECS is situated in a location where there is diagnostic and load testing performed. The testing is supplemented with idling to keep the ALECS fully employed.

No deterioration factors (DF) are used for the Tier 2 locomotives over the 20 year life of the ALECS system.

Table 23. Maximum Controlled Emissions for Each Scenario

Scenario #	PM (g/hr)	NO_x (g/hr)	THC (g/hr)
1 (Tier 0)	566	28,440	540
2 (Tier 0)	370	15,640	748
3 (Tier 0)	204	4,314	1,010
4 (Tier 2)	139	4,318	269

Table 24. Maximum Annual Controlled Emissions

Scenario #	Hours/yr	PM (ton/yr)	NO_x (ton/yr)	THC (ton/yr)
1 (Tier 0)	876	0.55	27.46	0.52
2 (Tier 0)	1,752	0.71	30.21	1.44
3 (Tier 0)	6,132	1.38	29.16	68.83
Total Tier 0	**8,760**	**2.64**	**86.83**	**8.80**
Total Tier 2	**8,760**	**1.34**	**41.70**	**2.60**

Deterioration factors (DFs) were applied to the emission factors for the Tier 0 case. Roseville rail yard is a major service center for Union Pacific where locomotives are brought for diagnostics and repair. Some of these locomotives have been observed to produce visible emissions not common to well-running engines. It is anticipated that some of these abnormally high emission locomotives would be connected to the ALECS during diagnostics.

The Dash-8 locomotive tested in this proof-of-concept project was obtained from the normal operational fleet, but was suspected of having higher than average emissions. When compared to the certification data for this locomotive type (see Table 21), the emissions for PM and NO_x were considerably higher. The DFs used for this Tier 0 example case were set at the average of the certification data and the test results obtained in this project. The project PM data were 229 percent greater than the certification data with the NO_x data 159 percent greater (THC was 44 percent). The DFs applied for PM is 1.64 with 1.29 applied to NO_x (THC factor is not applied).

Table 25. Tier 0 Deterioration and New Engine Introduction Factor

	PM	NO_x	THC
% Greater than Certification	229%	159%	-
Deterioration Factor	1.64	1.29	1
Reduction due to New Engines	14%	14%	13%
Adjusted Deterioration Factor	**1.42**	**1.12**	**0.87**

To recognize that over the next 20 years the fleet of locomotives is expected to trend toward lower emissions as new locomotives are added and the oldest locomotives are retired, a reduction factor was added to represent the upgrading of the fleet. This information was obtained from an EPA projection that lists fleet average emission factors by year going into the future (EPA, December 1997). Looking at the reduction projected from 2008 to 2028 and averaging over the 20 years gives emission factor reductions of 14 percent for PM, 14 percent for NO_x, and 13 percent for HC. Combining the DF and fleet average reduction into a single factor gives the following factors used for this analysis:

For the cost effectiveness calculations, the ALECS is assumed to have a 96 percent utilization factor (ACTI estimate) and the emission estimates for the Tier 0 example are shown in Table 26 and 27. The adjusted emissions shown in these tables include the factor of 20 for the PM_{10} adjustment and the adjusted DFs shown in Table 25 for PM10, NO_x and THC.

Table 26. Annual Tier 0 Controlled Emissions with ALECS at 96 Percent Utilization

Scenario #	Hours/yr	PM (ton/yr)	NO_x (ton/yr)	THC (ton/yr)
1	841	0.52	26.36	0.50
2	1,682	0.69	29.00	1.39
3	5,887	1.32	27.99	6.56
Sum	8,410	2.53	83.35	8.44
Adjusted Emissions		71.87	93.23	7.34

Table 27. Annual Tier 2 Controlled Emissions with ALECS at 96 Percent Utilization

Scenario #	Hours/yr	PM (ton/yr)	NO_x (ton/yr)	THC (ton/yr)
4	8,410	1.29	40.03	2.49
Adjusted Emissions		25.72	40.03	2.49

The total weighted controlled PM, NO_x, and THC emission for Tier 0 is 172.4 tons/yr with Tier 2 estimate of 68.2 tons/yr. SO_x emissions reductions are not considered in these estimates. Over the total 20 year life of the ALECS, the total weighted emissions reduced ranges from 1,365 tons to 3,449 tons. The resulting cost effectiveness is estimated to range from $18,437/ton to $7,297/ton of weighted pollutant reduced. Figure 29 shows the cost effectiveness curve over the 20 year projected life of the ALECS. The point to the furthest left of the figure represents Tier 2 locomotives operating only in idle mode (with a 96 percent ALECS uptime factor). The point on the curve to the furthest right of the graph represents Tier 0 Dash-8 locomotives operating 10 percent of the time at notch 8, 20 percent at notch 5, and the remaining 70 percent of the time at idle (also applying a 96 percent ALECS uptime factor and DFs). The single magenta point (square shape) is an estimated midpoint to be used for sensitivity analysis.

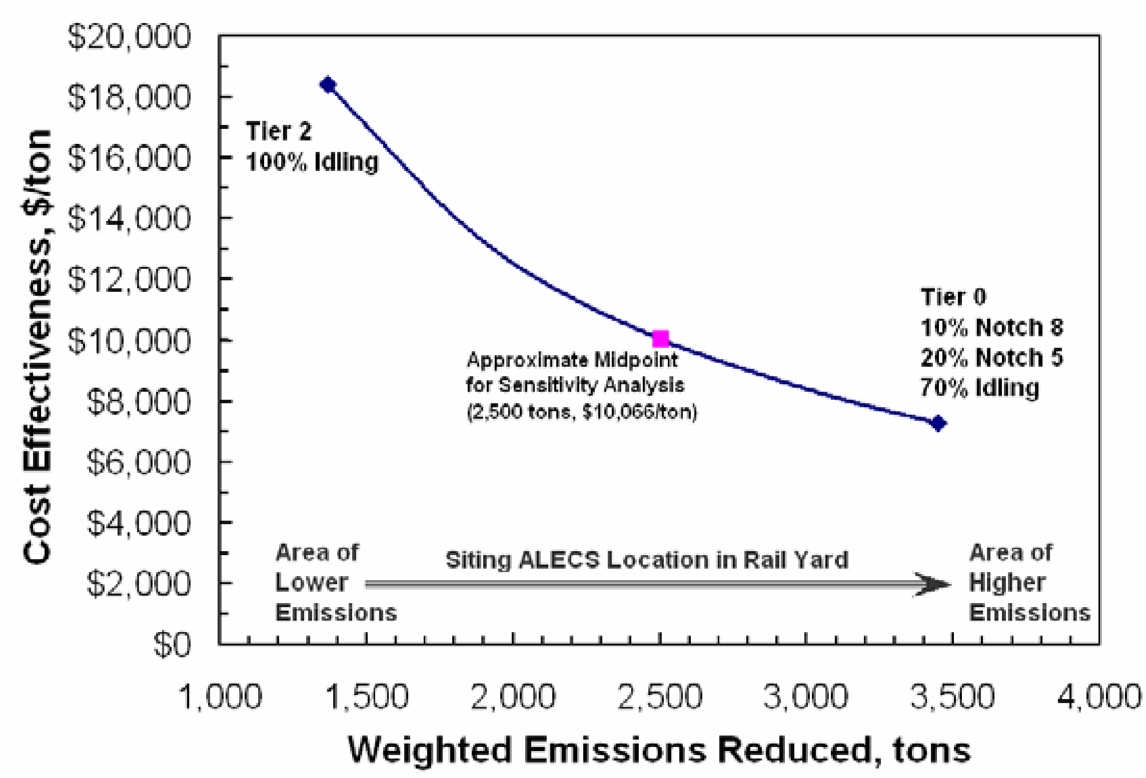

Figure 29. ALECS Cost Effectiveness

Figure 29 highlights the importance of installing the ALECS in an area of the rail yard where there are locomotives operating in higher notch settings. Installing the ALECS in an area where emissions reductions fall on the right side of the figure would result in better cost effectiveness than locations with emissions that fall further to the left. Higher emissions would result from higher engine settings than at idle, therefore, it is possible for less engines running at higher notch settings to have higher total emissions than if more engines were running, but were only idling. Careful analysis of the locomotive mix and how many engines are running in specific areas of the rail yard is important, but also knowing what notch setting and for how long each engine is running would also be important in determining where the ALECS should be located to maximize emissions reductions and provide best ALECS cost effectiveness.

Sensitivity analysis on the cost effectiveness was performed on the approximate midpoint according to the hypothetical base case parameters listed in Table 28. The results are graphed in the tornado chart in Figure 30.

Table 28. Parameters Used for the Cost Effectiveness Sensitivity Analysis

	Better Cost Effectiveness	Approximate Midpoint Case	Worse Cost Effectiveness
Throttle Notch Positions	10% N8, 20% N5, 70% Idle	5% N8, 10% N5, 85% Idle	100% Idle
Emissions Reduction Rate	150 ton/yr	125 ton/yr	100 ton/yr
System Utilization Rate	100%	96%	70%
ALECS Lifetime	25 years	20 Year Life	15 years
Interest (Discount Rate)	-	4%	6%

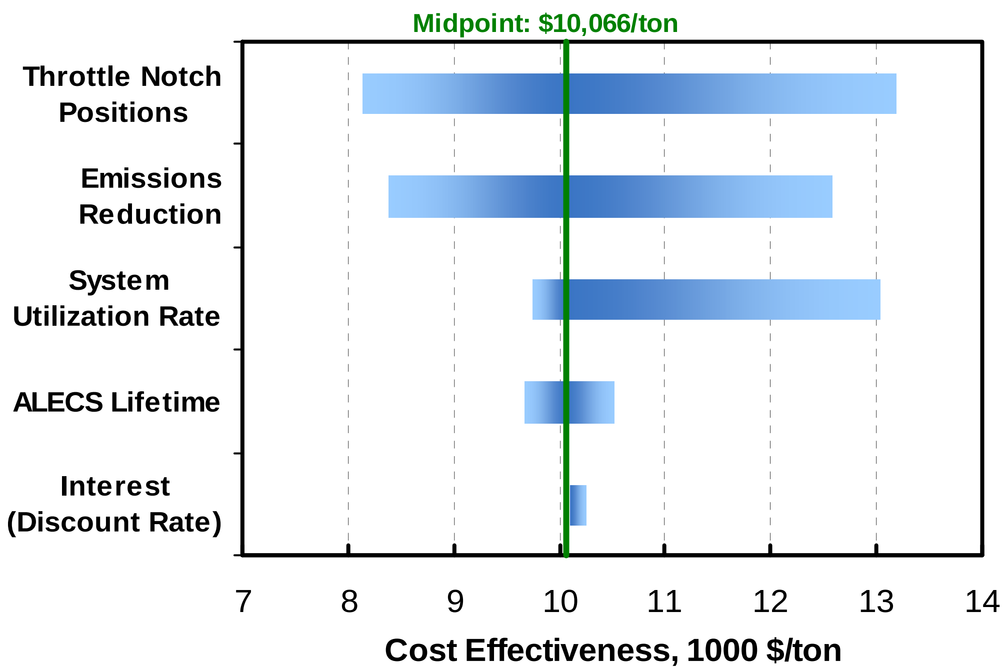

Figure 30. Cost Effectiveness Sensitivity on Midpoint

The estimated 96 percent system utilization rate is based upon locomotive emissions being generated 100 percent of the year (based upon the scenarios described above) and the ALECS being available 96 percent of the time. The minimum cost effectiveness value (better) was based on the ALECS being available 100 percent of the time. The maximum cost effectiveness value (worst) is based upon a 70 percent system utilization rate which is not only based upon the ALECS availability (ACTI expects ALECS to be available at least 96 percent of the time), but it also incorporates whether there are emissions being generated. The 70 percent would represent the ALECS being available and exhaust emissions are also being generated at the same time. A 30 percent increase in cost effectiveness would be due to a drop in system utilization rate to 70 percent. This highlights the importance of installing the ALECS in a busy area of the rail yard where there would be a high concentration of locomotives generating emissions.

The locomotive throttle notch positions were examined at 100 percent idling for the maximum cost effectiveness value and 10 percent at notch 8 with 20 percent at notch 5 for the minimum.

The increase in time at higher notch settings (with 70 percent of the remaining time spent idling) resulted in a 19 percent reduction in cost effectiveness. At 100 percent idling, the cost effectiveness jumps up 31 percent. Understanding the operational modes of the locomotives is important because they have a large impact on the cost effectiveness. Preference in placement of the ALECS would be in areas where locomotives would run at higher notches than areas where locomotives would only idle.

An increase of 20 percent of the pollutants reduced from the baseline resulted in a 17 percent reduction in cost effectiveness. A 20 percent reduction in pollutants from the base case increased the cost effectiveness by 25 percent.

Increasing the interest (discount rate) from the baseline of 4 percent (Moyer guideline) to 6 percent, results in a 2 percent higher cost effectiveness value. Analysis of interest rates less than 4 percent were not performed.

The ALECS was designed for a 20 year life, but if the system does not run after 15 years, the cost effectiveness increases 5 percent to $10,521/ton. If the system runs for 25 years, the cost effectiveness drops down 4 percent to $9,663/ton.

7. Summary/Next Steps

7.1 Summary

This project was a "proof-of-concept" effort designed to demonstrate the possible effectiveness of one set of stationary air pollution control equipment to capture and treat emissions from locomotives that are temporarily idling while sitting on a ready track, being prepared for servicing, being serviced, or undergoing engine load tests. The equipment was to be evaluated for effectiveness in capturing and treating PM, NO_x, SOx, and VOC emissions from such locomotives. The specific objectives of this proof-of-concept project and its accomplishments are summarized in Table 29.

Table 29. Summary of Project Objectives and Accomplishments

OBJECTIVE	ACCOMPLISHED?
Objective 1: Demonstrate the Possible Effectiveness of Stationary Control Equipment on Locomotive Exhaust: This proof-of-concept test of the ALECS equipment should quantify the overall capture and control efficiency of particulate matter (PM), NO_x, SO_x, and total hydrocarbons (THC) in actual locomotive exhaust in a rail yard environment. Locomotive engines in common use come in two distinct technologies; two-stroke and four-stroke. This proof-of-concept test will test one engine of each technology; a GP38 locomotive operating on ultra-low sulfur (15 ppmw) fuel, and a Dash-8 locomotive operating on a fuel with a sulfur content between 200 ppmw and 500 ppmw. Sound measurements will be taken with and without the control equipment to determine the extent of noise reduction due to the control equipment (sound measurements added during the project). Emissions testing will be conducted according to a test protocol developed for this project. The test protocol should prescribe accepted test methods appropriate to the pollutants being measured. The protocol will be reviewed by the air districts, CARB, and EPA. The testing will be conducted on the locomotive before the control equipment and upon exit from the control equipment and will determine emissions on a concentration and mass basis.	**Overall control efficiency:** ☑ **Accomplished** **Overall capture efficiency:** ☒ **Partially Accomplished:** Complete capture efficiency determination will require assessment of emission capture system functionality. Proof-of-concept project only tested one locomotive at a time in either motionless or short (50 feet) distance motion. **Testing according to protocol:** ☑ **Accomplished** (but note that emissions sampling at the locomotive stack was of questionable value)
Objective 2: Demonstrate the Attachment Scheme Between the Locomotive and the Stationary Control Equipment: Since a rail yard is a busy place where efficiency of operations is important, the attachment of the emissions control equipment to the locomotive must be quick, simple, and safe to the operating personnel. The operation of the ALECS must absolutely not impede the fluidity of normal railroad operations in any manner. Attachment, detachment, and capture efficiency will be demonstrated on locomotives with one and two emission stacks. During the emissions testing phase of this project, multiple attachments and disconnects shall be performed to demonstrate this capability. Rail yard personnel shall be given a chance to operate the attachment controls.	**Demonstrated on locomotives with one and two emission stacks:** ☑ **Accomplished** **Multiple attachments and disconnects:** ☑ **Accomplished** **Rail yard personnel given chance to operate the attachment controls:** ☒ **Not Accomplished**

Table 29. Summary of Project Objectives and Accomplishments (concluded)

OBJECTIVE	ACCOMPLISHED?
Objective 3: Demonstrate the Capability of Some Locomotive Movement While Connected to the Control Equipment: One of the design features of the ALECS is to allow movement of the locomotive along the track for a prescribed distance while connected to the emissions control equipment. During the emissions testing, some portion of the testing on each locomotive shall be conducted with the locomotive connected to the stationary control equipment and the locomotive moving to demonstrate this capability while fully capturing the exhaust from the engine in the locomotive.	**Testing while motionless and while moving:** ☑ **Accomplished**
Objective 4: Develop Improved Information on Capital Cost, Operating Procedures, and Operating Costs: The underlying purpose of this proof-of-concept test project is to provide information on performance, operation and cost of using stationary emissions control equipment to treat locomotive exhaust in rail yards that will enable the railroad and equipment suppliers to make business decisions on moving forward in deploying this type of equipment. During the installation and operation of the ALECS, information shall be collected and recorded that will enable capital and life cycle costs to be generated. Rail yard facility requirements for infrastructure and support utilities will be defined. These cost estimates shall be documented in the final report. Railroad personnel shall be instructed on operation and maintenance of the ALECS during the proof-of-concept project, and will provide to the PCAPCD estimates for all costs for impacts to yard or system operations (either capital or operating) are included in the final accounting. These cost estimates will be included in the project final report. The ALECS to be used for this proof-of-concept test is borrowed from another project where the equipment size was optimized for another application. As part of this objective, the cost of equipment appropriately sized and ALECS designed to serve the J. R. Davis Rail Yard will be estimated**.**	**Information collected to estimate cost.** **Rail yard infrastructure defined:** ☑ **Accomplished** **Cost estimates shall be documented:** ☑ **Accomplished** **Railroad personnel instructed on operation and maintenance of the ALECS:** ☒ **Not Accomplished** **Railroad provides estimates for all costs:** ☑ **Accomplished** **Cost estimates for rail yard impacts included in the project final report:** ☒ **Not Accomplished** **Cost of appropriately sized equipment:** ☑ **Accomplished**
Objective 5: Document Test Results and Project Findings in a Final Report: Since this proof-of-concept test project has, as one purpose, the generation of information on performance and operation of the ALECS sufficient to allow railroads to make business decisions on use of this stationary control equipment on their rail yards, the project results will be documented in a final report. The final report will include, as a minimum, details of the locomotives tested, configuration of the test setup, test equipment, test conditions, and test methods, logistic and operation issues identified during project implementation, and emission (and noise) test results before and after the control equipment.	**Information sufficient to allow railroads to make business decisions:** ☒ **Not Accomplished** **The final report details on test:** ☑ **Accomplished**

Table 30 summarizes the overall average pollutant control efficiencies of ALECS. The range of estimated emission reductions based upon two scenarios are presented in Table 31. ALECS installation in a rail yard is expected to yield emission reductions between the two assumptions, depending on the specific application.

Table 30. Summary of Pollutant Control Efficiencies

	NO_x	THC	PM	SO_2
Overall Average Control Efficiency[1]	97.8%	62.7%	92.1%	97.3%

[1] ALECS proof-of-concept test at Roseville rail yard

Table 31. Range of Estimated Emission Reductions (tons/yr)

	NO_x	HC	PM
Mixed Loads Tier 0 Emissions	83.4	8.44	2.53
Idling Only Tier 2 Emissions	40.0	2.49	1.29

The fully loaded total initial capital cost of the ALECS (for an estimated 12 bonnet system) is $8,680,126 with an annual operational cost estimate of $899,926 (not including the recurring $86,146 catalyst replacement every 5 years).

The total weighted controlled PM, NO_x, and THC emissions reduced over the 20 year life of ALECS is estimated to range from 1,365 tons to 3,449 tons. The resulting cost effectiveness ranged between $18,437/ton in the all idling mode to $7,297/ton of weighted pollutant reduced in the mixed mode of a combination of locomotives at idle and at higher loads.

Noise measurements made with, and without the bonnet attached to the locomotive, yielded noise reductions of 5.3 to 6.8 decibels, representing noise energy reductions of 70 to 79 percent.

7.2 Next Steps

While the ALECS proof-of-concept test mostly met the project objectives and yielded valuable information in confirming that the system is capable of capturing and treating locomotive emissions, there remains additional work in selected areas in order to support fielding a system in a rail yard with the anticipation of maximizing the ALECS potential in cost effective emissions reductions. The next steps towards possible implementation of the technology in a working rail yard are depicted in Figure 31, which identifies those areas where additional work is needed. It is envisioned that these steps, which may be viewed as pathways or tracks that should be followed in parallel, will yield more refined information in order to make implementation decisions. These tracks include public policy leadership, identification of a specific rail yard site for the initial system deployment, further technical demonstration, development of financial mechanisms for the funding of systems, and community benefits.

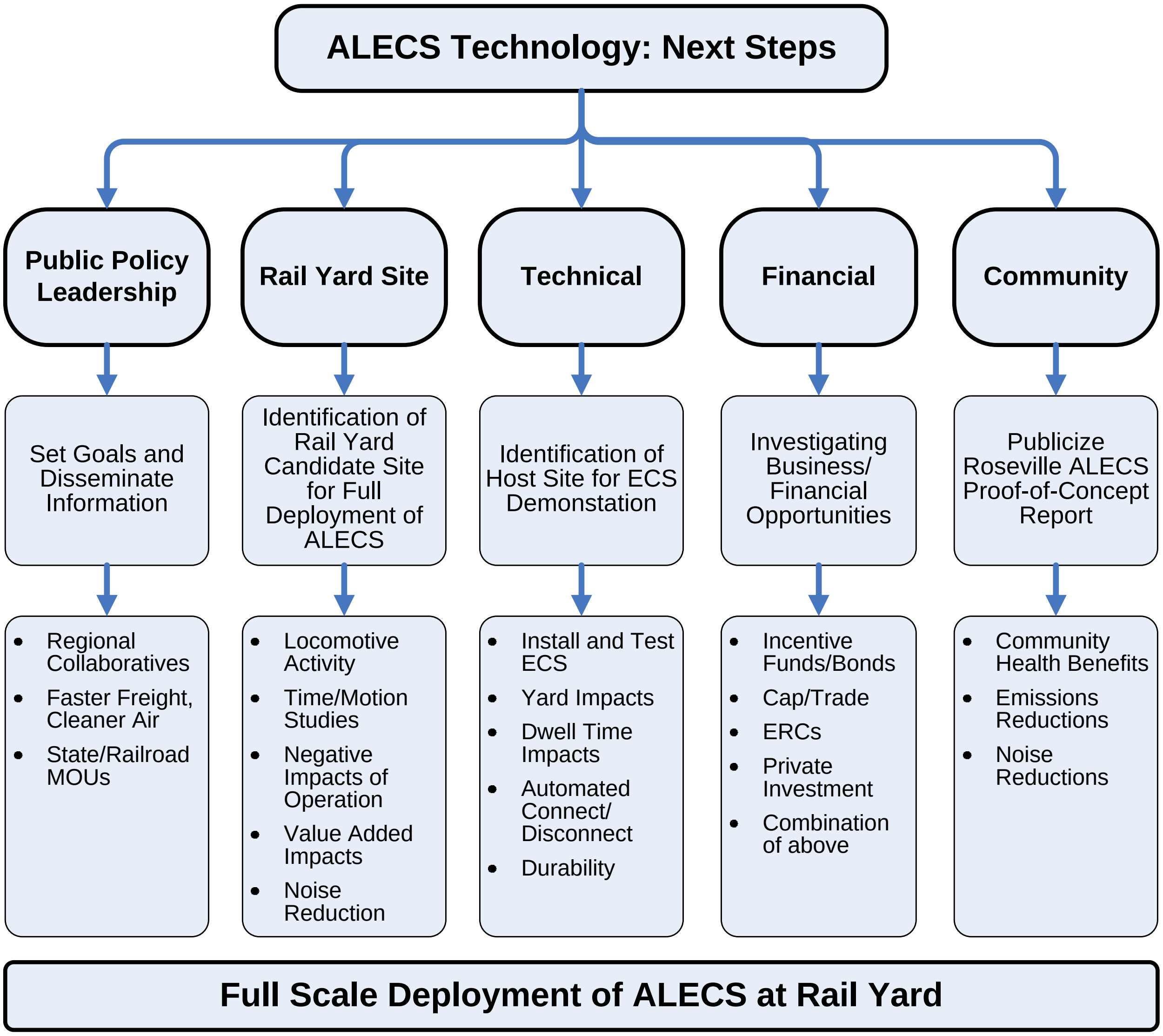

Figure 31. Next Steps Pathways

7.2.1 Public Policy Leadership

Government encouragement of utilization of this type of control equipment to reduce criteria and hazardous emissions from rail yards can have a positive effect on the railroad companies. Public agencies can encourage use by setting goals through regional diesel collaboratives and disseminating information in conferences like Faster Freight and Cleaner Air. State environmental agencies can encourage proliferation of this technology through agreements with the railroad companies which among other strategies to reduce rail emissions, includes implementation of the ALECS technology. Local air districts that have concerns over rail yard emissions in their territory can develop agreements with the railroad companies to utilize this technology in appropriate locations.

7.2.2 Rail Yard Site

Identification of the specific location of the initial full-scale system installation is critical. The operational experience of the first system will greatly influence the possibility of the installation of additional systems. Key considerations in choosing the location of the system in the rail yard are a continuous supply of an adequate number of running locomotives to keep the capacity of the ALECS fully utilized while not requiring additional effort from rail yard workers to route locomotives to this location.

It is recommended that the initial system deployment be at the J. R. Davis Rail Yard in Roseville, California. Some rail yard personnel are somewhat familiar with the ALECS and there are a number of potentially suitable sites for the system. Figure 32 is an aerial view of the rail yard with a number of potential sites labeled. Figure 33, Figure 34, and Figure 35 are photographs of potential ALECS locations in the diagnostics area of the diesel shop, the ready tracks, and the sanding station.

Figure 32. Aerial View of Potential ALECS Locations

Figure 33. Diagnostics Area of Diesel Shop

Figure 34. Ready Tracks

Figure 35. Sanding Stations

UPRR will need to perform an analysis of candidate locations to determine if current locomotive activity can support a high utilization factor for an ALECS at that location. Parameters to be considered are numbers of operating locomotives at the site over time, quantity of idle, diagnostic, and load testing conducted at that site, and typical mix of locomotive types using the site. For the more promising sites, UPRR should perform an in-depth time/motion study of the activity at the site and identify any operational changes that could improve the efficiency of the site operation using the ALECS. As part of these studies, UPRR should consider opportunities to use the capabilities of the ALECS to improve their rail yard efficiency and operations and reduce locomotive maintenance dwell time. Examples of these capabilities would be to utilize the emissions measurement function of the ALECS to aid in engine diagnostics, use particulate matter measurements to identify engines that have excessive visual emissions and need repair (higher levels of PM may be an indication of leaky fuel injectors), and perform high power load testing and diagnostics under the ALECS bonnets to reduce noise. Noise is a nuisance issue with the residential neighbors in Roseville.

7.2.3 Technical

Along a technical track, the proof-of-concept test program identified that additional demonstration is required for a redesigned trolley/bonnet and overhead manifold concept capable of hosting multiple locomotives. While a full-scale ALECS would include 12 trolley/bonnets and about 1,200 feet of overhead structure and collection manifold, it is recommended that approximately a one-half size subsystem should be installed and tested. The test system would not include the emissions control components, just the emissions capture subsystem. Any potential user of this system would require to see this demonstrated to evaluate automated connect/disconnect of multiple locomotives, impacts on the yard workflow and efficiency, and durability of the ECS components. This demonstration is estimated to cost $1.5 million. Funding for this demonstration is an open issue at this time. If possible, this demonstration should be conducted at a rail yard site with high potential to host a permanent ALECS installation.

7.2.4 Financial

There may be a number of options for funding the installation of ALECS systems in rail yards. In addition to the obvious option of railroad capital investment, there may be opportunities for incentive funds from state programs, private investment, cap/trade programs, and emission reduction credits. These funding options should be explored in parallel with the other next steps tracks.

Emission reduction credit (ERC) generation is an interesting funding option. Currently, the rules of most, if not all, California air districts are not structured in a way that would allow this type of credit generation. However, the ALECS can likely meet the general criteria for establishing ERCs. Noteworthy are the facts that the emission reductions from an ALECS are real and surplus. Surplus generally means that the emission reductions are not mandated by law, regulation or planned into the SIP; and the historical emissions are included in the state inventory. The California Air Pollution Control Officers Association (CAPCOA) has initiated an effort to develop protocols for non-traditional ERC generation. Currently, three pilot projects are proceeding, including one that includes the ALECS concept. PCAPCD is taking the lead on the rail yard stationary equipment ERC protocol development. EPA, CARB, and the air districts are involved in this effort. The goal of the effort is to produce a model protocol, approved by EPA and CARB, that can be adopted as a rule by the air districts. In the Roseville area, a number of industrial companies have expressed interest in possibly funding installation of an ALECS in order to have a claim on the ERCs generated.

Private investment and ownership of a system is another financial model that has potential to fund the installation of an ALECS. In this model, a third party company would own and maintain the system and lease its use to the railroad.

7.2.5 Community

Communities that are adjacent to rail yards are becoming more aware of the potential health impacts of rail yard emissions and more active in complaining of noise from the yard. In California, through the agreement between the major railroads and the California Air Resources Board, health risk assessments will soon be made public for the larger yards in the state. A community track of next steps should publicize the benefits of the ALECS in reducing diesel particulate emissions (and associated reduction in health risk) and the potential noise reduction of using the system on locomotives being tested at high power.

8. List of Acronyms

ACTI	Advanced Cleanup Technologies, Inc.
ALECS	Advanced Locomotive Emission Control System
CAPCOA	California Air Pollution Control Officers Association
CARB	California Air Resources Board
CCS	Cloud Chamber Scrubber (subsystem of ETS)
CEMS	Continuous Emission Monitoring System
CO	Carbon Monoxide
CO_2	Carbon Dioxide
Cp	Total Equipment Costs
DF	Deterioration Factor
ECS	Emissions Capture Subsystem
EF&EE	Engine, Fuel, and Emissions Engineering, Incorporated
EIB	Emissions Intake Bonnet
EMD	General Motors Electro-Motive Division
EPA	U.S. Environmental Protection Agency
ERC	Emission reduction credit
ETS	Emissions Treatment Subsystem
F	Fahrenheit
ft3	Cubic Feet
gal	Gallons
GE	General Electric
hr	Hour
ID	Induced Draft
ISO	International Standards Organization
kWh	Kilowatt Hours
lb	Pounds
mcf	Thousand Cubic Feet
MMBtu	Million British Thermal Units
MOU	Memorandum of Understanding
N_2O	Nitrous Oxide
NH_3	Ammonia
NO	Nitric Oxide
NO_x	Oxides of Nitrogen
O_2	Oxygen
OCU	Operational Control Unit of the ETS
PCAPCD	Placer County Air Pollution Control District
PCC	Preconditioning Chamber (subsystem of the ETS)
PEC	Purchased Equipment Cost
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter less than or equal to 2.5 microns
PM_{10}	Particulate Matter less than or equal to 10 microns
ppm	parts per million
RAVEM	Ride-Along Vehicle Emissions Measurement system
SCAQMD	South Coast Air Quality Management District
scfm	Standard Cubic Feet per Minute

SCR	Selective Catalytic Reduction
SMAQMD	Sacramento Metropolitan Air Quality Management District
SO_2	Sulfur Dioxide
SO_x	Oxides of Sulfur
THC	Total Hydrocarbons
TICI	Total Initial Capital Investment
UPRR	Union Pacific Railroad Company

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Appendix A. Test Plan

J.R. DAVIS RAILYARD

ADVANCED LOCOMOTIVE EMISSION CONTROL SYSTEM (ALECS) DEMONSTRATION PROJECT

EMISSION TESTING PROTOCOL
VERSION 2.1
MAY 25, 2006

Prepared by
Christopher Weaver, P.E.
Engine, Fuel, and Emissions Engineering, Inc.
Rancho Cordova, CA

1. INTRODUCTION

The Union Pacific Railroad's J.R. Davis Railyard has been determined to be a significant emissions source for diesel particulate matter (PM) and other toxic air contaminants related to locomotive emissions. An agreement between the Placer County Air Pollution Control District (APCD) and the Union Pacific Railroad Company includes a mitigation plan for reducing diesel particulate emissions from the railyard. This plan includes consideration of stationary air pollution control equipment to capture and treat emissions from stationary locomotives in the railyard while idling or undergoing engine load tests. To carry out this part of the plan, the APCD has initiated a project to demonstrate the Advanced Locomotive Emission Control System (ALECS).

The ALECS demonstration is a public-private collaborative project involving many parties, including the APCD, U.S. Environmental Protection Agency, Sacramento Metropolitan Air Quality Management District, Union Pacific Railroad, Advanced Cleanup Technologies Inc., the South Coast Air Quality Management District (AQMD), the California Air Resources Board, and the City of Roseville. Engine, Fuel, and Emissions Engineering, Inc. (EF&EE) has been tasked with carrying out the emissions measurements under a contract with the South Coast AQMD.

The ALECS is a system designed to control emissions from locomotives by capturing the exhaust stream from their engines and treating it to remove most harmful pollutants. The system includes a set of stationary emissions control equipment connected to an articulated bonnet or hood. The bonnet is designed to capture locomotive exhaust, delivering it to the ground-mounted emission control system by means of a flexible duct. The bonnet or hood remains attached while the locomotive is moving along the track to the extent of the flexible duct.

The emissions control equipment consists of a sodium hydroxide wash to remove sulfur dioxide (SO_2), a dual chamber cloud chamber scrubber for particulate matter (PM) removal, followed by a Selective Catalytic Reduction (SCR) reactor using urea as the ammonia source for oxides of nitrogen (NOx) reduction. The demonstration system is designed to treat exhaust flows between 2,000 and 12,000 standard cubic feet per minute (scfm).

1.1 OBJECTIVES

The objectives of the test program are:

- To measure and document the effectiveness of the ALECS system in controlling locomotive emissions of diesel particulate matter (PM), oxides of nitrogen (NOx) and other pollutants of concern under typical railyard operating conditions;
- to assure that the emission control process does not generate excessive amounts of other pollutants, such as ammonia; and
- to quantify the water and chemical consumption, operating costs, and waste generated by the ALECS system.

1.2 OVERVIEW OF THE TEST PROGRAM

The test program will include emission measurements at three locations: in the locomotive stack(s), at the inlet to the ground-mounted emission control system, and at the outlet from the emission control system**.** The effectiveness of the ALECS emission control system will be determined by comparing the mass emissions measured both at the locomotive stack and at the inlet to the emission control system with those measured at the system outlet to the system. Comparing the emissions measured at the locomotive stack to those at the inlet will make it possible to identify any effects on pollutant mass or characteristics due to the overhead manifold system.

The test program will include two locomotives, each of which will be operated in a defined sequence of test modes. Each of the test sequences will be repeated three times. Testing is scheduled to begin July 31, and will take two weeks (eight testing days, plus setup time) to complete.

Pollutants to be measured include particulate matter PM, NOx, CO, SO_2, and total hydrocarbons (THC). The test procedures for these pollutants will follow ISO standard 8178, which is extremely similar to the steady-state diesel testing procedures defined by the U.S. EPA and the California ARB. Ammonia (NH_3) and nitrous oxide (N_2O) will be measured only at the inlet and outlet of the emission control system, generally following the procedures specified in EPA Method 320.

2. LOCOMOTIVES TO BE TESTED

The locomotives to be tested are a Electromotive Division (EMD) GP 38 and a General Electric B39-8 or C39-8. The GP 38 is used primarily for switching and local service. It is equipped with a two-stroke, Roots-blown, EMD 16-645E engine. The engine has 16 cylinders and is rated at 2000 tractive horsepower. It has two exhaust stacks, fed by the front eight and rear eight cylinders, respectively. The maximum exhaust flow rate at full power approximately is 6,000 scfm.

The GE Dash-8 series locomotives are used primarily for line-haul freight service, and are equipped with four-stroke, turbocharged, GE FDL-16 engines. These 16-cylinder engines produce 3900 tractive horsepower, and discharge exhaust through a single rectangular stack connected directly to the turbocharger outlet. The maximum exhaust flow rate at full power is approximately 12,000 scfm.

The Union Pacific Railroad will be responsible for supplying the two locomotives for the test, and for ensuring that they are continuously available during the scheduled test period. Both locomotives will need to be available and have full tanks of fuel on July 21. The GE locomotive will then be needed from July 31 to August 5 for testing, and the GP 38 from August 7 to 11.

3. TEST FUEL

The test fuel for the GP 38 will be an ultra-low sulfur diesel fuel meeting ARB regulations for sulfur and aromatic content, as specified in 13 CC 2281 and 2282. The sulfur limit is 15 parts per million w/w, and the limit on aromatic content is 10% v/v unless the fuel is produced according to an approved alternative formulation. The test fuel for the Dash-8 will be a diesel fuel that is actually supplied to Union Pacific line-haul locomotives outside California, and that has a sulfur content between 200 and 500 ppm w/w.

The Union Pacific Railroad will be responsible for ensuring that the locomotives' tanks contain an adequate volume of the appropriate fuel: 3000 gallons for the Dash-8 and 2500 gallons for the GP 38 (this is double the estimated fuel consumption in the test program).

Table 1 shows the analyses to be performed on each fuel sample. EF&EE will collect fuel samples from each locomotive's fuel tank in time for the analyses to take place before the start of emission testing. The fuel tanks will then be sealed and labeled to ensure that fuel is not added to the tanks by mistake.

Table 1: Fuel analyses

ASTM Method	Description
D 2622-94	Sulfur content
D 5291	Carbon-hydrogen-nitrogen elemental content

4. TESTING SCHEDULE

The emission testing calendar is shown in Table 2. Fuel sampling will take place on July 21 to ensure that the results are available before the emission test equipment is installed on July 31. Steady-state emission testing on the Dash 8 will take place August 1 and August 3 to 4, to accommodate the media day scheduled for August 2. These tests will be conducted with the locomotive stationary, and the engine loaded using the "self test" capability of the dynamic brake system.

The test sequence for each day of stationary testing is shown in Table 3. The sequence provides for preconditioning the locomotive engine, and then measuring at idle, Notch 5, and Notch 8. The effects of "souping" (PM buildup in the exhaust system at light loads) will be determined by operating at Notch 3 for half-hour periods following each of the four-hour test periods at idle. The daily test sequence is 10 hours long.

Moving tests, with the locomotive moving back and forth within a restricted section of track, will be conducted on the day following the stationary tests. The schedule for these days is shown in Table 4. Three tests will be conducted, each one-half hour long. The limited length of these tests is based on considerations of operator fatigue, since the engineer will be constantly changing the throttle and reverser positions to move the locomotive back and forth on the 50 foot test section.

Table 2: Emission testing calendar

Date	Activity
July 21	Sample fuel on both locomotives
	Weekend
July 31	Set up emission test equipment for Dash-8
August 1	Stationary test Dash-8
2	Media day
3	Stationary test Dash-8
4	Stationary test Dash-8
5	Moving test Dash-8, remove emission test equipment
	Sunday
August 7	Set up emission test equipment for GP38
8	Stationary test GP38
9	Stationary test GP38
10	Stationary test GP38
11	Moving test GP38, remove emission test equipment

Table 3: Sequence of test modes and testing schedule for stationary test days

Step	Purpose	Throttle	Hours	Cumul. Hours	Test Activity
1	Precondition	3	0.5	0.5	Install filters/check instruments/calibrate
2	Souping baseline	3	0.5	1.0	Measure emissions
3	Stabilize	1	0.5	1.5	Change filters/calibrate
4	Idle Test	1	4.0	5.5	Measure emissions
5	Filter Change	1	0.5	6.0	Change filters/calibrate
6	Souping test	3	0.5	6.5	Measure emissions
7	Stabilize	5	0.5	7.0	Change filters/calibrate
8	Notch 5 Test	5	1.0	8.0	Measure emissions
9	Stabilize	8	0.5	8.5	Change filters/calibrate/refill day tank
10	Notch 8 Test	8	1.0	9.5	Measure emissions and noise
11	Cool down	Idle	0.5	10.0	Remove filters/refill day tank

Table 4: Sequence of test modes and testing schedule for moving test days

Step	Purpose	Throttle	Hours	Cumul. Hours	Test Activity
1	Precondition	3	0.5	0.5	Check/warmup instruments
2	Stabilize	Idle	0.5	1.0	Install filters/calibrate
3	Moving Test #1	Var	0.5	1.5	Measure emissions
4	Filter Change	Idle	0.5	2.0	Change filters/calibrate
5	Moving Test #2	Var	0.5	2.5	Measure emissions
6	Filter Change	Idle	0.5	3.0	Change filters/calibrate
7	Moving Test #3	Var	0.5	3.5	Measure emissions
8	Change locomotive	Off	2.0	5.5	Remove RAVEM

Five emission tests will be conducted during each of the three days of stationary testing on each locomotive, and three during the one day of moving tests. Thus, a total of 18 emission tests will be conducted on each locomotive.

5. PARTICULATE EMISSION MEASUREMENTS

PM emissions before and after the ALECS system will be measured according to the isokinetic partial flow dilution method specified as one option under ISO 8178. Raw exhaust will be extracted from the exhaust conduit using EF&EE's RAVEM isokinetic sampling system. In the RAVEM system, isokinetic sampling conditions are maintained by adjusting the flow rate of raw exhaust through the sample probe until the static pressures inside and outside the probe are equal. This adjustment is performed continuously in real time by the RAVEM system, allowing it to follow transient changes in exhaust flow rate.

The raw exhaust from the sample probe will pass through a 250 ^{o}C heated sample line to the RAVEM dilution tunnel. Dilution air will pass through a prefilter and a HEPA filter before entering the tunnel. Dilute exhaust containing PM will be drawn from the dilution tunnel through a PM10 cyclone (URG 2000-30ENB), and then through filters of Teflon film or Teflon coated borosilicate glass in accordance with ISO 8178 and 40 CFR 1065. The rate of exhaust extraction will be controlled to a constant value of 16.7 standard liters per minute by a mass flow controller (Alicat MC 50 slpm) using the laminar flow principle. The dilution flow rate in the CVS will be adjusted to ensure that the gas temperature at the filter face is no more than 52 ^{o}C. Blank filters exposed only to dilution air will be collected along with each sample. In addition to correcting for any background PM that makes it past the HEPA filter, subtracting the change in weight of the blank filter from the sample weight also automatically corrects for the effects of small differences in weighing chamber temperature, humidity, and atmospheric pressure.

ISO 8178 specifies the use of both primary and backup filters for each sample, while 40 CFR 1065 specifies the use of a single filter mounted in a filter cassette. Up to this point, EF&EE has used the ISO 8178 method, but the 40 CFR 1065 method appears advantageous in reducing the risk of filter damage during handling. During May, 2006, EF&EE will experiment with the Part 1065 method, and will recommend one or the other approach to the testing committee.

Separate RAVEM samplers will be used to sample the exhaust at the locomotive stack, at the inlet to the ALECS system, and in the outlet stack from the ALECS system. A total of 6 PM samples will be collected for each of the 36 emission tests – three PM samples and three blanks. Thus, a total of 216 pre-weighed filter cassettes (or pairs of pre-weighed filters, if the Committee opts to retain primary and backup filters) will be required.

At the request of the ARB Monitoring and Laboratory Division, the RAVEM sampler at the ALECS system inlet will be modified to allow a second PM sampler to be connected. The additional sampler will be provided by ARB, and will be used to collect 47 mm Teflon filters for characterization of the hydrocarbon content of the PM in an effort to identify potential marker chemicals for PM source apportionment.

6. GASEOUS EMISSION MEASUREMENTS

Gaseous emission measurements will include oxides of nitrogen (NOx), total hydrocarbons (THC), carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), oxygen (O_2), ammonia (NH_3), and nitrous oxide (N_2O). Table 5 summarizes the gas concentration measurement techniques to be used. Except for the FTIR measurements, all of the analyzers and measurement techniques will comply with ISO 8178 specifications.

The ALECS system itself includes continuous emission monitoring systems for NOx, SO_2, and O_2 at both the inlet and the outlet, and for THC and NH_3 at the outlet only. These analyzers are configured for raw gas sampling, which means that the results must be combined with a measured exhaust gas flow rate to calculate the total mass of emissions. The exhaust flowrate measurement is provided by venturis located in both the inlet and outlet sections.

Table 5: Gas concentration measurements by sampling location

	Locomotive Stack	ALECS Inlet	ALECS Outlet
NOx	Dilute**	Raw+/Bag**	Raw+/Bag**
THC		Raw	Raw+
CO	Dilute**	Raw/Bag**	Raw/Bag**
CO2	Dilute**	Raw/Bag**	Raw/Bag**
SO2	-	Raw+	Raw+
NH3	-	FTIR*	FTIR*/CLD+
N2O	-	FTIR*	FTIR*
Gas Flow	-	Venturi+	Venturi+

*Time-shared between inlet and outlet
+ALECS system equipment
**RAVEM system equipment

The RAVEM sampling systems perform exhaust gas dilution according to the constant volume sampling (CVS) principle, so that the pollutant concentration in the dilute gas is proportional to the pollutant mass flow rate in the exhaust. The RAVEM system located at the locomotive stack will be configured to measure dilute NOx, CO, and CO_2 continuously, as well as collecting integrated bag samples of the dilute gas to be analyzed after the end of each test. The RAVEM samplers at the ALECS inlet and outlet will collect integrated bag samples only, to be analyzed at the end of each test by the analyzers of the first RAVEM system. The results will be used to calculate a carbon balance check for the PM sampling. The dilute NOx results from these bags will also be available as a backup to NOx measurements of the ALECS CEMS systems.

The ALECS system includes an analyzer to measure ammonia emissions by oxidizing the ammonia to NOx, measuring NOx by CLD, and subtracting the NOx already present in the sample gas (determined by another CLD analyzer). The accuracy of this method potentially suffers from the difference-of-large-numbers problem. A more accurate measurement of ammonia emissions, as well as N_2O, can be obtained by Fourier Transform Infrared (FTIR) analysis. EF&EE will apply its MIDAC FTIR analyzer system to measure NH_3 and N_2O concentrations in the raw gas at both the ALECS inlet and outlet. Heated sample lines will bring gas samples from each source to a heated valve/filter combination next to the FTIR unit. The system will measure emissions primarily from the ALECS outlet, but will be switched to measure inlet emissions several times during each steady-state test.

Prior to beginning the emission testing, 10-point linearity checks will be performed on all gas analyzers using EF&EE's Environics 4000-series precision dilution system. The FTIR system will be checked using the diesel exhaust procedure specified in the Water Transit Authority testing protocol. Zero and span calibrations will be performed on each gas analyzer after each emission test.

7. FUEL CONSUMPTION MEASUREMENTS

Fuel consumption will be measured during each emission test as a check on the accuracy of the emission measurements. If these measurements are accurate, the sum of the carbon contained in the CO_2, CO, HC, and PM emissions should be equal to the mass of carbon in the fuel consumed.

Fuel consumption by the locomotive engine will be measured using a 250 gallon "tote" positioned on a pallet scale as a day tank. EF&EE staff will install three-way valves in the locomotive's fuel supply and return lines to allow these to be switched between the locomotive fuel tank and the day tank. Switching both supply and return lines to the day tank will mean that the change in weight of the day tank is equal to the fuel consumed by the engine. The day tank will be filled (and refilled, when necessary) from the locomotive fuel tank by running the electric fuel pump with the supply line connected to the locomotive tank, and the return line connected to the day tank.

Since locomotive fuel systems can contain voids and air pockets that affect the fuel balance during startup, the system will be stabilized while running on the day tank before beginning each emission test. The weight of fuel in the day tank will be recorded at frequent intervals automatically during the test.

Since the returned fuel picks up considerable heat in the engine, it will be necessary to cool it before returning it to the day tank. Otherwise, the relatively small volume of fuel in the day tank could become hot enough to affect the emissions results (hotter fuel is less viscous, atomizes and ignites more readily). Cooling will be achieved by running it through a fuel-to-air heat exchanger.

8. NOISE MEASUREMENTS

Locomotive noise measurements will be performed using a hand-held noise meter. Emission measurements will be made using the "slow" response function of the meter, at a point 30 meters away from the locomotive along a line passing through the center of the locomotive perpendicular to the track, and will follow the requirements of 40 CFR 201.20 et seq. as closely as possible, given the conditions of the test site. Notch 8 noise measurements will be made within 15 minutes of the end of the test. Background noise measurements will be made in the same location as soon as possible after the locomotive engine has cooled down from Notch 8 operation and been turned off.

Baseline noise tests at Notch 8 will be made once the locomotive is in place on the test track, but prior to attaching the locomotive exhaust to the ALECS system. The baseline noise test will be repeated at the end of testing, after disconnecting the locomotive from the ALECS system and before moving it from the test track.

9. USE OF WATER, ELECTRICITY, AND CONSUMABLES

9.1 Solid waste characterization

The solid waste (sludge) is collected in filter bags at two locations in the ALECS system: at the discharge of the Preconditioning Chamber (PCC), and at the discharge of the Cloud Chamber Scrubber (CCS). Total PM mass will be determined by weighing the bags after use. The variation in bag weight is negligible in comparison to the weight of particulate each will collect, so an average bag weight will be used for the "before" weight. The bags will be hung to dry before weighing in order to allow water retained in the bag fabric to evaporate.

Filter bags will be changed between tests for the two locomotives.

Samples of the collected sludge will be taken and sent to an outside lab for the following analyses:

- Oil & grease (Refer to EPA Method 413.1)
- Heat content (Btu content)
- ICP (Inductively Coupled Plasma) tests for metals such as Cu, Ni, Pb, Cr, and Zn (Refer to EPA Method 200.7)
- IC (Ion Chromatography) tests for anions such as Cl, F, NO2, NO3, and SO4 (Refer to EPA Method 300.0)
- TPH (Total Petroleum Hydrocarbons) (Refer to EPA Method 418.1)

9.2 Wastewater (blowdown) characterization

Rotometers will be adjusted to set the blowdown for the PCC and the CCS. These rates will be set to maintain the conductivity within specified limits. The blowdown rate will be a function of the sulfur content in the exhaust gas stream, and will be experimentally determined. The total blowdown for any period of time will be determined by measuring the level in the wastewater tank.

Properties of the water in the recirculation loops will be monitored as part of the control system, and will be used in part to determine the blowdown. These properties are:

- pH
- conductivity

Samples of wastewater will be collected for analysis prior to starting the test, at the changeover from the Dash 8 to the GP 38, at the end of the test, and periodically as deemed necessary during the test program. The analysis will include:

- suspended solids (Refer to EPA Method 160.2)
- dissolved solids (Refer to EPA Method 160.1)
- pH (Refer to EPA Method 150.1)
- conductivity (Refer to EPA Method 120.1)
- IC anions (Refer to EPA Method 300.0)
- ICP metals (Refer to EPA Method 200.7)
- Oil & grease (Refer to EPA Method 413.1)

9.3 Water usage

The inlet water flow rate will be intermittent. When the need for makeup water is detected by sensors in the system, a solenoid valve will be opened for a fixed, preset length of time to admit water to the system. The flow rate during the time the valve is open will be determined one time by physically measuring the amount of water that flows during one valve-open period. The control system will log the number of valve openings during system operation, and from these two quantities the total inlet water will be determined.

9.4 Electricity Use

Electricity use will be the sum of two parts as far as measurement is concerned. There is a base load, which is the usage for basic system functions such as instrumentation and controls, and a variable load, which is the power consumption of the various motors that drive pumps and fans.

The base load will be measured with a clamp-on meter. This will be an essentially constant quantity.

By far the majority of the power used is consumed by the pump and fan motors. These are all driven by variable frequency drives controlled by the control system, and the power consumption of each individual motor is logged by the control system. These are real time, continuous measurements and will form part of the output data. The sum of these motor powers and the base power will give the total power consumption.

9.5 Urea Consumption

The urea is introduced into the exhaust gas stream by three separate injection lances. Each lance has its own metering pump and flow transmitter. These flow data will be logged by the control system.

9.6 NaOH Consumption

Sodium hydroxide is fed into the system by constant volume pumps that are either on or off, and the feed will be controlled by the pH of the recirculating water. These pumps will initially be adjusted so that they will be running 60% to 80% of the time with the maximum expected sulfur load in the exhaust gas.

Following this initial adjustment, the pumps will either be on or off. The flow rate during the on state will be determined by a physical measurement of volume over a given time. This will give us the flow rate in gallons per minute of on-time.

The control system will log the on-time, both instantaneous and cumulative, and this will be used to determine the total NaOH usage.

Appendix B. EF&EE Emission Test Report

ENGINE, FUEL, AND EMISSIONS ENGINEERING, INCORPORATED

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March 27, 2007

Don Duffy
Placer County Air Pollution Control District
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Dear Don:

As you requested, this letter responds to two of the comments by the Union Pacific Railroad on our report, Emission Measurements on the Advanced Locomotive Emissions Control System at the J.R. Davis Rail Yard . These were received too late to be addressed in the final report.

One comment concerned the recommendation in the Executive Summary that "… locomotives should first be operated at higher load with the ALECS system in place after a prolonged period of idle or Notch 1 operation." Union Pacific commented that "The comment about the use of the ALECS following prolonged idle should be deleted, as it is not accompanied by an analysis of whether such an operating mode is practical, or what the emissions might be associated with moving a locomotive from another portion of the railyard to the location where the ALECS might be installed. At page 19, this recommendation is framed as continuing to leave the locomotive connected to the ALECS for a few minutes after a prolonged idle, and not as connecting a locomotive to ALECS after a prolonged idle."

We disagree with this comment. The sentence in the Executive Summary simply summarizes the recommendation on Page 19. Nothing in our report should be read as recommending that locomotives be moved from another location to the ALECS system *after* a prolonged idling period. Instead, our understanding of the potential use of the ALECS system is that locomotives would be moved to it and connected prior to *beginning* a prolonged period of idle.

In another comment, Union Pacific requested that we note that no emission tests were performed at idle, and that all references to idle in our report should be changed to Notch 1. This is correct. Although it was originally planned that testing would be carried out at idle, concerns about the minimum design exhaust flow rate for the ALECs system led to the test condition being changed to Notch 1. In several places in the final report, it is stated incorrectly that the test locomotive was operating at idle. All such references should be read as referring to "Notch 1" instead.

I hope that this will clarify any confusion on these issues.

Christopher S. Weaver, P.E.
President

EMISSION MEASUREMENTS ON THE ADVANCED LOCOMOTIVE EMISSION CONTROL SYSTEM AT THE J.R. DAVIS RAIL YARD

FINAL REPORT

February 26, 2007

submitted to:
Technology Advancement Office
South Coast Air Quality Management District
and
Placer County Air Pollution Control District

ENGINE, FUEL, AND EMISSIONS ENGINEERING, INCORPORATED

EMISSION MEASUREMENTS ON THE ADVANCED LOCOMOTIVE EMISSION CONTROL SYSTEM AT THE J.R. DAVIS RAIL YARD

Final Report

February 26, 2007

Submitted to
Technology Advancement Office
South Coast Air Quality Management District
21865 East Copley Drive
Diamond Bar, CA 91765
Contract No. 06184

Placer County Air Pollution Control District
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EXECUTIVE SUMMARY

The Union Pacific Railroad's J.R. Davis rail yard in Roseville, California, is a major center for locomotive maintenance, as well as for assembling and reassembling trains of freight cars. Locomotive operations at the rail yard have been determined to be a significant source of emissions of diesel particulate matter (PM) and other pollutants. An agreement between the Placer County Air Pollution Control District (APCD) and the Union Pacific Railroad Company includes a mitigation plan for reducing PM emissions from the rail yard. Part of this plan is an assessment of the use of stationary air pollution control equipment to capture and treat emissions from stationary locomotives while idling or undergoing engine load tests.

The Advanced Locomotive Emission Control System (ALECS) comprises a set of stationary emissions control equipment connected to an articulated bonnet or hood. The hood is designed to capture locomotive exhaust, delivering it to the ground-mounted emission control system by means of a flexible duct. The hood remains attached while the locomotive is moving along the track to the extent of the flexible duct. The emission control equipment comprises a sodium hydroxide wash to remove sulfur dioxide (SO_2), a triple cloud chamber scrubber for particulate matter (PM) removal, and a Selective Catalytic Reduction (SCR) reactor to reduce oxides of nitrogen (NOx). The demonstration ALECS is designed to treat exhaust flows between 2,000 and 12,000 standard cubic feet per minute (scfm). The former is slightly more than the exhaust flow from a locomotive at idle, while the latter is approximately the exhaust flow from a line-haul locomotive at Notch 8 (full power).

The ALECS demonstration is a public-private collaborative project involving the Placer County APCD, U.S. Environmental Protection Agency, Sacramento Metropolitan Air Quality Management District, Union Pacific Railroad, Advanced Cleanup Technologies Inc., the South Coast Air Quality Management District (SCAQMD), the California Air Resources Board, and the City of Roseville. Engine, Fuel, and Emissions Engineering, Inc. (EF&EE) was contracted by the SCAQMD to carry out emission measurements before and after the ALECS system.

Emission measurements were performed on two locomotives: an EMD GP38 and a General Electric C39-8 (Dash 8). The GP38 has a 2000 horsepower two-stroke diesel engine, and is typically used for switching and local service. The Dash-8 has a 3900 horsepower four-stroke engine, and is normally used for line-haul freight service. Tests were performed with the locomotives stationary at idle, Notch 3, Notch 5, and Notch 8 power settings, and while moving slowly in Notch 1.

Measurements before and after the ALECS system showed NOx removal efficiency of 96 to 100%, with efficiency of 99% or more in most test modes. SO_2 emissions were low to begin with, were further reduced by 85 to 100%. PM control efficiency ranged from 89 to 99% over most test modes, but was only 81% in Notch 5 operation on the Dash 8. This mode had a high exhaust flow rate with low PM concentration.

CO_2 emissions increased through the ALECS system, as a result of the fuel-fired reheat stage before the SCR reactor. CO emissions were very low to begin with, but increased somewhat

through the system. Emissions due to ammonia slip from the SCR system ranged from zero (in most operating modes) to 1.3 grams per minute in full-power operation on the Dash 8. The latter emission rate was about 1/700th of the mass of NOx emissions destroyed by the ALECS system.

Testing conducted before and after prolonged periods of Notch 1 operation showed that PM buildup or "souping" during Notch 1 accounted for 26 to 37% of the total emissions attributable to Notch 1 operation. Although produced in Notch 1, this material adheres to the exhaust system, and is emitted subsequently, when the locomotive returns to higher-power operation. The ALECS system was virtually 100% effective in controlling the PM spikes due to this buildup. This suggests that the locomotives should first be operated at higher load with the ALECS system in place after a prolonged period of idle or Notch 1 operation.

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1. INTRODUCTION

The Union Pacific Railroad's J.R. Davis rail yard in Roseville, California, is a major center for locomotive maintenance, as well as for assembling and reassembling trains of freight cars. Locomotive operations at the rail yard have been determined to be a significant source of emissions of diesel particulate matter (PM) and other pollutants.[1] An agreement between the Placer County Air Pollution Control District (APCD) and the Union Pacific Railroad Company includes a mitigation plan for reducing PM emissions from the rail yard. This plan includes considering the use of stationary air pollution control equipment to capture and treat emissions from stationary locomotives while idling or undergoing engine load tests. To carry out this part of the plan, the APCD initiated a project to demonstrate the Advanced Locomotive Emission Control System (ALECS).

The ALECS demonstration is a public-private collaborative project involving many parties. Participants include the APCD, U.S. Environmental Protection Agency, Sacramento Metropolitan Air Quality Management District, Union Pacific Railroad, Advanced Cleanup Technologies Inc., the South Coast Air Quality Management District (SCAQMD), the California Air Resources Board, and the City of Roseville. Engine, Fuel, and Emissions Engineering, Inc. (EF&EE) was tasked with carrying out the emissions measurements under a contract with the SCAQMD.

1.1 Overview of the ALECS

The ALECS is designed to control harmful emissions from locomotives by capturing the exhaust stream from their engines and treating it to remove most pollutants. The system includes a set of stationary emissions control equipment connected to an articulated bonnet or hood. The hood is designed to capture locomotive exhaust, delivering it to the ground-mounted emission control system by means of a flexible duct. The bonnet or hood remains attached while the locomotive is moving along the track to the extent of the flexible duct.

The ALECS's emissions control equipment comprises a sodium hydroxide wash to remove sulfur dioxide (SO_2), followed by a triple cloud chamber scrubber for particulate matter (PM) removal. The exhaust is then reheated and passed through a Selective Catalytic Reduction (SCR) reactor to reduce oxides of nitrogen (NOx). The SCR reactor uses urea as the ammonia source. The demonstration ALECS is designed to treat exhaust flows between 2,000 and 12,000 standard cubic feet per minute (scfm).

1.2 Objectives

The objectives of the test program were:

- To measure and document the effectiveness of the ALECS system in controlling locomotive emissions of diesel particulate matter (PM), oxides of nitrogen (NOx) and other pollutants of concern under typical railyard operating conditions;

- To assure that the emission control process does not generate excessive amounts of other pollutants, such as ammonia;

- To quantify the effect of the hood system on locomotive noise emissions at full power; and
- To quantify the water and chemical consumption, operating costs, and waste generated by the ALECS system. (This information was compiled by ACTI during the test program, and is outside the scope of the present report).

2. THE TEST PROGRAM

The test program included emission measurements at three locations: at the inlet to the ground-mounted emission control system, at the outlet from the emission control system**,** and in the locomotive stack(s). The effectiveness of the ALECS emission control system was determined by comparing the mass emissions measured at the inlet with those measured at the system outlet. Emission measurements at the locomotive stack were obtained to make it possible to identify any effects on pollutant mass or characteristics due to the overhead manifold system.

The test program included two locomotives, each of which was operated in a defined set of test modes. Each of the test modes was repeated at least three times. Pollutants measured included PM, NOx, CO, SO_2, and total hydrocarbons (THC). The test procedures for these pollutants followed ISO standard 8178, which is extremely similar to the steady-state diesel testing procedures defined by the U.S. EPA and the California ARB. Ammonia (NH_3) and nitrous oxide (N_2O) were measured at the inlet and outlet of the emission control system during some of the tests, generally following the procedures specified in EPA Method 320.

2.1 TEST LOCOMOTIVES

The two locomotives tested were made available by the Union Pacific Railroad. They were a General Electric (GE) C39-8 line-haul locomotive (UPRR 9143) and an Electromotive Division (EMD) GP38 road-switcher (UPRR 604). The GE Dash-8 series locomotives are used primarily for line-haul freight service, and are equipped with four-stroke, turbocharged, GE FDL-16 engines. These 16-cylinder engines produce 3900 tractive horsepower, and discharge exhaust through a single rectangular stack connected directly to the turbocharger outlet. The maximum exhaust flow rate at full power is approximately 12,000 scfm.

The GP38 is used primarily for switching and local service. It is equipped with a two-stroke, Roots-blown, EMD 16-645E engine. The engine has 16 cylinders and is rated at 2000 tractive horsepower. It has two exhaust stacks, fed by the front eight and rear eight cylinders, respectively. The maximum exhaust flow rate at full power approximately is 6,000 scfm.

2.2 TEST FUEL

The test fuel for the GP38 was ultra-low sulfur diesel fuel meeting ARB regulations for sulfur and aromatic content, as specified in 13 CC 2281 and 2282. The sulfur limit is 15 parts per million w/w, and the limit on aromatic content is 10% v/v unless the fuel is produced according to an approved alternative formulation. The test fuel for the Dash-8 was a diesel fuel that is actually supplied to Union Pacific line-haul locomotives outside California. This fuel was specified with a sulfur content between 200 and 500 ppm w/w.

Table 1 shows the results of analyses performed on each fuel sample. EF&EE collected fuel samples from each locomotive's fuel tank during the test program. The fuel tanks were sealed and labeled to ensure that fuel was not added to the tanks by mistake.

Table 1: Fuel analyses

	Method	Dash 8	GP38
Carbon Content	D-5291	86.00%	86.10%
Hydrogen Content	D-5291	13.33%	13.73%
Nitrogen Content	D-5291	0.50%	0.06%
Sulfur Content (ppm)	D-4294	500	<15

2.3 TESTING SCHEDULE

The test sequence originally planned for each day of stationary testing is shown in Table 2. The sequence was designed to provide for preconditioning the locomotive engine, and then for measuring at Notch 1, Notch 5, and Notch 8. The effects of "souping" (PM buildup in the exhaust system at light loads) were determined by operating at Notch 3 for half-hour periods following each of the test periods at Notch 1, and comparing the results to a baseline measurement made at Notch 3 following a half hour of preconditioning at Notch 3.

Because of equipment problems and other issues, the actual test program diverged considerably from the sequence shown in Table 2. However, each test mode except the "Souping" tests was always preceded by at least 30 minutes of operation at the same mode to stabilize engine temperature. Notch 1 tests were also preceded by at least 30 minutes at Notch 3 to eliminate any "soup" buildup before the start of the test. The "Souping" test always followed a substantial period of operation at idle, generally comprising a Notch 1 test, the preceding stabilization period, and the time required for changing filters and reading sample bags at the end of the test.

The original schedule called for each Notch 1 test to be four hours long, and each test at Notches 5 and 8 to be one hour. This was based on considerations of the minimum detectable PM emission level at the outlet, assuming 99% collection efficiency by the ALECS. Based on the PM buildup observed on the filters during the first few tests, however, it was concluded that the length of the Notch 1 and Notch 8 tests could be cut in half.

Moving tests were conducted with the locomotive moving back and forth within a restricted section of track. The schedule for these days is shown in Table 3. Three tests were conducted, each one-half hour long. The limited length of these tests is based on considerations of operator fatigue, since the engineer will be constantly changing the throttle and reverser positions to move the locomotive back and forth on the 50 foot test section.

Table 2: Planned sequence of test modes and testing schedule for stationary test days

Step	Purpose	Throttle	Hours	Cumul. Hours	Test Activity
1	Precondition	3	0.5	0.5	Install filters/check instruments/calibrate
2	Souping baseline	3	0.5	1.0	Measure emissions
3	Stabilize	1	0.5	1.5	Change filters/calibrate
4	Idle test	1	4.0	5.5	Measure emissions
5	Filter Change	1	0.5	6.0	Change filters/calibrate
6	Souping test	3	0.5	6.5	Measure emissions
7	Stabilize	5	0.5	7.0	Change filters/calibrate
8	Notch 5 test	5	1.0	8.0	Measure emissions
9	Stabilize	8	0.5	8.5	Change filters/calibrate/refill day tank
10	Notch 8 test	8	1.0	9.5	Measure emissions and noise
11	Notch 8 noise baseline	8	.1	9.6	Raise bonnet and re-measure noise
12	Cool down	Idle	0.4	10.0	Remove filters/refill day tank

Table 3: Planned sequence of test modes and testing schedule for moving test days

Step	Purpose	Throttle	Hours	Cumul. Hours	Test Activity
1	Precondition	3	0.5	0.5	Check/warmup instruments
2	Stabilize	Idle	0.5	1.0	Install filters/calibrate
3	Moving Test #1	Var	0.5	1.5	Measure emissions
4	Filter Change	Idle	0.5	2.0	Change filters/calibrate
5	Moving Test #2	Var	0.5	2.5	Measure emissions
6	Filter Change	Idle	0.5	3.0	Change filters/calibrate
7	Moving Test #3	Var	0.5	3.5	Measure emissions
8	Change locomotive	Off	2.0	5.5	Remove RAVEM

2.4 PARTICULATE EMISSION MEASUREMENTS

PM emissions before and after the ALECS system were measured using EF&EE's Ride-Along Vehicle Emissions Measurement (RAVEM) system. The RAVEM uses the isokinetic partial flow dilution method specified as one option under ISO 8178. Raw exhaust is extracted from the exhaust conduit using an isokinetic sampling system. Isokinetic sampling conditions are maintained by adjusting the flow rate of raw exhaust through the sample probe until the static pressures inside and outside the probe are equal. This adjustment is performed continuously in real time by the RAVEM system, allowing it to follow transient changes in exhaust flow rate.

The raw exhaust from the sample probe was passed through an insulated sample line to the RAVEM dilution tunnel. Dilution air passed through a prefilter and a HEPA filter before entering the tunnel. Dilute exhaust containing PM was then drawn from the dilution tunnel through a PM2.5 cyclone (URG 2000-30EH), and then through filters of Teflon film in accordance with ISO 8178 and 40 CFR 1065. The rate of exhaust extraction was controlled to constant values of 16.7 standard liters per minute (SLPM) for the RAVEM systems measuring outlet and stack emissions, and 10 SLPM for the inlet RAVEM. The dilution flow rate in the

CVS was adjusted to ensure that the gas temperature at the filter face was no more than 52 °C. Blank filters exposed only to dilution air were collected along with each sample. In addition to correcting for any background PM that makes it past the HEPA filter, subtracting the change in weight of the blank filter from the sample weight also automatically corrects for the effects of small differences in weighing chamber temperature, humidity, and atmospheric pressure.

ISO 8178 specifies the use of both primary and backup filters for each sample, while 40 CFR 1065 specifies the use of a single filter mounted in a filter cassette. For compatibility with the ongoing ambient sampling program at the railyard, EF&EE used the 40 CFR 1065 method during these tests.

Separate RAVEM samplers were used to sample the exhaust at the locomotive stack, at the inlet to the ALECS system, and in the outlet stack from the ALECS system. One Teflon sample filter and one Teflon blank were collected by each RAVEM during each test. In addition, the RAVEM system at the ALECS inlet collected one sample and one dilution air blank on 47 mm quartz filters during each test. These filters are to undergo analysis for elemental vs. organic carbon (EC/OC) content by the South Coast AQMD.

Figure 1: RAVEM installations at the ALECS inlet and outlet

At the request of the ARB Monitoring and Laboratory Division, the RAVEM sampler at the ALECS system inlet was also modified to allow a third PM sampler to be connected. The additional sampler was provided by ARB, and was used without a cyclone to collect 47 mm Teflon filters. These will be analyzed by ARB for mass and characterization of the hydrocarbon content of the PM in an effort to identify potential marker chemicals for PM source apportionment.

2.5 GASEOUS EMISSION MEASUREMENTS

Gaseous emission measurements included oxides of nitrogen (NOx), total hydrocarbons (THC), carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), oxygen (O_2), ammonia (NH_3), and nitrous oxide (N_2O). Table 4 summarizes the gas concentration measurement techniques used. Except for the FTIR measurements, all of the analyzers and measurement techniques complied with ISO 8178 specifications.

The ALECS system itself includes continuous emission monitoring systems (CEMS) for NOx, SO_2, and O_2 at both the inlet and the outlet, and for THC and NH_3 at the outlet only. For these tests, EF&EE provided another THC analyzer for the inlet. The CEMS analyzers are configured for raw gas sampling, which means that the results must be combined with a measured exhaust gas flow rate to calculate the total mass of emissions. The exhaust flowrate measurement is provided by venturis located in both the inlet and outlet sections.

THC emissions in the CEMS are measured “hot” and “wet” – directly from a heated line maintained at 190 +/- 10 C. The other pollutants are measured “dry” -- after moisture is removed by a sample conditioning system. The NH_3 measurement method used by the ALECS is that specified in ISO 8178 – conversion of NH_3 to NO, followed by quantification using a chemilumenescent analyzer. Since NH_3 is highly soluble in water, it was converted to NO prior to the sample conditioning step.

Table 4: Gas concentration measurements by sampling location

	Locomotive Stack	**ALECS Inlet**	**ALECS Outlet**
NOx	Dilute**	Raw+/Bag**	Raw+/Bag**
THC		Raw	Raw+
CO	Dilute**	Raw/Bag**	Raw/Bag**
CO_2	Dilute**	Raw/Bag**	Raw/Bag**
SO_2	-	Raw+	Raw+
NH_3	-	FTIR*	FTIR*/CLD++
N_2O	-	FTIR*	FTIR*
Gas Flow	-	Venturi+	Venturi+

*Fourier Transform Infrared of raw gas, time-shared between inlet and outlet
+ALECS system equipment **RAVEM system equipment
++ALECS system ammonia-to-NO with chemilumenescent detector

The effect of removing water vapor on pollutant concentrations in the remaining gas is substantial, especially in the outlet from the ALECS system. The water vapor concentration in the inlet gas was calculated from the absolute humidity of the ambient air and the chemical composition of the fuel. For the outlet gas, the water vapor concentration is determined by the exit conditions from the cloud chambers. According to the supplier, Tri-Met Corporation, these conditions were 140 to 150 ^{o}F and 95% relative humidity. For the emission calculations, we assumed 24.7% by volume of water vapor in the outlet gas, corresponding to conditions of 145 ^{o}F and 95% humidity.

The RAVEM sampling systems perform exhaust gas dilution according to the constant volume sampling (CVS) principle, so that the pollutant concentration in the dilute gas is proportional to the pollutant mass flow rate in the exhaust. The RAVEM system located at the ALECS inlet was configured to measure dilute NOx, CO, and CO_2 continuously, as well as collecting integrated bag samples of the dilute gas to be analyzed after the end of each test. The RAVEM samplers at the outlet and at the locomotive stack collected integrated bag samples only. These were analyzed at the end of each test by the analyzers of the first RAVEM system.

The results of the CO_2 measurements were used to calculate a carbon balance check for the PM sampling. The dilute NOx results from these bags were also compared to the NOx measurements of the ALECS CEMS systems.

The ALECS system ammonia analyzer works by oxidizing the ammonia to NO, measuring NO by CLD, and subtracting the NO already present in the sample gas (determined by another CLD analyzer). The accuracy of this method potentially suffers from the difference-of-large-numbers problem. A more accurate measurement of ammonia emissions, as well as N_2O, can be obtained by Fourier Transform Infrared (FTIR) analysis. During several emission tests, EF&EE applied a MIDAC FTIR analyzer system to measure NH_3 and N_2O concentrations in the raw gas at both the ALECS inlet and outlet. A heated sample line was used to bring gas samples from each source to a heated filter next to the FTIR unit.

2.6 FUEL CONSUMPTION MEASUREMENTS

Fuel consumption was measured during each stationary emission test as a check on the accuracy of the results. If the measurements are accurate, the sum of the carbon contained in the CO_2, CO, HC, and PM emissions should be equal to the mass of carbon in the fuel consumed.

Fuel consumption by the locomotive engine was measured using a 250 gallon intermediate bulk container positioned on a pallet scale as a day tank, as shown in Figure 2. Three-way valves were installed in the locomotive's fuel supply and return lines to allow these to be switched between the locomotive fuel tank and the day tank. Switching both supply and return lines to the day tank meant that the change in weight of the day tank was equal to the fuel consumed by the engine. The day tank was filled (and refilled, when necessary) from the locomotive fuel tank by running the electric fuel pump with the supply line connected to the locomotive tank, and the return line connected to the day tank.

Since locomotive fuel systems can contain voids and air pockets that affect the fuel balance during startup, the system was stabilized while running on the day tank before beginning each emission test. The weight of fuel in the day tank was recorded at 1-second intervals automatically during the test.

Although the returned fuel can pick up considerable heat in the engine, the relatively large volume of fuel in the day tank and the length of the supply and return hoses made it unnecessary to cool the fuel during these tests.

Figure 2: Dash 8 locomotive under emission testing, showing the fuel day tank

3. EMISSION RESULTS

This program employed three different approaches to emission measurements: the RAVEM partial-flow dilution systems, the ALECS's own CEMS systems using conventional analyzers, and FTIR analysis of the raw exhaust for ammonia and N_2O. The RAVEM results are presented and discussed in Section 3.1, the CEMS results in Section 3.2, and the FTIR results in Section 3.3. The effects of "souping" – the buldup of PM in the exhaust system at light loads, to be emitted later when the exhaust temperature increases – are quantified in Section 3.4. Section 3.5, finally, compares the limited RAVEM measurements conducted in the locomotive exhaust stacks with those at the inlet to the ALECS system.

3.1 RAVEM RESULTS: PM, NOX, CO, AND CO_2

RAVEM system measurements from the stationary testing of the Dash 8 locomotive are shown in Table 5. Emissions were measured separately at the inlet and outlet the ALECS system, using two separate RAVEM units. Results (in grams of pollutant per minute) are shown for each test, as well as for the mean and coefficient of variation (standard deviation divided by the mean) in each test mode. Except for the Test 959 (the final souping test), the coefficients of variation are relatively low, and within expectations for test-to-test variability.

The emission control effectiveness of the ALECS system can be calculated from the ratio of the pollutant mass flow at the outlet to that at the inlet. For NOx, the control efficiencies ranged from 96.8% to 100%. For PM, the control efficiency ranged from 97% at low loads to 81% at Notch 5; increasing to 88.8% at Notch 8. CO emissions were extremely low at the inlet, and increased slightly in passing through the system. CO_2 emissions also increased through the ALECS system, due to the use of fuel to reheat the exhaust before the SCR system.

Table 5 also compares the fuel consumption measured by the change in weight of the day tank to that calculated from the emission results by carbon balance. Only the inlet fuel data are shown, as the outlet CO_2 emissions include the fuel used by the exhaust reheater in the ALECS system, and are thus not directly comparable to the measured fuel use. Except at Notch 1, the measured and calculated fuel consumption agree within a few percent, showing that the RAVEM was accurately collecting a proportional sample of the exhaust. The results for Notch 1, however, show that the RAVEM was oversampling by about 50%. The exhaust velocities and flow rates in this condition are extremely low, and the differential pressure signal used by the RAVEM system is proportional to the square of the exhaust velocity. Thus, at very low velocities, any inaccuracy in the sampling system can have a substantial effect. Thus, assuming that the measured fuel consumption data are accurate, the RAVEM results at idle should be multiplied by a factor 0.67 to get the true emissions.

Table 5: ALECS inlet vs. outlet emissions - RAVEM data for the Dash 8

Test No.	Start Date/Time	Inlet Emissions (g/min)				Outlet Emissions (g/min)				Inlet Fuel (g/min)		
		CO_2	CO	NOx	PM	CO_2	CO	NOx	PM	Calc.	Meas.	Ratio
DASH 8 - NOTCH 8												
T0946	9/8/2006 18:29	30,424	122	689	24.6	11,658	40	0.0	1.5	9,642	10,058	96%
T0951	9/10/2006 10:44	31,281	110	647	28.3	36,274	162	22.4	2.9	9,975	10,043	99%
T0952	9/10/2006 12:23	29,197	113	631	26.5	32,697	134	18.4	2.9	9,316	8,543	109%
T0953	9/11/2006 11:23	30,059	120	651	23.0	33,564	143	26.6	2.6	9,592	10,021	96%
T0955	9/11/2006 13:33	30,073	130	624	25.0	32,697	143	14.3	3.0	9,602	9,850	97%
Average		30,207	119	648	25.5	33,808	146	20.4	2.9	9,703	9,993	97%
Coeff. Of Deviation		2.5%	6.5%	3.9%	7.9%	5.0%	8.0%	25.9%	6.2%	1.9%	1.0%	
Control Efficiency						**-11.9%**	**-22.0%**	**96.8%**	**88.8%**			
DASH 8 - NOTCH 8 - 2 CLOUD CHAMBERS												
T0954	9/11/2006 12:25	29,798	121	629	25.0	32,818	141	13.7	3.4	9,510	9,913	96%
Control Efficiency						**-10.1%**	**-15.9%**	**97.8%**	**86.5%**			
DASH 8 - NOTCH 5												
T0941	9/6/2006 18:06	18,058	131	428	3.2	23,600	188	5.3	1.4	5,792	6,152	94%
T0945	9/7/2006 19:32	17,348	122	411	6.5	20,639	151	1.6	1.0	5,562	6,111	91%
T0950	9/9/2006 18:41	18,065	113	438	7.0	20,355	123	13.2	1.2	5,745	6,079	95%
T0956	9/11/2006 15:28	18,971	145	433	5.8	19,697	142	6.8	1.4	6,088	6,218	98%
Average		18,111	128	427	6.4	21,073	151	6.7	1.2	5,797	6,140	94%
Coeff. Of Deviation		3.7%	10.8%	2.7%	8.9%	8.2%	18.0%	71.9%	12.9%	3.8%	1.0%	
Control Efficiency						**-16.4%**	**-18.1%**	**98.4%**	**80.9%**			
DASH 8 - NOTCH 1												
T0943	9/7/2006 13:01	3,961	26	90	4.3	3,539	18	1.4	0.1	1,261	783	161%
T0948	9/9/2006 11:02	3,528	13	106	4.9	3,550	17	0.1	0.1	1,105	799	138%
T0958	9/12/2006 15:25	3,865	13	94	4.7	3,781	19	4.0	0.1	1,232	808	152%
Average		3,785	17	97	4.6	3,623	18	1.9	0.1	1,199	797	150%
Coeff. Of Deviation		6.0%	45.6%	8.4%	6.5%	3.8%	6.0%	107%	2.9%	6.9%	1.6%	
Control Efficiency						**4.3%**	**-3.0%**	**98.1%**	**98.6%**			
DASH 8 SOUPING BASELINE												
T0947	9/9/2006 9:54	11,148	32	271	4.5	11,044	38	0.0	0.3	3,552	3,558	100%
T0957	9/12/2006 14:00	10,825	38	263	3.1	#N/A	#N/A	#N/A	0.4	3,428	#N/A	#N/A
T0960	9/13/2006 13:28	11,087	41	268	3.9	13,094	58	0.0	0.3	3,536	3,510	101%
Average		11,020	37	267	3.8	12,069	48	0.0	0.4	3,505	3,534	99%
Coeff. Of Deviation		1.6%	11.6%	1.6%	18%	12.0%	29.5%	141%	22.0%	1.9%	1.0%	
Control Efficiency						**-9.5%**	**-28.5%**	**100%**	**90.7%**			
DASH 8 SOUPING TEST												
T0944	9/7/2006 18:24	9,926	40	242	10.9	12,864	61	7.5	0.4	3,168	#N/A	#N/A
T0949	9/9/2006 16:30	11,654	33	265	12.1	11,517	53	15.5	0.3	3,687	3,437	107%
T0959	9/12/2006 18:17	10,943	50	265	31.6	13,146	62	0.0	1.0	3,495	3,321	105%
Average		10,841	41	257	18.2	12,509	58	7.7	0.5	3,450	3,379	102%
Coeff. Of Deviation		8.0%	19.8%	5.3%	64%	7.0%	8.7%	101%	65.4%	7.6%	2.4%	
Control Efficiency						**-15.4%**	**-42.6%**	**97.0%**	**97.0%**			

The shaded cells in Table 5 indicate results that were excluded from the averages due to technical problems with the measurements. In Test 941, the PM results were affected by a leak into the PM filter suction when the suction line to the aethelometer became disconnected. Test 946 was the first test conducted at Notch 8, and the resulting exhaust flow was so high that the RAVEM was unable to maintain isokinetic sampling. The outlet RAVEM was originally equipped with a one-inch diameter isokinetic probe to maximize the amount of pollutant collected at low loads. A one-half inch probe was used for subsequent testing at Notch 5 and Notch 8, while the one inch probe continued to be used at lower power settings.

In Test 952, the locomotive engine shut down due to low lube oil pressure at 22 minutes into the test. While this did not affect the validity of the emission results, fuel in the locomotive engine circuit drained back into the day tank after the shutdown, affecting the mass fuel consumption measurement.

RAVEM system results from the stationary testing on the GP38 locomotive are summarized in Table 6. Exhaust mass flow and pollutant flow rates were significantly lower from this 2000 horsepower locomotive than from the 3900 horsepower Dash 8, and both the emission testing crew and the ALECS operations had gained experience during the earlier testing. Fewer technical problems were experienced, therefore, and the carbon balance results show close agreement between the measured and calculated fuel consumption.

The NOx control efficiency of the ALECs system in these tests ranged from 95 to 99%, while the PM control efficiency was 90% or better across all of the test modes. Except at Notch 8, CO emissions were too low to measure accurately, so that the high percentage increases shown for this pollutant are of little actual significance.

RAVEM system results from the moving tests on both locomotives are presented in Table 7. Because of the motion, the day tank had to be disconnected, so that mass fuel consumption measurements were not possible. Since the locomotives were only able to move very slowly, and over a restricted distance, the power required, calculated fuel consumption, and emissions were very low. The mass emission rates and calculated fuel consumption rates are even lower than those for continuous Notch 1 operation. PM and NOx control efficiencies under these conditions were well above 90%.

Table 6: ALECS inlet vs. outlet emissions - RAVEM data for the GP38

Test No.	Start Date/Time	Inlet Emissions (g/min)				Outlet Emissions (g/min)				Inlet Fuel (g/min)		
		CO_2	CO	NOx	PM	CO_2	CO	NOx	PM	Calc.	Meas.	Ratio
GP 38 - NOTCH 8												
T0967	9/16/2006 16:09	18,189	34	462	7.7	20,679	42	16.8	0.5	5,778	6,175	94%
T0968	9/16/2006 17:19	19,535	32	469	6.3	22,153	46	2.1	0.5	6,204	6,167	101%
T0969	9/16/2006 18:18	20,509	44	468	5.7	21,567	48	1.3	0.8	6,518	6,150	106%
Average		19,411	37	466	6.6	21,466	45	6.8	0.6	6,167	6,164	100%
Coeff. Of Deviation		6.0%	18.2%	0.8%	16%	3.5%	6.5%	129%	27.8%	6.0%	0.2%	
Control Efficiency						**-10.6%**	**-24.0%**	**98.6%**	**90.7%**			
GP 38 - NOTCH 5												
T0964	9/16/2006 10:50	9,754	3	201	5.5	10,811	10	0.0	0.4	3,091	3,208	96%
T0965	9/16/2006 12:33	10,036	6	209	4.5	11,281	12	1.4	0.4	3,182	3,178	100%
T0966	9/16/2006 14:18	9,816	1	204	4.0	11,356	18	2.9	0.5	3,110	3,168	98%
Average		9,869	3	205	4.7	11,150	14	1.4	0.4	3,128	3,185	98%
Coeff. Of Deviation		1.5%	77.3%	2.0%	16%	2.6%	32.3%	101%	6.2%	1.5%	0.7%	
Control Efficiency						**-13.0%**	**-324%**	**99.3%**	**90.7%**			
GP 38 - NOTCH 1												
T0962	9/15/2006 16:30	1,600	3	27	0.40	2,292	3	-0.4	0.03	505	438	115%
T0971	9/17/2006 11:43	1,326	2	28	0.20	2,223	3	2.6	0.03	421	430	98%
T0973	9/17/2006 15:27	1,628	(7)	27	0.36	2,256	5	0.3	0.04	509	426	119%
Average		1,518	(1)	27	0.32	2,257	4	0.8	0.03	478	431	111%
Coeff. Of Deviation		11.0%	638%	2.6%	34%	1.5%	31.7%	194%	9.4%	10.4%	1.4%	
Control Efficiency						**-48.7%**	**#N/A**	**97.0%**	**89.6%**			
GP 38 SOUPING BASELINE												
T0961	9/15/2006 15:15	6,085	(1)	114	1.9	6,777	9	2.5	0.2	1,916	1,759	109%
T0970	9/17/2006 10:30	5,316	2	100	1.7	5,971	6	2.3	0.1	1,685	1,765	95%
T0975	9/17/2006 19:10	5,489	3	102	1.4	6,294	8	0.1	0.2	1,740	1,732	100%
Average		5,630	1	106	1.7	6,347	8	1.6	0.2	1,780	1,752	102%
Coeff. Of Deviation		7.2%	159%	7.1%	14%	6.4%	18.9%	79.8%	6.4%	6.8%	1.0%	
Control Efficiency						**-12.7%**	**-474%**	**98.4%**	**90.8%**			
GP 38 SOUPING TEST												
T0963	9/15/2006 19:17	6,222	(2)	109	3.5	6,192	9	12.1	0.1	1,970	1,698	116%
T0972	9/17/2006 14:16	5,065	(1)	96	2.6	6,213	7	2.0	0.2	1,604	1,692	95%
T0974	9/17/2006 18:08	4,694	(2)	93	2.7	5,045	7	0.3	0.1	1,477	1,459	101%
Average		5,327	(2)	99	2.9	5,817	8	4.8	0.1	1,684	1,617	104%
Coeff. Of Deviation		15.0%	55.5%	8.4%	17%	11.5%	13.7%	133%	14.0%	15.2%	8.4%	
Control Efficiency						**-9.2%**	**#N/A**	**95.2%**	**94.9%**			

Table 7: ALECS inlet vs. outlet emissions - RAVEM data for moving tests

Test No.	Start Date/Time	Inlet Emissions (g/min)				Outlet Emissions (g/min)				Inlet Fuel (g/min)		
		CO_2	CO	NOx	PM	CO_2	CO	NOx	PM	Calc.	Meas.	Ratio
DASH 8 MOVING TEST												
T0980	9/20/2006 14:11	2,116	9	51	5.6	2,398	15	1.4	0.0	675	#N/A	#N/A
T0981	9/20/2006 15:28	2,306	10	53	3.1	2,563	14	0.0	0.1	736	#N/A	#N/A
T0982	9/20/2006 16:24	969	(1)	26	1.0	1,947	7	0.3	0.0	307	#N/A	#N/A
Average		1,797	6	43	3.2	2,303	12	0.6	0.0	573	#N/A	#N/A
Coeff. Of Deviation		40.3%	97.6%	35.4%	71%	13.9%	38.9%	129%	16.8%	40.6%	#N/A	
Control Efficiency						**-28.2%**	**-99.4%**	**98.7%**	**98.5%**			
GP 38 MOVING TEST												
T0976	9/19/2006 15:00	1,072	4	22	0.2	1,508	2	2.3	0.0	342	#N/A	#N/A
T0978	9/20/2006 9:41	884	1	23	0.0	1,705	3	0.0	0.0	281	#N/A	#N/A
T0979	9/20/2006 10:52	739	1	21	0.5	1,769	4	0.2	0.0	235	#N/A	#N/A
Average		898	2	22	0.2	1,661	3	0.8	0.0	286	#N/A	#N/A
Coeff. Of Deviation		18.6%	70.9%	6.5%	116%	8.2%	20.1%	158%	66.8%	18.8%	#N/A	
Control Efficiency						**-84.9%**	**-47.7%**	**96.3%**	**93.5%**			

3.2 CEMS Results: NOx, SO_2, THC, and NH_3

CEMS results for the stationary emission tests on the Dash 8 locomotive are shown in Table 8, while those for the GP38 are shown in Table 9. Results of the moving tests on both locomotives are shown in Table 10. The CEMS data recording was not fully functional during the first few tests in this program, so that these data are shown as #NA in the tables.

The CEMS data, like the RAVEM data, show extremely high control efficiency for NOx. Although SO_2 emissions in these tests were already low, the ALECS system reduced these to barely-detectable levels. Ammonia emissions were also below or close to the limits of detectability over most of the test period. Control of THC emissions was considerably less effective, ranging from about 31% to 85% effective. THC control was least efficient in the test conditions with the highest THC emissions.

Since NOx emissions were measured using both the CEMS and the RAVEM systems, a comparison between these two methods provides insight into the accuracy of the measurements. Figure 3 is a cross-plot of the NOx emission rate at the ALECS inlet as measured by the CEMS vs. that measured by the RAVEM. As this figure shows, the relationship is nearly 1:1, except at the highest NOx flow rates (measured at Notch 8 on the Dash 8 locomotive), where the CEMS results are about 12% higher. Since the carbon balance data for the RAVEM agree closely with the mass fuel consumption measurements, it is likely that the error lies in the CEMS data. This discrepancy may be due to excess water vapor from water injected into the exhaust duct to protect it from overheating. This would have had the effect of increasing apparent exhaust flow through the venturi. According to ACTI personnel, water injection was done only at high load, and the amount of water injected was not measured.

Table 8: ALECS inlet vs. outlet emissions - CEMS data for the Dash 8

Test No.	Start Date/Time	Inlet (g/min) NOx	Inlet (g/min) SO_2	Inlet (g/min) THC	Outlet (g/min) NOx	Outlet (g/min) SO_2	Outlet (g/min) THC	Outlet (g/min) NH3	Flow SCFM Inlet	Flow SCFM Outlet
DASH 8 - NOTCH 8										
T0946	9/8/2006 18:29	732.9	31.06	#N/A	31.5	0.00	7.11	1.1	12,829	14,011
T0951	9/10/2006 10:44	737.4	29.12	13.26	26.2	0.30	6.76	1.2	12,365	14,010
T0952	9/10/2006 12:23	725.9	26.18	9.87	16.5	0.00	7.39	1.6	12,028	13,941
T0953	9/11/2006 11:23	727.3	26.68	8.11	24.8	0.00	6.41	1.1	12,115	13,992
T0955	9/11/2006 13:33	710.9	23.68	8.36	14.6	0.00	6.02	1.2	11,801	13,812
Average		726.9	27.34	9.90	22.7	0.07	6.64	1.3	12,077	13,939
Coeff. Of Deviation		1.4%	10.4%	24.0%	31.0%	198.7%	8.7%	17.8%	1.9%	0.6%
Control Efficiency					**96.9%**	**99.7%**	**32.9%**			
DASH 8 - NOTCH 8 - 2 CLOUD CHAMBERS										
T0954	9/11/2006 12:25	718.8	25.19	8.05	15.9	0.00	6.16	1.8	11,983	13,898
Control Efficiency					**97.8%**	**100.0%**	**23.5%**			
DASH 8 - NOTCH 5										
T0941	9/6/2006 18:06	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
T0945	9/7/2006 19:32	#N/A	19.23	#N/A	1.1	0.00	1.58	1.7	7,515	8,040
T0950	9/9/2006 18:41	462.7	18.82	4.02	9.4	0.00	3.46	0.8	7,015	8,140
T0956	9/11/2006 15:28	469.6	16.43	4.10	6.1	0.00	3.33	0.0	6,998	8,173
Average		466.1	#N/A	4.06	5.5	0.00	2.79	0.8	7,176	8,117
Coeff. Of Deviation		1.0%	#N/A	1.3%	75.2%	173.2%	37.7%	103.9%	4.1%	0.9%
Control Efficiency					**98.8%**	**#N/A**	**31.4%**			
DASH 8 - NOTCH 1										
T0943	9/7/2006 13:01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
T0948	9/9/2006 11:02	52.8	1.48	1.08	1.3	0.02	0.73	0.0	2,257	2,948
T0958	9/12/2006 15:25	57.1	1.39	1.70	2.5	0.00	0.45	0.6	2,326	2,936
Average		55.0	1.44	1.39	1.9	0.01	0.59	0.3	2,291	2,942
Coeff. Of Deviation		5.5%	4.3%	31.5%	47.5%	97.4%	33.4%	136.0%	2.1%	0.3%
Control Efficiency					**96.5%**	**99.1%**	**57.6%**			
DASH 8 SOUPING BASELINE										
T0947	9/9/2006 9:54	277.2	12.68	#N/A	0.1	0.00	2.27	0.0	4,417	4,699
T0957	9/12/2006 14:00	278.6	9.97	3.84	3.0	0.00	2.77	0.0	4,169	4,540
T0960	9/13/2006 13:28	277.2	9.95	3.95	0.2	0.00	2.94	0.0	4,221	4,516
Average		277.7	10.87	3.90	1.1	0.00	2.60	0.0	4,319	4,607
Coeff. Of Deviation		0.3%	14.4%	2.1%	152.6%	0.0%	13.5%	115.2%	3.0%	2.2%
Control Efficiency					**99.6%**	**100.0%**	**33.2%**			
DASH 8 SOUPING TEST										
T0944	9/7/2006 18:24	#N/A	9.75	#N/A	3.1	0.04	1.43	0.2	4,333	4,378
T0949	9/9/2006 16:30	255.5	9.80	4.89	7.1	0.16	3.09	0.1	4,095	4,437
T0959	9/12/2006 18:17	244.9	8.71	4.33	6.5	0.02	2.20	0.0	3,980	4,354
Average		250.2	9.42	4.61	5.6	0.07	2.24	0.1	4,136	4,390
Coeff. Of Deviation		3.0%	6.6%	8.7%	39.3%	104.9%	37.0%	75.5%	4.4%	1.0%
Control Efficiency					**97.8%**	**99.2%**	**51.4%**			

Table 9: ALECS inlet vs. outlet emissions - CEMS data for the GP 38

Test No.	Start Date/Time	Inlet (g/min) NOx	Inlet (g/min) SO_2	Inlet (g/min) THC	Outlet (g/min) NOx	Outlet (g/min) SO_2	Outlet (g/min) THC	Outlet (g/min) NH3	Flow SCFM Inlet	Flow SCFM Outlet
GP 38 - NOTCH 8										
T0967	9/16/2006 16:09	490.3	16.26	3.74	14.4	0.00	0.92	0.0	8,376	9,413
T0968	9/16/2006 17:19	486.6	16.19	3.23	1.5	0.00	0.89	0.0	8,288	9,369
T0969	9/16/2006 18:18	480.9	16.25	3.17	0.9	0.00	0.91	0.4	8,270	9,355
Average		485.9	16.23	3.38	5.6	0.00	0.90	0.1	8,311	9,379
Coeff. Of Deviation		1.0%	0.2%	9.3%	136.0%	0.00	1.7%	173.1%	0.7%	0.3%
Control Efficiency					**98.8%**	**100.0%**	**73.2%**			
GP 38 - NOTCH 5										
T0964	9/16/2006 10:50	196.9	4.73	1.47	0.3	0.00	0.22	0.0	6,522	7,023
T0965	9/16/2006 12:33	202.0	4.75	1.66	1.0	0.00	0.23	0.0	6,320	6,924
T0966	9/16/2006 14:18	204.8	4.63	1.71	2.2	0.00	0.24	0.0	6,270	6,889
Average		201.2	4.70	1.62	1.2	0.00	0.23	0.0	6,371	6,945
Coeff. Of Deviation		2.0%	1.4%	7.8%	79.9%	0.00	2.4%	99.0%	2.1%	1.0%
Control Efficiency					**99.4%**	**100.0%**	**85.7%**			
GP 38 - NOTCH 1										
T0962	9/15/2006 16:30	21.0	0.27	0.46	0.07	0.06	0.08	0.0	3,286	3,827
T0971	9/17/2006 11:43	21.6	0.12	0.50	1.73	0.00	0.10	1.9	3,735	4,245
T0973	9/17/2006 15:27	21.8	0.11	0.60	0.08	0.00	0.09	0.0	3,677	4,193
Average		21.5	0.17	0.52	0.63	0.02	0.09	0.6	3,566	4,088
Coeff. Of Deviation		1.9%	52.4%	13.9%	152.6%	173.2%	11.2%	169.1%	6.8%	5.6%
Control Efficiency					**97.1%**	**88.4%**	**83.1%**			
GP 38 SOUPING BASELINE										
T0961	9/15/2006 15:15	98.6	1.66	0.99	2.5	0.00	0.13	0.0	4,802	5,197
T0970	9/17/2006 10:30	97.5	1.24	0.84	2.3	0.00	0.14	0.1	5,872	6,355
T0975	9/17/2006 19:10	97.9	1.13	1.01	0.1	0.00	0.16	0.0	5,493	6,037
Average		98.0	1.35	0.95	1.6	0.00	0.14	0.0	5,389	5,863
Coeff. Of Deviation		0.6%	20.9%	9.7%	80.6%	0.0%	10.6%	157.3%	10.1%	10.2%
Control Efficiency					**98.3%**	**100.0%**	**84.9%**			
GP 38 SOUPING TEST										
T0963	9/15/2006 19:17	86.5	1.44	0.92	9.4	0.14	0.14	0.3	4,962	5,399
T0972	9/17/2006 14:16	92.0	0.99	1.02	1.3	0.00	0.15	0.0	5,620	6,135
T0974	9/17/2006 18:08	92.5	1.00	0.98	0.2	0.00	0.17	0.3	5,486	5,987
Average		90.3	1.14	0.97	3.6	0.05	0.15	0.2	5,356	5,840
Coeff. Of Deviation		3.7%	22.2%	5.3%	137.2%	173.2%	7.4%	87.6%	6.5%	6.7%
Control Efficiency					**96.0%**	**96.0%**	**84.2%**			

A cross-plot of the outlet NOx concentrations measured by the CEMS vs. the RAVEM shows a similar 1:1 relationship, but with much greater variability, due to the low NOx concentrations involved.

Table 10: ALECS inlet vs. outlet emissions - CEMS data for the moving tests

Test No.	Start Date/Time	Inlet (g/min)			Outlet (g/min)				Flow SCFM	
		NOx	SO_2	THC	NOx	SO_2	THC	NH3	Inlet	Outlet
DASH 8 MOVING TEST										
T0980	9/20/2006 14:11	36.4	0.94	1.67	1.1	0.00	0.91	0.000	2,645	3,154
T0981	9/20/2006 15:28	35.4	0.88	1.36	0.1	0.00	0.53	0.000	2,458	2,946
T0982	9/20/2006 16:24	19.5	0.44	0.78	0.2	0.00	0.23	0.000	2,196	2,838
Average		30.4	0.75	1.27	0.4	0.00	0.56	0.000	2,433	2,979
Coeff. Of Deviation		31.2%	36.6%	35.3%	131.5%	0.0%	60.9%	100.2%	9.3%	5.4%
Control Efficiency					**98.5%**	**100.0%**	**56.0%**			
GP 38 MOVING TEST										
T0976	9/19/2006 15:00	17.1	0.22	0.47	2.1	0.00	0.11	0.001	3,636	4,177
T0978	9/20/2006 9:41	17.2	0.27	0.46	0.1	0.11	0.10	0.000	3,905	4,401
T0979	9/20/2006 10:52	16.0	0.25	0.46	0.1	0.00	0.09	0.000	3,843	4,331
Average		16.8	0.24	0.46	0.8	0.04	0.10	0.000	3,795	4,303
Coeff. Of Deviation		4.1%	9.1%	1.1%	154.8%	173.2%	9.6%	139.2%	3.7%	2.7%
Control Efficiency					**95.4%**	**84.9%**	**78.6%**			

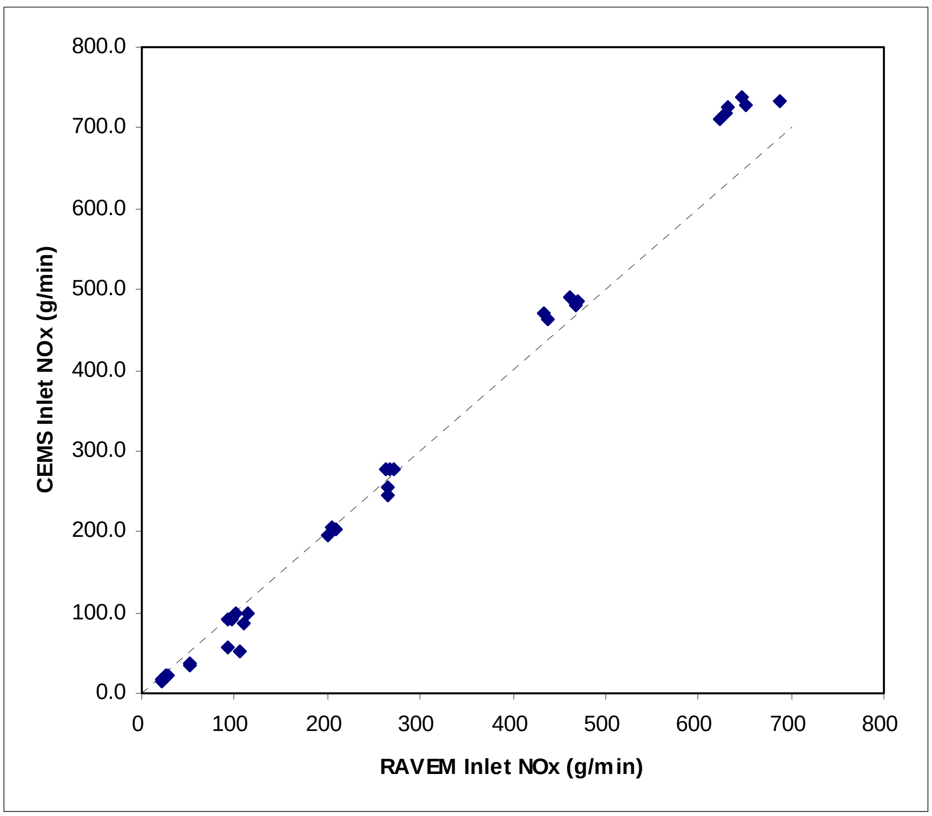

Figure 3: CEMS vs. RAVEM NOx measurements

3.3 FTIR RESULTS: NH_3 AND N_2O

FTIR measurements of ammonia and N_2O concentrations were carried out alternately on the outlet and inlet gas streams in parallel with tests 964 through 979. The ammonia concentrations measured by the FTIR system were extremely low (generally in the range of zero to 2 ppm), and consistent with the results of the chemilumenescent ammonia analyzer incorporated in the CEMS system. The N_2O concentrations reported by the FTIR system were also generally in the range of zero to 2 ppm, and less than the estimated error calculated by the FTIR software. N_2O concentrations measured at the ALECS inlet were similar to those measured at the outlet, suggesting that the reported values were likely due to the presence of interfering species rather than N_2O as such.

3.4 SOUPING EMISSIONS: PM BUILDUP DURING NOTCH 1

During prolonged periods of low-load operation, particulate matter (mostly semi-volatile hydrocarbons) tends to build up on the walls of the exhaust system, forming a liquid deposit, colloquially known as “soup”. Since locomotives are often left idling for long periods, substantial amounts of material can build up. Once the locomotive returns to higher-load operation, the accumulated material comes back off of the walls and into the exhaust. If soup deposits are heavy, some of this material is blown out of the exhaust system as large liquid droplets. Much of it, however, is emitted as fine particulate matter, forming a transient cloud of visible white or gray smoke during the first seconds after the engine load increases.

The transient PM spike due to re-mobilization of the soup deposits is not captured by the present Federal test procedure for locomotives, since it measures emissions only under stabilized conditions. Previous testing by EF&EE[2] showed that these soup emissions can be significant: accounting for 0.10 and 0.19 grams per minute (15% and 49% of idling PM emissions, respectively) from two turbocharged EMD locomotives.

To determine the PM emissions in this test program due to soup buildup, we compared the PM results at Notch 3 in the souping baseline tests with those measured in the souping tests, going from Notch 1 to Notch 3 after a prolonged period of Notch 1 operation. This calculation is shown in Table 11. Average PM emissions during the baseline tests on each locomotive were subtracted from the measured PM emissions during the souping test to calculate the excess PM emission due to soup buildup. This excess was then divided by the length of the preceding buildup period to calculate the rate of soup PM buildup for per minute of Notch 1 operation.

As Table 11 shows, the PM emissions attributable to souping in the GP38 are comparable to those measured in our earlier study, averaging 0.38 g/min or 38% of total Notch 1 PM emissions attributable to Notch 1 operation. Souping emissions from the Dash 8 locomotive were much higher, but the Notch 1 PM emissions were higher still, so that souping accounted for only 26% of the Notch 1 PM emissions attributable to this locomotive (see Table 12). The souping emissions from the Dash 8 also exhibited great variability, with one test producing seven times higher emissions than the other two. Such a large discrepancy normally suggests a measurement error, such as an error in PM filter handling or weighing. That is not a likely explanation in this case, however, since the higher PM emissions were also observed in the RAVEM measurements on the ALECS outlet.

Table 11: Calculation of "soup" PM buildup during Notch 1 operation

Test No	Buildup (minutes)	ALECS Inlet PM (g)			Souping g/min	ALECS Outlet PM (g)			Souping g/min
		Total	Baseline	Excess		Total	Baseline	Excess	
Dash 8									
944	435.6	326.5	115.1	211.4	0.49	11.0	10.7	0.3	0.001
949	366.3	362.5	115.1	247.5	0.68	9.4	10.7	-1.3	-0.004
959	227.3	950.9	115.1	835.7	3.68	28.6	10.7	17.9	0.079
GP 38									
963	211.5	105.2	50.4	54.8	0.26	4.2	4.6	-0.5	-0.002
972	195.5	76.7	50.4	26.3	0.13	5.2	4.6	0.6	0.003
974	202.2	81.7	50.4	31.3	0.15	4.1	4.6	-0.5	-0.003

Table 12: Souping PM as percentage of total PM emissions during Notch 1

Locomotive	Notch 1 PM Emissions (g/min)			Soup as Pct of Total
	Direct	Soup	Total	
ALECS Inlet				
Dash 8	4.64	1.61	6.25	26%
GP 38	0.32	0.18	0.50	37%
ALECS Outlet				
Dash 8	0.07	0.025	0.09	27%
GP 38	0.03	-0.001	0.03	-2%

As Tables 11 and 12 show, the ALECS system was nearly 100% effective in controlling the incremental emissions due to soup buildup and re-entrainment. This suggests that it would be good policy, after a prolonged idle period, to run locomotives at Notch 3 for a few minutes before disconnecting them from the ALECS system.

3.5 RAVEM MEASUREMENTS IN THE LOCOMOTIVE STACK VS. ALECS INLET

To determine whether the emission measurements at the ALECS inlet had been affected by the passage of exhaust through the exhaust duct, RAVEM emission measurements were also conducted at the locomotive exhaust stack. In the case of the Dash 8, these measurements faced a number of complications. First, the exhaust composition is not homogeneous in the exhaust stack. As can be seen in Figure 4, the venturi effect of the exhaust velocity provides suction for the crankcase vent tube (right) and three tubes coming from the air cleaner. The function of these latter tubes is unknown, but they appear to carry a significant flow of air into the exhaust. The RAVEM probe was located on the centerline between the left and right sides, but could still have been affected by special variation in the velocity and chemical composition of the exhaust.

Installation of the RAVEM probe on the GP 38 was also complicated, since the GP38 has two round exhaust stacks. This required the use of two probes, with the raw exhaust lines connected together in a T configuration. Two of the four delta-pressure lines from the isokinetic sampler were connected to each probe to maintain approximately isokinetic sampling, but this arrangement would not have been able to compensate for any substantial difference in exhaust velocity between the two stacks.

Figure 4: View into the Dash 8 exhaust stack, showing the crankcase vent and air filter suction tubes

Another complicating factor was the interaction between the ALECS hoods and the sample lines and delta-pressure lines of the RAVEM system. The magnets on the hood hold it to the locomotive with considerable force, and this resulted in the crushing of the sample or delta-pressure lines on several occasions. In retrospect, a preferable approach would have been to install the probes in the hood of the ALECS system instead of directly in the stack.

Table 13 compares the NO, PM, and CO_2 emissions measured at the locomotive stack and at the inlet to the ALECS system. Because of the uncertainties involved in sampling directly from the stacks, it is more useful to compare the pollutant-to-CO_2 ratios measured in these two locations rather than the mass emissions as such. As Table 13 shows, the NOx to CO_2 ratios measured in the two locations generally agree well. However, the PM-to-CO_2 ratio measured in the stack is generally lower than that in measured at the ALECS inlet.

Table 13: RAVEM measurements at the locomotive stack vs. inlet emissions

Test No.	Inlet (g/min)			Stack (g/min)			PM/CO_2		NOx/CO_2	
	CO_2	NOx	PM	CO_2	NOx	PM	Inlet	Stack	Inlet	Stack
DASH 8 - NOTCH 1										
T0958	3865	93.7	4.72	662	17.8	0.60	1.22	0.91	24.24	26.81
DASH 8 SOUPING TEST										
T0959	10943	264.9	31.64	4465	110.2	1.16	2.89	0.26	24.21	24.68
DASH 8 MOVING TEST										
T0980	2116	51.0	5.62	2980	72.8	6.59	2.66	2.21	24.12	24.43
T0981	2306	52.8	3.09	3617	88.9	4.11	1.34	1.14	22.90	24.57
T0982	969	25.5	1.02	2906	65.3	2.06	1.06	0.71	26.37	22.45
GP 38 - NOTCH 5										
T0964	9754	200.6	5.46	#N/A	#N/A	5.16	0.56	#N/A	20.56	#N/A
T0965	10036	208.6	4.52	9412	162.1	3.70	0.45	0.39	20.79	17.22
T0966	9816	204.5	4.01	4249	80.2	2.41	0.41	0.57	20.83	18.87
GP 38 - NOTCH 1										
T0962	1600	26.7	0.40	1162	18.8	0.21	0.25	0.18	16.70	16.22
GP 38 SOUPING BASELINE										
T0961	6085	114.1	1.92	4778	81.1	1.43	0.32	0.30	18.76	16.97
GP 38 SOUPING TEST										
T0963	6222	108.9	3.50	3594	60.1	2.56	0.56	0.71	17.50	16.72
GP 38 MOVING TEST										
T0976	1072	21.6	0.17	620	11.9	0.22	0.16	0.36	20.11	19.16
T0978	884	23.4	0.00	750	14.9	0.23	0.00	0.30	26.46	19.80
T0979	739	20.6	0.52	759	14.7	0.25	0.71	0.33	27.89	19.41

4. NOISE MEASUREMENTS

Locomotive noise emissions were measured using a Larson-Davis model 720 sound level meter. The meter was calibrated before use. The time-weighted average equivalent sound level (Leq) was measured over a three minute period, using the "A" frequency weighting filter. Emission measurements were made at a point 30 meters away from the locomotive, and along a line passing through the center of the locomotive perpendicular to the track, as specified in 40 CFR 201.20 et seq. To minimize the effects of background noise, measurements were taken only when no trains were operating nearby. However, it was not possible to eliminate the noise from other locomotives idling in the vicinity.

The purpose of the noise measurements was to assess the noise reduction due to the exhaust hood, especially the noise experienced during power tests at Notch 8. Noise was measured both with the hood in place, and with the hood raised approximately two feet above the exhaust stack. The results are summarized in Table 14. Due to the silencing effect of its turbocharger, the Dash 8 had noticeably less exhaust noise than the GP38. For the GP38 at full power, and the Dash 8 at part-load, the exhaust hood reduced the average sound level by 6.8 dB(A). Since the dB measurement is logarithmic, this is equivalent to an actual 79% reduction in sound power level. For the Dash 8 at full load, non-exhaust sources such as cooling fans contributed significantly to the overall noise level, so that the percentage reduction was less.

Table 14: Noise measurements with and without the hood in place

	Leq dB(a)			**Pct Red. In**
	w/o Hood	**w Hood**	**Reduction**	**Sound Energy**
Dash 8				
Notch 8	87.0	81.7	5.3	70%
Notch 5	84.5	77.7	6.8	79%
GP 38				
Notch 8	91.6	84.8	6.8	79%

5. REFERENCES

[1] California Air Resources Board, Roseville Railyard Study, October, 2004.

[2] C.S. Weaver and L.E. Petty, Start-Up and Idling Emissions from Two Locomotives, report under South Coast Air Quality Management District contract No. 00112, Engine, Fuel, and Emissions Engineering, Inc. January 16, 2006.

Appendix C. Laboratory Report of Fuel Analysis

Saybolt
A CORE LABORATORIES COMPANY

SAYBOLT LP
21730 S. Wilmington Avenue
Suite 201
Carson, CA 90810
310-518-4400 Telephone
310-518-4455 Facsimile

Fast To The Point

Saybolt LP

Certificate of Analysis

ENGING, FUEL & EMISSIONS ENGINEERING, INC.
LARRY PETTY
3215 LUYUNG DRIVE
RANCHO CORDOVA, CA 95742

ORIGINAL

Report Date:	9/30/2006	Date Sampled:	
Job No:	13091-00002913	Product:	Diesel Fuel
Sample Number:	601719-01	Location:	Rancho Cordova, CA
Client Ref:		Sample ID:	Desl- 8 # 1
		Vessel:	

Test	Method	Result	Units
Carbon/Hydrogen /Nitrogen Content			
Carbon Content	ASTM D-5291M	86.00	wt%
Hydrogen Content	ASTM D-5291M	13.33	wt%
Nitrogen Content	ASTM D-5291M	0.05	wt%
Total Sulfur	ASTM D-4294	0.060	wt%

*Analysis results for D5291M are submitted by a third party laboratory. Saybolt was not present whilst the analysis was carried out, and has signed for receipt only with no liability accepted.

Approved By: Signature On File
Ken Nabl
Laboratory Manager

Saybolt
A CORE LABORATORIES COMPANY

SAYBOLT LP
21730 S. Wilmington Avenue
Suite 201
Carson, CA 90810
310-518-4400 Telephone
310-518-4455 Facsimile

Fast To The Point

Saybolt LP

Certificate of Analysis

ENGING, FUEL & EMISSIONS ENGINEERING, INC.
LARRY PETTY
3215 LUYUNG DRIVE
RANCHO CORDOVA, CA 95742

		Date Sampled:	
Report Date:	9/30/2006	Product:	Diesel Fuel
Job No:	13091-00002913	Location:	Rancho Cordova, CA
Sample Number:	601719-02	Sample ID:	TP38
Client Ref:		Vessel:	

Test	Method	Result	Units
Carbon/Hydrogen /Nitrogen Content			
Carbon Content	ASTM D-5291M	86.10	wt%
Hydrogen Content	ASTM D-5291M	13.73	wt%
Nitrogen Content	ASTM D-5291M	0.06	wt%
Total Sulfur	ASTM D-4294	<0.0150	wt%

*Analysis results for D5291M are submitted by a third party laboratory. Saybolt was not present whilst the analysis was carried out, and has signed for receipt only with no liability accepted.

Approved By: Signature On File
Ken Nabl
Laboratory Manager

Appendix D. Laboratory Reports on Solid and Wastewater Analyses

CAL TECH Environmental Laboratories
6814 Rosecrans Avenue. Paramount. CA 90723-3146
Telephone: (562) 272-2700 Fax: (562) 272-2789

ANALYTICAL RESULTS*

CTEL Project No: CT-0701092
Client Name: ACTI
18414 S. Santa Fe Ave.
Rancho Dominguez, CA 90221
Phone:(310) 763-1423
Fax: (310) 763-9076
Attention: Mr. John Powel

Project ID:
Project Name: UPRP

Date Sampled: 01/05/07 @ 13:00 p.m.
Date Received: 01/12/07 @ 17:00 p.m.
Date Analyzed 01/12/07 – 01/18/07
Matrix: Solid

Laboratory ID:	0701-092-1	0701-092-2	**Method**	**Units:**	**Detection Limit**
Client Sample ID:	ROC #89	R21 #7			
Dilution	100	100			
Dichlorodifluoromethane	ND	ND	EPA 8260B	mg/Kg	0.005
Chloromethane	ND	ND	EPA 8260B	mg/Kg	0.005
Vinyl Chloride	ND	ND	EPA 8260B	mg/Kg	0.005
Bromomethane	ND	ND	EPA 8260B	mg/Kg	0.005
Chloroethane	ND	ND	EPA 8260B	mg/Kg	0.005
Trichlorofluoromethane	ND	ND	EPA 8260B	mg/Kg	0.005
Iodomethane	ND	ND	EPA 8260B	mg/Kg	0.005
Acetone	ND	ND	EPA 8260B	mg/Kg	0.005
1,1-Dichloroethene	ND	ND	EPA 8260B	mg/Kg	0.005
t-Butyl Alcohol (TBA)	ND	ND	EPA 8260B	mg/Kg	0.020
Methylene Chloride	ND	ND	EPA 8260B	mg/Kg	0.02
Freon 113	ND	ND	EPA 8260B	mg/Kg	0.01
Carbon disulfide	ND	ND	EPA 8260B	mg/Kg	0.005
Trans,1,2-Dichloroethene	ND	ND	EPA 8260B	mg/Kg	0.005
Methyl-tert-butyl-ether(MtBE)	ND	ND	EPA 8260B	mg/Kg	0.002
1,1-Dichloroethane	ND	ND	EPA 8260B	mg/Kg	0.005
Vinyl acetate	ND	ND	EPA 8260B	mg/Kg	0.005
Diisopropyl Ether (DIPE)	ND	ND	EPA 8260B	mg/Kg	0.002
Methyl Ethyl Ketone	ND	ND	EPA 8260B	mg/Kg	0.01
Cis,1,2-Dichloroethene	ND	ND	EPA 8260B	mg/Kg	0.005
Bromochloromethane	ND	ND	EPA 8260B	mg/Kg	0.005
Chloroform	ND	ND	EPA 8260B	mg/Kg	0.005
2,2-Dichloropropane	ND	ND	EPA 8260B	mg/Kg	0.005
Ethyl-t-butyl ether (ETBE)	ND	ND	EPA 8260B	mg/Kg	0.002
1,1,1-Trichloroethane	ND	ND	EPA 8260B	mg/Kg	0.005
1,2-Dichloroethane	ND	ND	EPA 8260B	mg/Kg	0.005
1,1-Dichloropropene	ND	ND	EPA 8260B	mg/Kg	0.005
Carbon Tetrachloride	ND	ND	EPA 8260B	mg/Kg	0.005
Benzene	ND	ND	EPA 8260B	mg/Kg	0.001
t-Amyl Methyl Ether (TAME)	ND	ND	EPA 8260B	mg/Kg	0.002
1,2-Dichloropropane	ND	ND	EPA 8260B	mg/Kg	0.005
Trichloroethene	ND	ND	EPA 8260B	mg/Kg	0.005
Dibromomethane	ND	ND	EPA 8260B	mg/Kg	0.005
Bromodichloromethane	ND	ND	EPA 8260B	mg/Kg	0.005
2-Chloroethylvinylether	ND	ND	EPA 8260B	mg/Kg	0.005
Cis, 1,3-Dichloropropene	ND	ND	EPA 8260B	mg/Kg	0.005
4-Methyl-2-pentanone(MI)	ND	ND	EPA 8260B	mg/Kg	0.01
Trans,1,3-Dichloropropene	ND	ND	EPA 8260B	mg/Kg	0.005
Toluene	ND	ND	EPA 8260B	mg/Kg	0.001
1,1,2-Trichloroethane	ND	ND	EPA 8260B	mg/Kg	0.005

CTEL Project No:	CT-0701092
Project ID:	
Project Name:	UPRP

Laboratory ID: / **Client Sample ID:**	0701-092-1 ROC #89	0701-092-2 R21 #7	**Method**	**Units**	**Detection Limit**
1,2-Dibromoethane(EDB)	ND	ND	EPA 8260B	mg/Kg	0.005
1,3-Dichloropropane	ND	ND	EPA 8260B	mg/Kg	0.005
Dibromochloromethane	ND	ND	EPA 8260B	mg/Kg	0.005
2-Hexanone	ND	ND	EPA 8260B	mg/Kg	0.01
Tetrachloroethene	ND	ND	EPA 8260B	mg/Kg	0.005
Chlorobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
1,1,1,2-Tetrachloroethane	ND	ND	EPA 8260B	mg/Kg	0.005
Ethylbenzene	ND	ND	EPA 8260B	mg/Kg	0.001
m.p-Xylene	ND	ND	EPA 8260B	mg/Kg	0.001
Bromoform	ND	ND	EPA 8260B	mg/Kg	0.005
Styrene	ND	ND	EPA 8260B	mg/Kg	0.005
o-Xylene	ND	ND	EPA 8260B	mg/Kg	0.001
1,1,2,2-Tetrachloroethane	ND	ND	EPA 8260B	mg/Kg	0.005
1,2,3-Trichloropropane	ND	ND	EPA 8260B	mg/Kg	0.005
Isopropylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
Bromobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
2-Chlorotoluene	ND	ND	EPA 8260B	mg/Kg	0.005
n-Propylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
4-Chlorotoluene	ND	ND	EPA 8260B	mg/Kg	0.005
1,3,5-Trimethylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
Tert-Butylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
1,2,4-Trimethylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
Sec-Butylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
1,3-Dichlorobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
1,4-Dichlorobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
p-Isopropyltoluene	ND	ND	EPA 8260B	mg/Kg	0.005
1,2-Dichlorobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
n-Butylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
1,2 Dibromo-3-Chloropropane	ND	ND	EPA 8260B	mg/Kg	0.005
1,2,4-Trichlorobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
Naphthalene	ND	ND	EPA 8260B	mg/Kg	0.005
1,2,3-Trichlorobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
Hexachlorobutadiene	ND	ND	EPA 8260B	mg/Kg	0.005
Oil & Grease	85000	78000	EPA 413.2	mg/Kg	10
TRPH	88000	80000	EPA 418.1	mg/Kg	10

ND = Not Detected at the indicated Detection Limit

SURROGATE SPIKE	% SURROGATE RECOVERY		Control Limit
Dibromofluoromethane	97	96	70-130
1,2 Dichloromethaned4	119	120	70-130
Toluene-d8	101	102	70-130
Bromofluorobenzene	113	115	70-130

CTEL Project No: CT-0701092

Project ID:
Project Name: UPRP

Laboratory ID: / **Client Sample ID:**	0701-092-1 ROC #89	0701-092-2 R21 #7	**Method**	**Units**	**Detection Limit**
1,2-Dibromoethane(EDB)	ND	ND	EPA 8260B	mg/Kg	0.005
1,3-Dichloropropane	ND	ND	EPA 8260B	mg/Kg	0.005
Dibromochloromethane	ND	ND	EPA 8260B	mg/Kg	0.005
2-Hexanone	ND	ND	EPA 8260B	mg/Kg	0.01
Tetrachloroethene	ND	ND	EPA 8260B	mg/Kg	0.005
Chlorobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
1,1,1,2-Tetrachloroethane	ND	ND	EPA 8260B	mg/Kg	0.005
Ethylbenzene	ND	ND	EPA 8260B	mg/Kg	0.001
m.p-Xylene	ND	ND	EPA 8260B	mg/Kg	0.001
Bromoform	ND	ND	EPA 8260B	mg/Kg	0.005
Styrene	ND	ND	EPA 8260B	mg/Kg	0.005
o-Xylene	ND	ND	EPA 8260B	mg/Kg	0.001
1,1,2,2-Tetrachloroethane	ND	ND	EPA 8260B	mg/Kg	0.005
1,2,3-Trichloropropane	ND	ND	EPA 8260B	mg/Kg	0.005
Isopropylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
Bromobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
2-Chlorotoluene	ND	ND	EPA 8260B	mg/Kg	0.005
n-Propylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
4-Chlorotoluene	ND	ND	EPA 8260B	mg/Kg	0.005
1,3,5-Trimethylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
Tert-Butylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
1,2,4-Trimethylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
Sec-Butylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
1,3-Dichlorobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
1,4-Dichlorobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
p-Isopropyltoluene	ND	ND	EPA 8260B	mg/Kg	0.005
1,2-Dichlorobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
n-Butylbenzene	ND	ND	EPA 8260B	mg/Kg	0.005
1,2 Dibromo-3-Chloropropane	ND	ND	EPA 8260B	mg/Kg	0.005
1,2,4-Trichlorobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
Naphthalene	ND	ND	EPA 8260B	mg/Kg	0.005
1,2,3-Trichlorobenzene	ND	ND	EPA 8260B	mg/Kg	0.005
Hexachlorobutadiene	ND	ND	EPA 8260B	mg/Kg	0.005
Oil & Grease	85000	78000	EPA 413.2	mg/Kg	10
TRPH	88000	80000	EPA 418.1	mg/Kg	10

ND = Not Detected at the indicated Detection Limit

SURROGATE SPIKE	% SURROGATE RECOVERY		Control Limit
Dibromofluoromethane	97	96	70-130
1,2 Dichloromethaned4	119	120	70-130
Toluene-d8	101	102	70-130
Bromofluorobenzene	113	115	70-130

CALIFORNIA LABORATORY SERVICES

3249 Fitzgerald Road Rancho Cordova, CA 95742

January 09, 2007

CLS Work Order #: CPJ0336
COC #: 76759

Robert Puga
ACTI
18414 So. Santa Fe Avenue
Rancho Dominguez, CA 90221

Project Name: Alecs

Enclosed are the results of analyses for samples received by the laboratory on 10/09/06 17:35. Samples were analyzed pursuant to client request utilizing EPA or other ELAP approved methodologies. I certify that the results are in compliance both technically and for completeness.

Analytical results are attached to this letter. Please call if we can provide additional assistance.

Sincerely,

James Liang, Ph.D.
Laboratory Director

CA DOHS ELAP Accreditation/Registration number 1233

CALIFORNIA LABORATORY SERVICES

01/09/07 09:13

ACTI
18414 So. Santa Fe Avenue
Rancho Dominguez, CA 90221

Project: Alecs
Project Number: [none]
Project Manager: Robert Puga

CLS Work Order #: CPJ0336
COC #: 76759

Conventional Chemistry Parameters by APHA/EPA Methods

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
East Side Tank (CPJ0336-01) Water	**Sampled: 10/09/06 16:35**	**Received: 10/09/06 17:35**							
Specific Conductance (EC)	**2300**	1.0	µmhos/cm	1	CP07821	10/10/06	10/10/06	EPA 120.1	
Fluoride	**2.5**	2.0	mg/L	20	CP07801	10/10/06	10/10/06	EPA 300.0	
Chloride	**17**	10	"	"	"	"	"	"	
Nitrite as NO2	**500**	50	"	100	"	"	"	"	
Bromide	**0.59**	0.10	"	1	"	"	"	"	
Nitrate as NO3	**1.5**	0.50	"	"	"	"	"	"	
Sulfate as SO4	**260**	10	"	20	"	"	"	"	
Hexane Extractable Material (HEM)	**33**	5.0	"	1	CP07807	10/10/06	10/10/06	EPA 1664	
pH	**8.58**	0.001	pH Units	"	CP07805	10/10/06	10/10/06	EPA 150.1	
Orthophosphate as PO4	ND	0.15	mg/L	"	CP07829	10/10/06	10/10/06	EPA 365.2	
Total Dissolved Solids	**1800**	10	"	"	CP07817	10/10/06	10/11/06	EPA 160.1	
Total Suspended Solids	**34**	5.0	"	"	CP07816	10/10/06	10/11/06	EPA 160.2	
West Side Tank (CPJ0336-02) Water	**Sampled: 10/09/06 16:40**	**Received: 10/09/06 17:35**							
Specific Conductance (EC)	**2200**	1.0	µmhos/cm	1	CP07821	10/10/06	10/10/06	EPA 120.1	
Fluoride	**2.0**	1.0	mg/L	10	CP07801	10/10/06	10/10/06	EPA 300.0	
Chloride	**12**	5.0	"	"	"	"	"	"	
Nitrite as NO2	**570**	50	"	100	"	"	"	"	
Bromide	**0.38**	0.10	"	1	"	"	"	"	
Nitrate as NO3	**1.9**	0.50	"	"	"	"	"	"	
Sulfate as SO4	**210**	5.0	"	10	"	"	"	"	
Hexane Extractable Material (HEM)	**73**	7.6	"	1	CP07807	10/10/06	10/10/06	EPA 1664	
pH	**8.56**	0.001	pH Units	"	CP07805	10/10/06	10/10/06	EPA 150.1	
Orthophosphate as PO4	ND	0.15	mg/L	"	CP07829	10/10/06	10/10/06	EPA 365.2	
Total Dissolved Solids	**1600**	10	"	"	CP07817	10/10/06	10/11/06	EPA 160.1	
Total Suspended Solids	**34**	5.0	"	"	CP07816	10/10/06	10/11/06	EPA 160.2	

CALIFORNIA LABORATORY SERVICES

01/09/07 09:13

ACTI
18414 So. Santa Fe Avenue
Rancho Dominguez, CA 90221

Project: Alecs
Project Number: [none]
Project Manager: Robert Puga

CLS Work Order #: CPJ0336
COC #: 76759

Metals by EPA 200 Series Methods

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
East Side Tank (CPJ0336-01) Water	**Sampled: 10/09/06 16:35**	**Received: 10/09/06 17:35**							
Aluminum	**110**	50	µg/L	1	CP07833	10/10/06	10/11/06	EPA 200.7	
Antimony	ND	50	"	"	"	"	"	"	
Arsenic	ND	100	"	"	"	"	"	"	
Barium	**35**	20	"	"	"	"	"	"	
Beryllium	ND	5.0	"	"	"	"	"	"	
Cadmium	ND	10	"	"	"	"	"	"	
Calcium	**45000**	1000	"	"	"	"	"	"	
Chromium	**11**	10	"	"	"	"	"	"	
Cobalt	ND	20	"	"	"	"	"	"	
Copper	ND	10	"	"	"	"	"	"	
Iron	**100**	100	"	"	"	"	"	"	
Lead	ND	50	"	"	"	"	"	"	
Magnesium	**3100**	1000	"	"	"	"	"	"	
Manganese	ND	20	"	"	"	"	"	"	
Molybdenum	**300**	20	"	"	"	"	"	"	
Nickel	ND	20	"	"	"	"	"	"	
Potassium	**2400**	1000	"	"	"	"	"	"	
Selenium	ND	100	"	"	"	"	"	"	
Silver	ND	10	"	"	"	"	"	"	
Sodium	**510000**	1000	"	"	"	"	"	"	
Strontium	**130**	20	"	"	"	"	"	"	
Thallium	ND	200	"	"	"	"	"	"	
Vanadium	ND	20	"	"	"	"	"	"	
Zinc	**75**	20	"	"	"	"	"	"	
Boron	**250**	50	"	"	"	"	"	"	
Tin	ND	100	"	"	"	"	"	"	
Titanium	ND	50	"	"	"	"	"	"	

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CALIFORNIA LABORATORY SERVICES

01/09/07 09:13

ACTI 18414 So. Santa Fe Avenue Rancho Dominguez, CA 90221	Project: Alecs Project Number: [none] Project Manager: Robert Puga	**CLS Work Order #: CPJ0336** COC #: 76759

Conventional Chemistry Parameters by APHA/EPA Methods

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
East Side Tank (CPJ0336-01) Water	**Sampled: 10/09/06 16:35**	**Received: 10/09/06 17:35**							
Specific Conductance (EC)	**2300**	1.0	µmhos/cm	1	CP07821	10/10/06	10/10/06	EPA 120.1	
Fluoride	**2.5**	2.0	mg/L	20	CP07801	10/10/06	10/10/06	EPA 300.0	
Chloride	**17**	10	"	"	"	"	"	"	
Nitrite as NO2	**500**	50	"	100	"	"	"	"	
Bromide	**0.59**	0.10	"	1	"	"	"	"	
Nitrate as NO3	**1.5**	0.50	"	"	"	"	"	"	
Sulfate as SO4	**260**	10	"	20	"	"	"	"	
Hexane Extractable Material (HEM)	**33**	5.0	"	1	CP07807	10/10/06	10/10/06	EPA 1664	
pH	**8.58**	0.001	pH Units	"	CP07805	10/10/06	10/10/06	EPA 150.1	
Orthophosphate as PO4	ND	0.15	mg/L	"	CP07829	10/10/06	10/10/06	EPA 365.2	
Total Dissolved Solids	**1800**	10	"	"	CP07817	10/10/06	10/11/06	EPA 160.1	
Total Suspended Solids	**34**	5.0	"	"	CP07816	10/10/06	10/11/06	EPA 160.2	
West Side Tank (CPJ0336-02) Water	**Sampled: 10/09/06 16:40**	**Received: 10/09/06 17:35**							
Specific Conductance (EC)	**2200**	1.0	µmhos/cm	1	CP07821	10/10/06	10/10/06	EPA 120.1	
Fluoride	**2.0**	1.0	mg/L	10	CP07801	10/10/06	10/10/06	EPA 300.0	
Chloride	**12**	5.0	"	"	"	"	"	"	
Nitrite as NO2	**570**	50	"	100	"	"	"	"	
Bromide	**0.38**	0.10	"	1	"	"	"	"	
Nitrate as NO3	**1.9**	0.50	"	"	"	"	"	"	
Sulfate as SO4	**210**	5.0	"	10	"	"	"	"	
Hexane Extractable Material (HEM)	**73**	7.6	"	1	CP07807	10/10/06	10/10/06	EPA 1664	
pH	**8.56**	0.001	pH Units	"	CP07805	10/10/06	10/10/06	EPA 150.1	
Orthophosphate as PO4	ND	0.15	mg/L	"	CP07829	10/10/06	10/10/06	EPA 365.2	
Total Dissolved Solids	**1600**	10	"	"	CP07817	10/10/06	10/11/06	EPA 160.1	
Total Suspended Solids	**34**	5.0	"	"	CP07816	10/10/06	10/11/06	EPA 160.2	

CALIFORNIA LABORATORY SERVICES

3249 Fitzgerald Road Rancho Cordova, CA 95742

January 09, 2007

CLS Work Order #: CPJ0336
COC #: 76759

Robert Puga
ACTI
18414 So. Santa Fe Avenue
Rancho Dominguez, CA 90221

Project Name: Alecs

Enclosed are the results of analyses for samples received by the laboratory on 10/09/06 17:35. Samples were analyzed pursuant to client request utilizing EPA or other ELAP approved methodologies. I certify that the results are in compliance both technically and for completeness.

Analytical results are attached to this letter. Please call if we can provide additional assistance.

Sincerely,

James Liang, Ph.D.
Laboratory Director

CA DOHS ELAP Accreditation/Registration number 1233

ACTI
18414 So. Santa Fe Avenue
Rancho Dominguez, CA 90221

Project: Alecs
Project Number: [none]
Project Manager: Robert Puga

CLS Work Order #: CPJ0336
COC #: 76759

Conventional Chemistry Parameters by APHA/EPA Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP07801 - General Prep										
Matrix Spike Dup (CP07801-MSD1)		**Source: CPJ0343-01**		Prepared & Analyzed: 10/10/06						
Fluoride	2.34	0.10	mg/L	2.00	0.19	108	75-125	4.37	25	
Chloride	9.24	0.50	"	2.00	7.3	97.0	75-125	2.08	25	
Nitrite as NO2	2.02	0.50	"	2.00	ND	101	75-125	4.04	25	
Bromide	2.11	0.10	"	2.00	ND	106	75-125	3.37	25	
Nitrate as NO3	2.14	0.50	"	2.00	ND	107	75-125	3.33	25	
Sulfate as SO4	17.2	0.50	"	5.00	12	104	75-125	2.35	25	
Batch CP07807 - Solvent Extract										
Blank (CP07807-BLK1)				Prepared & Analyzed: 10/10/06						
Hexane Extractable Material (HEM)	ND	5.0	mg/L							
LCS (CP07807-BS1)				Prepared & Analyzed: 10/10/06						
Hexane Extractable Material (HEM)	41.1	5.0	mg/L	40.0		103	80-120		20	
LCS Dup (CP07807-BSD1)				Prepared & Analyzed: 10/10/06						
Hexane Extractable Material (HEM)	41.3	5.0	mg/L	40.0		103	80-120	0.485	20	
Batch CP07816 - General Preparation										
Blank (CP07816-BLK1)				Prepared: 10/10/06 Analyzed: 10/11/06						
Total Suspended Solids	ND	5.0	mg/L							
Batch CP07817 - General Preparation										
Blank (CP07817-BLK1)				Prepared: 10/10/06 Analyzed: 10/11/06						
Total Dissolved Solids	ND	10	mg/L							

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ACTI 18414 So. Santa Fe Avenue Rancho Dominguez, CA 90221	Project: Alecs Project Number: [none] Project Manager: Robert Puga	**CLS Work Order #: CPJ0336** COC #: 76759

Conventional Chemistry Parameters by APHA/EPA Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP07821 - General Preparation										
Blank (CP07821-BLK1)				Prepared & Analyzed: 10/10/06						
Specific Conductance (EC)	ND	1.0	µmhos/cm							
Batch CP07829 - General Preparation										
Blank (CP07829-BLK1)				Prepared & Analyzed: 10/10/06						
Orthophosphate as PO4	ND	0.15	mg/L							
LCS (CP07829-BS1)				Prepared & Analyzed: 10/10/06						
Orthophosphate as PO4	0.947	0.15	mg/L	0.918		103	80-120		20	
LCS Dup (CP07829-BSD1)				Prepared & Analyzed: 10/10/06						
Orthophosphate as PO4	0.907	0.15	mg/L	0.918		98.8	80-120	4.31	20	
Matrix Spike (CP07829-MS1)	**Source: CPJ0342-01**			Prepared & Analyzed: 10/10/06						
Orthophosphate as PO4	0.947	0.15	mg/L	0.918	0.013	102	75-125		25	
Matrix Spike Dup (CP07829-MSD1)	**Source: CPJ0342-01**			Prepared & Analyzed: 10/10/06						
Orthophosphate as PO4	0.943	0.15	mg/L	0.918	0.013	101	75-125	0.423	25	

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 01/09/07 09:13

ACTI 18414 So. Santa Fe Avenue Rancho Dominguez, CA 90221	Project: Alecs Project Number: [none] Project Manager: Robert Puga	**CLS Work Order #: CPJ0336** COC #: 76759

Metals by EPA 200 Series Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP07833 - EPA 3010A										
Blank (CP07833-BLK1)				Prepared & Analyzed: 10/10/06						
Aluminum	ND	50	µg/L							
Antimony	ND	50	"							
Arsenic	ND	100	"							
Barium	ND	20	"							
Beryllium	ND	5.0	"							
Cadmium	ND	10	"							
Calcium	ND	1000	"							
Chromium	ND	10	"							
Cobalt	ND	20	"							
Copper	ND	10	"							
Iron	ND	100	"							
Lead	ND	50	"							
Magnesium	ND	1000	"							
Manganese	ND	20	"							
Molybdenum	ND	20	"							
Nickel	ND	20	"							
Potassium	ND	1000	"							
Selenium	ND	100	"							
Silver	ND	10	"							
Sodium	ND	1000	"							
Strontium	ND	20	"							
Thallium	ND	200	"							
Vanadium	ND	20	"							
Zinc	ND	20	"							
Boron	ND	50	"							
Tin	ND	100	"							
Titanium	ND	50	"							

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ACTI 18414 So. Santa Fe Avenue Rancho Dominguez, CA 90221	Project: Alecs Project Number: [none] Project Manager: Robert Puga	**CLS Work Order #: CPJ0336** COC #: 76759

Metals by EPA 200 Series Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP07833 - EPA 3010A										
LCS (CP07833-BS1)				Prepared & Analyzed: 10/10/06						
Aluminum	1720	50	µg/L	2000		86.0	80-120		20	
Antimony	418	50	"	500		83.6	80-120		20	
Arsenic	2260	100	"	2000		113	80-120		20	
Barium	1840	20	"	2000		92.0	80-120		20	
Beryllium	44.3	5.0	"	50.0		88.6	80-120		20	
Cadmium	43.9	10	"	50.0		87.8	80-120		20	
Calcium	8690	1000	"	10000		86.9	80-120		20	
Chromium	190	10	"	200		95.0	80-120		20	
Cobalt	455	20	"	500		91.0	80-120		20	
Copper	235	10	"	250		94.0	80-120		20	
Iron	890	100	"	1000		89.0	80-120		20	
Lead	463	50	"	500		92.6	80-120		20	
Magnesium	8970	1000	"	10000		89.7	80-120		20	
Manganese	452	20	"	500		90.4	80-120		20	
Molybdenum	455	20	"	500		91.0	80-120		20	
Nickel	440	20	"	500		88.0	80-120		20	
Potassium	9120	1000	"	10000		91.2	80-120		20	
Selenium	1790	100	"	2000		89.5	80-120		20	
Silver	46.5	10	"	50.0		93.0	80-120		20	
Sodium	9120	1000	"	10000		91.2	80-120		20	
Strontium	464	20	"	500		92.8	80-120		20	
Thallium	1720	200	"	2000		86.0	80-120		20	
Vanadium	457	20	"	500		91.4	80-120		20	
Zinc	473	20	"	500		94.6	80-120		20	
Boron	2240	50	"	2500		89.6	80-120		20	
Tin	1970	100	"	2000		98.5	80-120		20	
Titanium	1820	50	"	2000		91.0	80-120		20	

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ACTI
18414 So. Santa Fe Avenue
Rancho Dominguez, CA 90221

Project: Alecs
Project Number: [none]
Project Manager: Robert Puga

CLS Work Order #: CPJ0336
COC #: 76759

Metals by EPA 200 Series Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP07833 - EPA 3010A										
LCS Dup (CP07833-BSD1)				Prepared & Analyzed: 10/10/06						
Aluminum	1710	50	µg/L	2000		85.5	80-120	0.583	20	
Antimony	431	50	"	500		86.2	80-120	3.06	20	
Arsenic	2250	100	"	2000		112	80-120	0.443	20	
Barium	1830	20	"	2000		91.5	80-120	0.545	20	
Beryllium	43.3	5.0	"	50.0		86.6	80-120	2.28	20	
Cadmium	41.0	10	"	50.0		82.0	80-120	6.83	20	
Calcium	8580	1000	"	10000		85.8	80-120	1.27	20	
Chromium	189	10	"	200		94.5	80-120	0.528	20	
Cobalt	451	20	"	500		90.2	80-120	0.883	20	
Copper	233	10	"	250		93.2	80-120	0.855	20	
Iron	883	100	"	1000		88.3	80-120	0.790	20	
Lead	458	50	"	500		91.6	80-120	1.09	20	
Magnesium	8900	1000	"	10000		89.0	80-120	0.783	20	
Manganese	447	20	"	500		89.4	80-120	1.11	20	
Molybdenum	457	20	"	500		91.4	80-120	0.439	20	
Nickel	440	20	"	500		88.0	80-120	0.00	20	
Potassium	9110	1000	"	10000		91.1	80-120	0.110	20	
Selenium	1780	100	"	2000		89.0	80-120	0.560	20	
Silver	46.0	10	"	50.0		92.0	80-120	1.08	20	
Sodium	9030	1000	"	10000		90.3	80-120	0.992	20	
Strontium	459	20	"	500		91.8	80-120	1.08	20	
Thallium	1750	200	"	2000		87.5	80-120	1.73	20	
Vanadium	452	20	"	500		90.4	80-120	1.10	20	
Zinc	466	20	"	500		93.2	80-120	1.49	20	
Boron	2220	50	"	2500		88.8	80-120	0.897	20	
Tin	1940	100	"	2000		97.0	80-120	1.53	20	
Titanium	1810	50	"	2000		90.5	80-120	0.551	20	

ACTI 18414 So. Santa Fe Avenue Rancho Dominguez, CA 90221	Project: Alecs Project Number: [none] Project Manager: Robert Puga	**CLS Work Order #: CPJ0336** COC #: 76759

Metals by EPA 200 Series Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP07833 - EPA 3010A										
Matrix Spike (CP07833-MS1)		**Source: CPJ0343-01**		Prepared & Analyzed: 10/10/06						
Aluminum	1660	50	µg/L	2000	ND	83.0	75-125		25	
Antimony	433	50	"	500	ND	86.6	75-125		25	
Arsenic	2100	100	"	2000	ND	105	75-125		25	
Barium	1880	20	"	2000	130	87.5	75-125		25	
Beryllium	42.0	5.0	"	50.0	ND	84.0	75-125		25	
Cadmium	35.8	10	"	50.0	ND	71.6	75-125		25	QM-7
Calcium	14800	1000	"	10000	7600	72.0	75-125		25	QM-7
Chromium	176	10	"	200	ND	88.0	75-125		25	
Cobalt	424	20	"	500	ND	84.8	75-125		25	
Copper	225	10	"	250	ND	90.0	75-125		25	
Iron	2450	100	"	1000	1800	65.0	75-125		25	QM-7
Lead	439	50	"	500	ND	87.8	75-125		25	
Magnesium	12200	1000	"	10000	3700	85.0	75-125		25	
Manganese	889	20	"	500	510	75.8	75-125		25	
Molybdenum	433	20	"	500	ND	86.6	75-125		25	
Nickel	410	20	"	500	ND	82.0	75-125		25	
Potassium	14100	1000	"	10000	5400	87.0	75-125		25	
Selenium	1680	100	"	2000	ND	84.0	75-125		25	
Silver	26.2	10	"	50.0	3.0	46.4	75-125		25	QM-7
Sodium	25800	1000	"	10000	17000	88.0	75-125		25	
Strontium	546	20	"	500	110	87.2	75-125		25	
Thallium	1700	200	"	2000	ND	85.0	75-125		25	
Vanadium	427	20	"	500	ND	85.4	75-125		25	
Zinc	494	20	"	500	60	86.8	75-125		25	
Boron	2140	50	"	2500	32	84.3	75-125		25	
Tin	1860	100	"	2000	ND	93.0	75-125		25	
Titanium	1730	50	"	2000	ND	86.5	75-125		25	

CALIFORNIA LABORATORY SERVICES

 01/09/07 09:13

ACTI
18414 So. Santa Fe Avenue
Rancho Dominguez, CA 90221

Project: Alecs
Project Number: [none]
Project Manager: Robert Puga

CLS Work Order #: CPJ0336
COC #: 76759

Metals by EPA 200 Series Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP07833 - EPA 3010A										
Matrix Spike Dup (CP07833-MSD1)		**Source: CPJ0343-01**		Prepared & Analyzed: 10/10/06						
Aluminum	1640	50	µg/L	2000	ND	82.0	75-125	1.21	25	
Antimony	430	50	"	500	ND	86.0	75-125	0.695	25	
Arsenic	2080	100	"	2000	ND	104	75-125	0.957	25	
Barium	1870	20	"	2000	130	87.0	75-125	0.533	25	
Beryllium	41.9	5.0	"	50.0	ND	83.8	75-125	0.238	25	
Cadmium	38.0	10	"	50.0	ND	76.0	75-125	5.96	25	
Calcium	14800	1000	"	10000	7600	72.0	75-125	0.00	25	QM-7
Chromium	173	10	"	200	ND	86.5	75-125	1.72	25	
Cobalt	422	20	"	500	ND	84.4	75-125	0.473	25	
Copper	219	10	"	250	ND	87.6	75-125	2.70	25	
Iron	2440	100	"	1000	1800	64.0	75-125	0.409	25	QM-7
Lead	424	50	"	500	ND	84.8	75-125	3.48	25	
Magnesium	12100	1000	"	10000	3700	84.0	75-125	0.823	25	
Manganese	885	20	"	500	510	75.0	75-125	0.451	25	
Molybdenum	429	20	"	500	ND	85.8	75-125	0.928	25	
Nickel	409	20	"	500	ND	81.8	75-125	0.244	25	
Potassium	13900	1000	"	10000	5400	85.0	75-125	1.43	25	
Selenium	1680	100	"	2000	ND	84.0	75-125	0.00	25	
Silver	31.2	10	"	50.0	3.0	56.4	75-125	17.4	25	QM-7
Sodium	25600	1000	"	10000	17000	86.0	75-125	0.778	25	
Strontium	544	20	"	500	110	86.8	75-125	0.367	25	
Thallium	1710	200	"	2000	ND	85.5	75-125	0.587	25	
Vanadium	424	20	"	500	ND	84.8	75-125	0.705	25	
Zinc	495	20	"	500	60	87.0	75-125	0.202	25	
Boron	2130	50	"	2500	32	83.9	75-125	0.468	25	
Tin	1860	100	"	2000	ND	93.0	75-125	0.00	25	
Titanium	1720	50	"	2000	ND	86.0	75-125	0.580	25	

ACTI 18414 So. Santa Fe Avenue Rancho Dominguez, CA 90221	Project: Alecs Project Number: [none] Project Manager: Robert Puga	**CLS Work Order #: CPJ0336** COC #: 76759

Notes and Definitions

QM-7	The spike recovery was outside acceptance limits for the MS and/or MSD. The batch was accepted based on acceptable LCS/LCSD recovery.
DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference

3249 Fitzgerald Road Rancho Cordova, CA 95742 www.californialab.com 916-638-7301 Fax: 916-638-4510

Evaluation of the Advanced Maritime Emissions Control System (AMECS)

AMECS Demonstration at the Port of Long Beach, California

Report to

South Coast Air Quality Management District (SCAQMD)
Technology Advancement Office
21865 Copley Drive
Diamond Bar, CA 91765-4182

Date: 11/19/08

Prepared by
Michael Chan
Michael D. Jackson
TIAX LLC
20813 Stevens Creek Blvd., Suite 250
Cupertino, California 95014-2107

TIAX Case D5593

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Executive Summary

The Port of Long Beach (the port or POLB) is a major international gateway for commerce entering California (and the United States) and one of the world's busiest seaports. The demand for goods moving through the San Pedro Bay region is expected to double before the year 2020. The POLB's ability to accommodate the growth in trade will depend upon their ability to address adverse environmental impacts on air quality. In the South Coast Air Basin, 11% of particulate matter (PM) emissions, 5% oxides of nitrogen (NOx) emissions, and 32% oxides of sulfur (SOx) emissions are attributed to port-related emission from the POLB (Starcrest, June 2008).

The POLB's shipping terminals import and export more than $100 billion worth of goods and products every year to the region and nation.[1]

One of the major contributors to port-related emissions is ocean-going vessels. While docked at the port, the ocean-going vessels shut off their propulsion engines, but use auxiliary diesel engines to power refrigeration, lights, pumps and other functions (activities commonly called 'hotelling'). Auxiliary boilers, also a significant source of particulate matter, heat the very viscous heavy fuel oil (often referred to as residual fuel or bunker fuel) that can be used for propulsion and/or auxiliary engines, heating of water for crew/passengers, and/or space heating of cabins while docked.

Diesel engines release harmful air pollutants, comprised of gaseous and solid material. The solid material in diesel exhaust is known as particulate matter. In 1998, the California Air Resources Board (CARB) identified diesel PM as a toxic air contaminant based on its potential to cause cancer, premature death, and other health problems.

Advanced Cleanup Technologies, Incorporated (ACTI) Advanced Maritime Emissions Control System (AMECS) is designed to significantly reduce harmful exhaust pollutants from the auxiliary engines and auxiliary boilers of ocean-going vessels while at berth or anchored within the port before they are exhausted into the surrounding environment.

Testing of ACTI's AMECS was performed at the Metropolitan Stevedore, Incorporated terminal Pier G, Berth 214 in the Port of Long Beach.

Metropolitan Stevedore, Incorporated is a leading petroleum coke terminal operator and handles stevedore operations in the Port of Long Beach, Berths 212 through 214, exporting cargoes such as petroleum coke, coal, potash, borax and soda ash.

AMECS consists of two major components: a) the Exhaust Capture System (ECS), which is the interface with the ship; and b) the Emissions Treatment System (ETS). The ECS captures the exhaust from the vessel and directs it through a duct into an emissions treatment system. An induced draft fan is used to draw the exhaust from the bonnet (which is attached to the vessel's stack) through the duct and into the ETS, where sulfur dioxide (SO_2), particulate matter (PM), nitrogen oxides (NOx) and volatile organic compounds (VOC) are removed.

[1] Downloaded 10/24/08: http://www.polb.com/economics/stats/default.asp

In 2007, preliminary testing of AMECS was conducted on the Western Seattle, a Handymax class, 45,630 dwt Bulk Cargo Vessel, using an Octagonal Capture Bonnet. The successful test led to the testing of AMECS on two bulk cargo vessels, the Queen Lily (see Figure 1) and the Angela, on May 26 and July 19, 2008 respectively for this report.

Figure 1. AMECS Attached to the Queen Lily

Table 1 summarizes the overall average control efficiencies resulting from the demonstration testing by an independent South Coast Air Quality Management District (SCAQMD) approved testing company of AMECS at the POLB. The emission source test reports were reviewed by the South Coast Air Quality Management District and the control efficiencies represent the performance of AMECS. For the cost effectiveness analysis, the NOx control efficiency was reduced to 97.6% to conservatively account for the estimated selective catalytic reduction reactor catalyst degradation over the estimated six year catalyst life.

Table 1. Summary of AMECS Pollutant Control Efficiencies

	NOx	PM	VOC	SO_2	CO
Overall Average Control Efficiency	>99.1%	95.0%	96.3%	99.8%	43.8%

The number of vessels serviced by each ETS is calculated based upon the peak flow rates of the auxiliary engine and auxiliary boiler. The pollutant emission rates for the auxiliary engine and auxiliary boiler for each vessel type were calculated from the average California hotelling loads and their respective emission factors. The average California hotelling times for each vessel call are given in Table 2 (CARB, June 2008). It is expected that AMECS will be installed in a location with a high berth occupancy rate to fully utilize AMECS' capacity. Conservatively, for this analysis, the dock (and hence AMECS) utilization is estimated at 65%. Both the Barge-Based and the Dock-Based ECS design utilize the same ETS. It is possible that the Barge-Based ECS would have a higher utilization rate than the Dock-Based ECS due to the Dock-Based ECS being limited to only treating vessels moored next to the dock and adjacent docks. The Barge-Based ECS was not demonstrated at the POLB. Therefore, the cost effectiveness analysis only examined the Dock-Based ECS. Table 3 presents the resulting estimated total annual auxiliary engine and auxiliary boiler emissions for each vessel type.

Table 2. Hotelling Time and Utilization

Vessel Type	Average Hotelling Time hours/call	Dock Utilization %	Dock Usage calls/year
Auto Carrier	18.4	65%	310
Bulk	64.5	65%	88
Container Ship	34.9	65%	163
General Cargo	46.1	65%	123
Passenger	11.7	20%	150
Reefer	41.9	65%	136
Roll-on/Roll-off	28.4	65%	200
Tanker	33.5	65%	170

Table 3. Annual Auxiliary Engine & Boiler Emissions per Vessel Type

Vessel Type	PM ton/yr	NOx ton/yr	SOx ton/yr	VOC ton/yr	CO ton/yr
Auto Carrier	7.1	74.5	70.3	2.5	5.7
Bulk	2.2	23.4	21.6	0.8	1.8
Container Ship	12.7	138.3	117.6	4.7	10.6
General Cargo	1.8	17.6	19.8	0.6	1.4
Passenger	20.4	202.2	165.2	6.5	15.3
Reefer	10.3	109.3	97.5	3.7	8.4
Roll-on/Roll-off	5.4	62.6	44.6	2.1	4.8
Tanker	12.5	76.2	197.4	2.9	6.2

The cost effectiveness methodology is based upon the Carl Moyer Program (CARB, April 2008) which only considers PM, NOx, and VOC. Weighting factors of 1 are used for NOx and VOC, but a weighting factor of 20 is used for PM to account for the increased risk to human health. The Moyer method utilizes the Annualized Cash Flow method for initial capital costs but does not account for future recurring annual operation and maintenance costs. This analysis employs Moyer's method for initial capital costs, and applies the Discounted Cash Flow method for recurring annual operation and maintenance costs.

Table 4 summarizes the weighted emissions reduced (weighting factor of 20 applied to PM) based upon the AMECS control efficiencies (with 1.5% reduction in NOx control efficiency to account for the SCR degradation over time). The total pollutants reduced do not include the SOx and CO emissions (Moyer methodology).

Table 4. Emissions Reduction per Vessel Type

Vessel Type	PM[1] ton/yr	NOx ton/yr	VOC ton/yr	TOTAL ton/yr
Auto Carrier	135.8	72.7	2.4	210.9
Bulk	42.3	22.9	0.8	65.9
Container Ship	242.0	135.0	4.5	381.5
General Cargo	34.7	17.2	0.6	52.5
Passenger	386.7	197.4	6.2	590.3
Reefer	194.8	106.8	3.6	305.2
Roll-on/Roll-off	102.7	61.1	2.0	165.8
Tanker	237.2	74.4	2.8	314.4

[1] Moyer weighting factor of 20 was applied to the PM emissions.

Table 5 presents the total 20 year AMECS life cost effectiveness and the number of vessels that can be serviced by AMECS simultaneously. Figure 2 graphs the cost effectiveness for each vessel type (assumes each AMECS is dedicated to a specific vessel type). The costs are fully loaded with burden and markup. Sensitivity analysis showed that placement of the AMECS in berths with high vessel occupancy is important in increasing the AMECS utilization rate and consequently improve the cost effectiveness.

Table 5. Cost Effectiveness Over 20 Year AMECS Life

Vessel Type	Maximum Number of Vessels Treated by AMECS Simultaneously	Total Life Cost 2008$	Weighted Emissions Reduced tons	Cost Effectiveness 2008$/ton
Auto Carrier	2	61,101,546	8,437	7,242
Bulk	3	54,920,407	3,954	13,890
Container Ship	1	50,337,176	7,630	6,597
General Cargo	4	65,586,036	4,197	15,627
Passenger	1	135,358,120	11,807	11,465
Reefer	2	65,263,489	12,206	5,347
Roll-on/Roll-off	3	66,742,301	9,951	6,707
Tanker	1	51,464,390	6,288	8,184

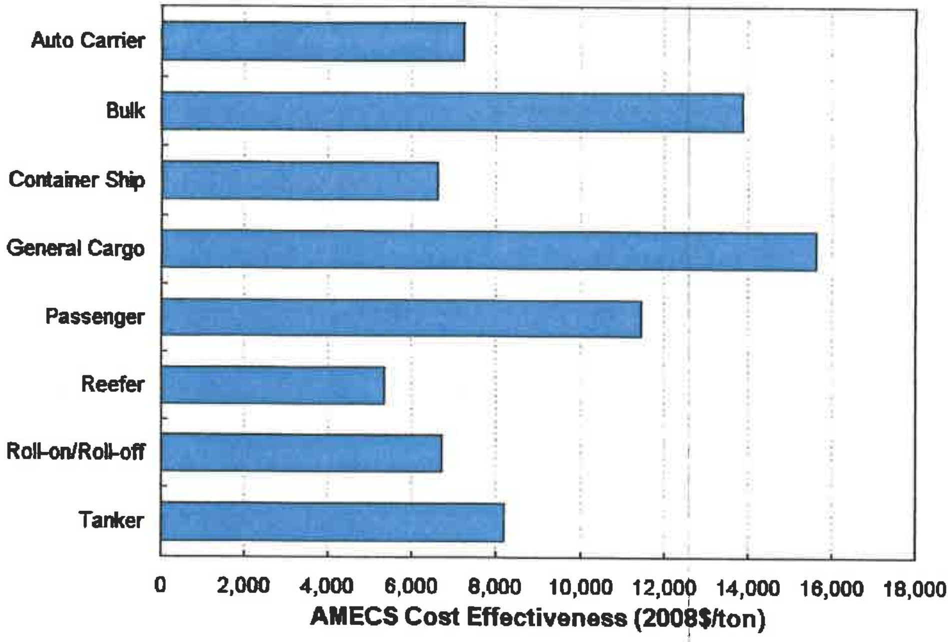

Figure 2. AMECS Cost Effectiveness

Additional benefits of AMECS that are not captured by the cost effectiveness analysis are the 99.8% reduction in SOx emissions and 43.8% reduction in CO emissions. An advantage of AMECS is the ability to treat vessel exhaust emissions without requiring any vessel modification.

The AMECS demonstration accomplished the the objective of achieving at least 95% average pollutant removal efficiencies for PM, NOx, VOC, and SOx.

The second objective of AMECS having no adverse affects to Metropolitan Stevedore's normal operations and no adverse effects on the vessels, auxiliary engines, and auxiliary boilers was also accomplished. Robert Waterman, Assistant Vice-President of Bulk Operations for Metropolitan Stevedore, confirmed that AMECS did not delay nor affect their operation. ACTI's personnel were present in the ship's engine control room throughout all the tests and confirmed with the ship's engineer that there were no observable effects on the ship's operation due to AMECS' attachment, operation, and detachment from the ships.

The successful capture efficiencies demonstrated by AMECS at the Port of Long Beach resulted in Barry Wallerstein, Executive Officer of the SCAQMD, stating that the implementation of AMECS (and ALECS for locomotives) could "provide large benefits to the South Coast Air Basin and, in particular, the communities adjacent to these sources."

1. Introduction

1.1 Project Background and Overview

The Port of Long Beach (POLB) is one of the world's busiest seaport and a major international gateway for commerce entering California and the United States. The demand for goods moving through the San Pedro Bay region is expected to more than double by the year 2020. The POLB's ability to accommodate the projected growth in trade will depend upon their ability to address adverse environmental impacts and, in particular, air quality impacts that result from such trade. In the South Coast Air Basin, 11% of particulate matter emissions, 5% oxides of nitrogen emissions, and 32% oxides of sulfur emissions are attributed to port-related emission from the POLB (Starcrest, June 2008).

The POLB's shipping terminals import and export more than $100 billion worth of goods and products every year bringing products to the region and nation.[2]

Ports are a major source of air pollution with one of the major contributors being ocean-going vessels. While docked at the port, the ocean-going vessels (OGV) shut off their propulsion engines, but use auxiliary diesel engines (usually coupled to generators) to power refrigeration, lights, pumps and other functions (activities commonly called 'hotelling'). Auxiliary boilers, also a significant source of particulate matter, burn fuel to heat heavy fuel oil, heat water for crew/passengers, drive steam turbine pumps to offload petroleum products carried by tankers, distillation of seawater to generate fresh water, or space heating of cabins while docked.

Diesel engines create a complex mixture of harmful air pollutants, comprised of gaseous and solid material. The visible emissions in diesel exhaust, as well as a considerable quantity of tiny particles that are not generally visible, are known as particulate matter (PM). In 1998, the California Air Resources Board (CARB) identified diesel PM as a toxic air contaminant based on its potential to cause cancer, premature death, and other health problems. The resultant air emissions have an adverse affect on air quality and pose a significant health risk to the surrounding environment. Diesel engine emissions are responsible for the majority of California's potential airborne cancer risk from combustion sources.[3]

Metropolitan Stevedore, Incorporated is a leading petroleum coke terminal operator and handles stevedore operations in the Port of Long Beach for cargoes such as petroleum coke, coal, potash, borax and soda ash, concentrates, and prilled sulfur.

In 2005, Metropolitan Stevedore began working with Advanced Cleanup Technologies, Inc. (ACTI) on its emissions control technology for use on bulk freighters hotelling at POLB's pier G. The goal was to capture and significantly reduce the harmful pollutants emitted by the vessels while loading petroleum coke and other products.

[2] Downloaded 10/24/08: http://www.polb.com/economics/stats/default.asp

[3] Downloaded 11/10/08: http://www.arb.ca.gov/diesel/factsheets/dieselpmfs.pdf

In 2007, preliminary testing was conducted on the Western Seattle, a Handymax class, 45,630 dwt bulk cargo vessel, using an octagonal capture bonnet. The tests were performed to demonstrate the ability to attach the bonnet to a ship's exhaust stack, and to measure the exhaust capture effectiveness. Figure 3 shows testing with the bonnet attached to the Western Seattle.

Figure 3. Western Seattle with Octagonal Capture Bonnet

Based upon the successful testing using the Western Seattle, an Emission Testing Protocol (see Appendix A) was developed and reviewed by the Ports of Long Beach and Los Angeles, South Coast Air Quality Management District, and the California Air Resources Board. This report documents the demonstration testing of ACTI's Advanced Maritime Emissions Control System (AMECS) in the Port of Long Beach at Metropolitan Stevedore, Pier G, Berth 214 on May 26 and July 19, 2008. A major advantage of the AMECS technology is that no vessel modifications are required for AMECS to treat the exhaust emissions.

The test program consisted of testing the emissions of two vessels, the Queen Lily and the Angela, at the POLB. Both are bulk cargo vessels that frequent the Metropolitan Stevedore berths. Duplicate emissions tests were conducted at AMECS' Emission Treatment System inlet and outlet for pollutants such as particulate matter, oxides of nitrogen, volatile organic compounds and sulfur dioxide.

1.2 Project Objectives

The objectives of the test program are:

a. To document the effectiveness of the AMECS system in reducing ocean-going vessel emissions of particulate matter (PM), oxides of nitrogen (NOx), volatile organic compounds (VOC) and other pollutants under typical at-berth operating conditions. The criterion for a successful demonstration will be no less than 90% reduction in PM, NOx, and VOC.

b. To assure that the emission control equipment, process, and procedures do not interfere with normal Metropolitan Stevedore operations. This would include not affecting the loading/offloading operations of Metropolitan Stevedore as well as the auxiliary engine/boiler operation of the vessel.

2. Description of Technology

2.1 Overall Description

ACTI's AMECS is designed to capture exhaust emissions from the auxiliary engines and auxiliary boilers of ocean-going vessels (OGV) in hotelling mode (at berth or anchored within the port) and direct them to an emissions treatment system for removal of harmful pollutants before being exhausted into the surrounding environment.

AMECS is comprised of two major components: a) the Exhaust Capture System (ECS) and b) the Emissions Treatment System (ETS). The ECS can be Dock-Based or Barge-Based. The Dock-Based ECS is stationary and can only service vessels moored next to the berth or adjacent berths, whereas the Barge-Based ECS is mobile which can treat exhaust emissions of vessels anchored and waiting to come into an available berth. The POLB testing demonstrated the Dock-Based design, which is the main focus of this report.

2.2 Emissions Capture System

The ECS, which attaches to the ship's exhaust stack, captures the exhaust from the vessel and directs it through a duct into an emissions treatment system. An induced draft fan is used to draw the exhaust from the bonnet through the duct and into the ETS, where sulfur dioxide (SO_2), PM, NOx and VOC (hydrocarbons that are not classified as VOC by the Environmental Protection Agency, such as methane and ethane) may also be removed. Multiple ECS may be used to capture the exhaust emissions (up to the exhaust volume capacity of the ETS) from multiple vessels simultaneously utilizing an interconnecting ducting system.

The ECS consists of a Capture System Placement Device, an Octagonal Capture Bonnet, and a Duct Management system (see Figure 4). The bonnet, which is designed to fit over a wide variety of unique geometries of vessel exhaust stacks, collects the exhausted emissions. The bottom of the bonnet contains a self-adjusting 10-inch thick Pneumatic Interface Collar (Figure 5) that closes around the vessel's stack, limiting the amount of tramp air entering the bonnet as well as preventing exhaust emissions from escaping (see Figure 6). The Pneumatic Interface Collar can be adjusted (offset) to accommodate exhaust stacks that are located in close proximity to the vessel's house and/or antenna farm.

The Capture System Placement Device is the instrument that lifts the Octagonal Capture Bonnet onto the vessel's exhaust stack, and is the attachment interface for the ECS intake ducting. Figure 7 shows a picture of Dock-Based Capture System Placement Device deployed on the Ginga Merlin (Handysize class 19,999 dwt chemical tanker) on June 19, 2008. The purpose of this test was to demonstrate the repeated attachment and detachment of the Exhaust Capture System.

Figure 4. Octagonal Capture Bonnet (furled)

Figure 5. Octagonal Capture Bonnet's Pneumatic Interface Collar

Figure 6. Octagonal Capture Bonnet (attached to the Angela)

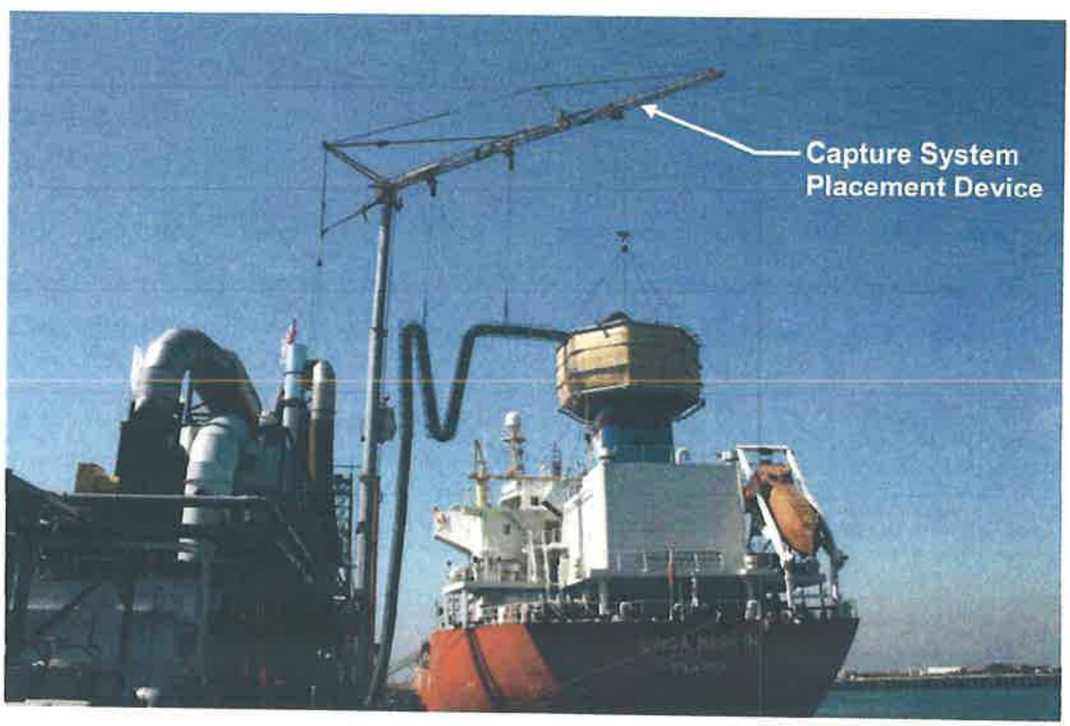

Figure 7. Capture System Placement Device (attached to the Ginga Merlin)

System backpressure will be controlled by a pressure sensor located within the bonnet, which in turn controls a damper located at the top of the bonnet. Backpressure is controlled between atmospheric and minus 0.25 inch of water gauge pressure, which puts the exhaust system under a slight vacuum. This vacuum essentially captures all of the vessel's exhaust and may also add some dilution air from the surrounding atmosphere into the capture system.

This POLB demonstration tests used a single ECS, but the full scale deployment of AMECS is expected to have multiple ECS depending upon the port design, and the expected types of vessels being treated. Vessels with lower exhaust volumes may be treated simultaneously (with multiple ECS) by a single ETS.

2.3 Emissions Treatment System

The three major components of the ETS consist of a Preconditioning Chamber (PCC), three patented Cloud Chamber Scrubbers (CCS) and a Selective Catalytic Reduction (SCR) Reactor to remove the harmful exhaust emissions. Figure 8 shows the relative location of the components on the ETS.

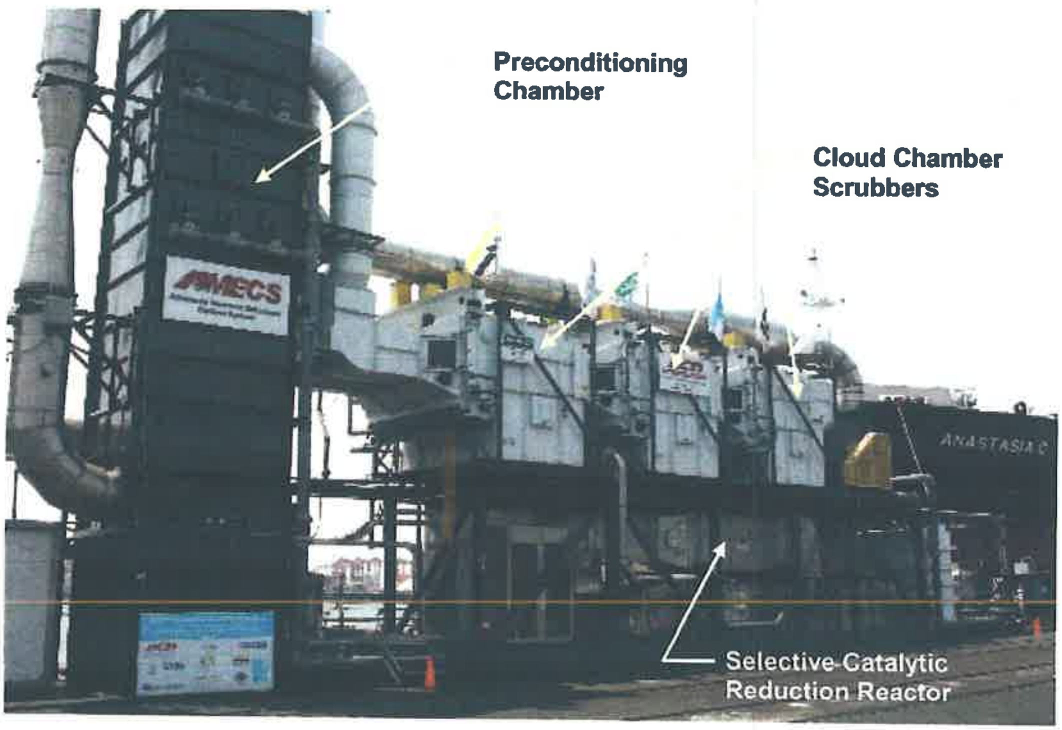

Figure 8. Emissions Treatment System

The first unit the exhaust gas encounters as it enters the system is the Preconditioning Chamber which serves several functions. First, it cools the gas through a countercurrent flow water spray and in the process increases the water vapor content to near saturation. This feature is required by the following stage, which cannot accept hot gas. Secondly, it removes water soluble VOC. Third, the water is rendered caustic by means of a metered injection of sodium hydroxide to remove SO_2. The fourth function of the PCC is to cause the nanometer size PM particles to agglomerate into larger particulate globules, which facilitates their removal. Many of these larger particles are captured by the liquid spray and enter the PCC water stream where they are carried to an inline filter. The particulates that are larger than the effective pore size of the filter bags are captured and retained in the bags for later removal and disposal.

For those particles that are not captured by the water stream in the PCC, they continue effectively as an aerosol in the gas stream, but those that have been enlarged in size through interaction with other PM particles and water vapor in the PCC are more efficiently captured downstream in the CCS.

The path of the captured exhaust emissions flow through the ETS, along with the relative positions of the major components is shown in Figure 9.

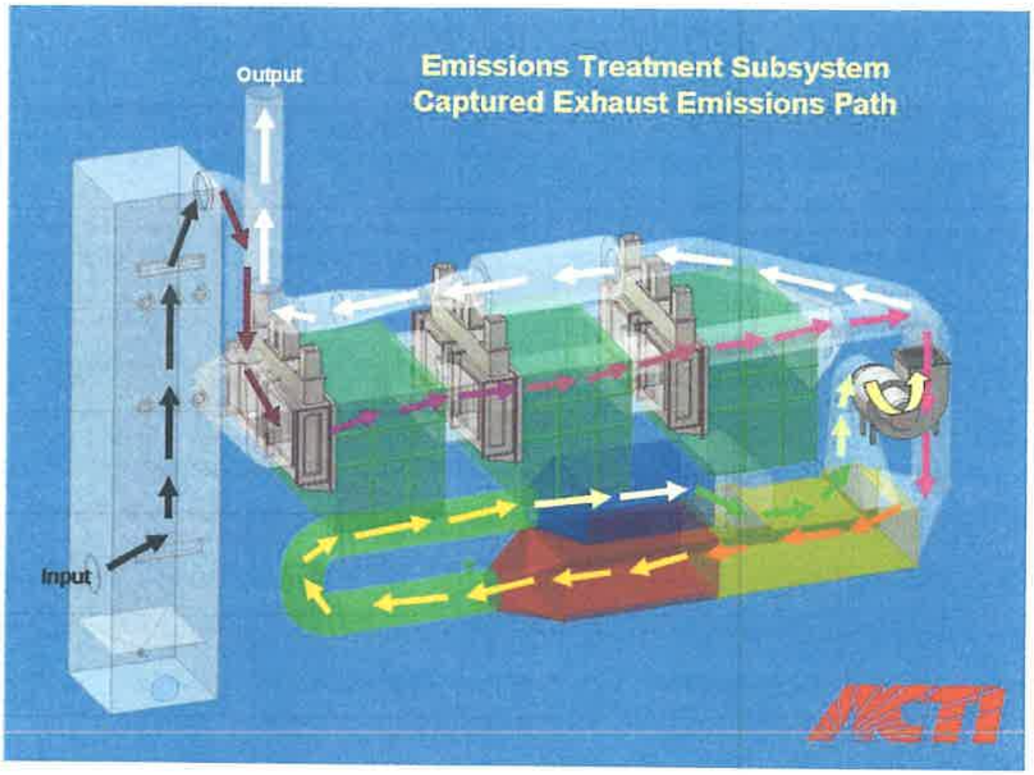

Figure 9. Emissions Treatment System Captured Exhaust Emissions Path

The CCS is composed of three stages that are identical except for the polarity of the charge imparted to the water droplets. Each CCS stage or chamber generates a fog of very fine water droplets and charges them to a high voltage. PM particles, including ultrafine particles, are attracted to these micron-size water droplets.

The water, which now has many PM particles adhering to each water droplet, coalesces into a stream of water and is routed to a second filter where the agglomerated PM particles are filtered out, as in the PCC. Also as in the PCC, sodium hydroxide is metered into the water streams of the CCS stages to remove the remaining sulfur dioxide.

The particles thus collected in the water reservoir are flushed through a solids removal system where they are collected for subsequent removal from the premises and disposal using approved regulatory means. The removal system consists of a solids separation device for inline solids removal, water extraction, and compaction.

The Selective Catalytic Reduction (SCR) Reactor is designed to remove NOx. Liquid urea is injected into the hot gas stream ahead of the SCR. The urea is converted to ammonia by the hot gas, and the ammonia reacts with the NOx in the presence of the catalyst to form nitrogen gas and water vapor, which are vented to atmosphere. A 40% or less solution of urea, a non-hazardous compound, is used rather than ammonia, which is hazardous, to increase safety and simplify storage and transport.

The SCR Reactor subassembly includes a Heat Management System comprised of a heat exchanger and burner. The heat exchanger is used to recover heat from the SCR discharge for preheating the exhaust gas entering the SCR. The SCR requires a gas temperature of 570 to 650 °F at the inlet. The exhaust gas exiting the CCS is cooled to about 140 °F and stripped of SO_2, PM, soluble hydrocarbons, and condensed (particulate) hydrocarbons and sulfates. This clean but cool gas must then be reheated. The additional heat required is provided by a natural gas or propane fired burner (an electric heater could also be used).

The heat exchanger uses the heat of the cleaned exhaust gas exiting the SCR to heat the exhaust gas prior to it entering the SCR. The heat exchanger captures 80% of the heat that would otherwise be exhausted. The duct burner is therefore required to provide a temperature boost of only about 100 °F, minimizing fuel usage as well as keeping burner emissions to a low level.

Refer to Figure 10 for the component locations of the Heat Management System.

Figure 10. ETS: SCR Heat Management System

A second function of the burner is to remove any remaining VOC that are not water-soluble, and those that are water-soluble that were not removed in the PCC and CCS. As the exhaust emissions pass through the ducting leading from the heat exchanger through the burner to the SCR reactor, the gas flow is deliberately perturbed to provide turbulent flow and subsequent thorough mixing of the urea/ammonia with the exhaust gas as well as maximal efficiency of the plate-type heat exchanger.

An Induced Draft (ID) fan is located downstream of the SCR Reactor and Thermal Management System, and a silencer is located downstream of the ID fan. This fan draws the exhaust gas from the vessel through the ducting into the ETS. The flow and pressures are controlled by dampers and the fan's variable speed drive motor.

The silencer (downstream of the ID fan) reduces the system's operating noise level to an acceptable level.

Control System Description

The AMECS Control System is an integrated network which automatically operates and monitors all aspects of the AMECS operation. The ETS has its own Operational Control Unit (OCU), which controls all the ETS processes. The OCU houses all sensing, monitoring, recording and control system functions for AMECS. These systems acquire, monitor, store and transmit the data required to maintain efficient emissions control operations as well as to document emissions reduction performance.

Failsafe strategies are built into the control system. This system keeps all ECS and ETS operational parameters within design limits, makes automatic adjustments where appropriate, switches to redundant components or systems in the event of a malfunction or out-of-spec condition, and records significant parameters to verify performance.

As part of the control system, measured data (including failures) are recorded into a Microsoft SQL (Structured Query Language) Database, a Relational Database Management System, to assist in determining the failure mode, identifying the failure to a most probable cause. The software is used to identify trends so that corrective action can be taken proactively.

In addition, the Barge-Based Emissions Capture Systems would be equipped with a Global Positioning System (GPS) that will provide barge location and status, such as connected to a vessel, on standby, requires service, etc. The Barge-Based design was not part of AMECS demonstration at the POLB.

The Continuous Emissions Monitoring System (CEMS) measures the following parameters:

- At the ETS inlet (source measurement)
  - NOx
  - SOx
  - VOC
  - Flow
  - Temperature

- At the ETS outlet (discharge to atmosphere)
  - NOx
  - SOx
  - VOC
  - NH_3 (ammonia)
  - Flow
  - Temperature

PM would also be measured at the ETS inlet and outlet, but the measurements would not be continuous, nor in real time like the CEMS. PM measurements will be performed periodically (depending upon the local air quality agency) by withdrawing the particulate isokinetically from the source and collecting them on glass fiber filters for gravimetric analysis. These measurements could be used to supplement the emissions inventory database for the port.

The CEMS instrumentation consists of gaseous stack gas analysis equipment. Typically, a chemiluminescent analyzer is used for NOx measurement, a non-dispersive infrared analyzer for SOx, and a flame ionization analyzer for measuring total hydrocarbons.

The sample conditioning system includes a solid state thermoelectric pre-cooler with stainless steel impingers, a solid state thermoelectric sample cooler, primary and secondary particulate filters, an acid mist catcher, magnetically coupled sample pump and booster pump, temperature controller for the heated sample line, temperature controller for the sample probe primary filter, automatic temperature and pressure control, and automatic system calibration.

Figure 11 is a picture of the CEMS utilized in the ALECS demonstration testing.

Figure 11. Continuous Emission Monitoring System

2.4 System Installation for Demonstration at the POLB

The ETS of AMECS came from the 2006 demonstration of the Advanced Locomotive Emission Control System (ALECS) tested at the Union Pacific Railroad's J. R. Davis Rail Yard in Roseville, California (TIAX, 2007). Figure 12 shows an aerial view of the approximate location of the AMECS demonstration test location in the POLB. The overall layout of AMECS on the dock for purposes of this demonstration is shown in Figure 13. The 1,200 foot marker near the location of the crane is approximately across from where the ship stack was located when the vessel was berthed. In this configuration, flexible ducting conveyed the exhaust gas from the bonnet to the ETS. The ETS was mounted on a temporary foundation that provided a level surface for the ETS.

Figure 12. Aerial View of the POLB Site where AMECS was Installed

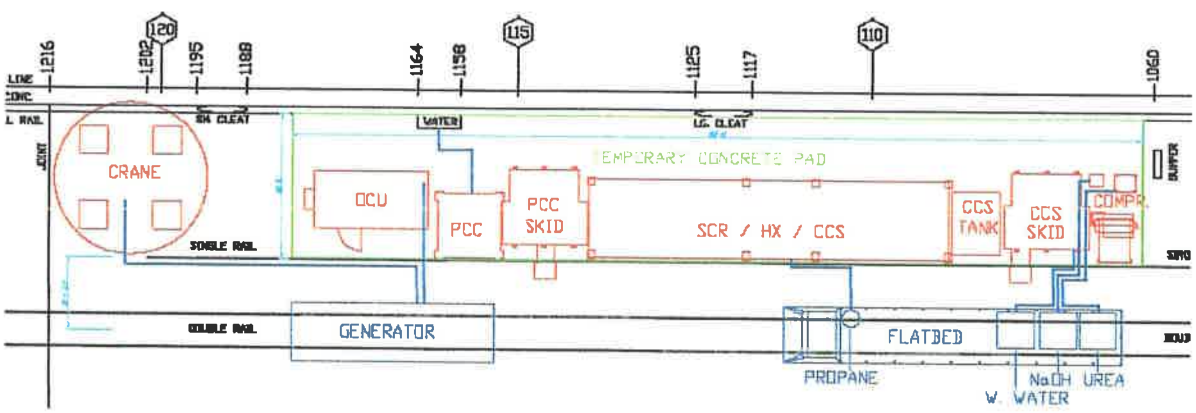

Figure 13. AMECS equipment arrangement on the dock at berth G-214

3. Testing of System

3.1 Overall Test Plan

The test program consisted of testing the emissions of two vessels at the POLB. Both are bulk cargo vessels that frequent the Metropolitan Stevedore facility. Duplicate emissions tests were conducted at AMECS' ETS inlet and outlet for NOx, CO, SO_2, VOC, and PM. Ammonia was tested only on the outlet of the ETS for ammonia slip from the SCR. There were no emissions measured at the vessel stack outlet. The complete source test protocol is included in Appendix A.

The test program only tested one vessel at a time operating in its normal hotelling mode, which consisted of operating an auxiliary engine(s) and one auxiliary boiler.

3.2 Vessels Tested (Queen Lily and Angela)

The larger of the two vessels tested with the ETS was the bulk carrier, the Queen Lily. The smaller vessel tested with the ETS, the Angela, is also a bulk carrier. The exhaust emissions were tested while the vessels conducted their normal operations docked at berth (such as being loaded with petroleum coke). Table 6 summarizes the ocean-going vessel characteristics. Auxiliary boilers were operating intermittently in addition to the auxiliary engine operating during testing, but Boiler specifications and operational data during emissions testing were not available.

Table 6. Vessel Characteristics

	Ocean-Going Vessel	
	Queen Lily	Angela
Year Built	2004	2004
Cargo Capacity (dwt)	76,629	52,571
Ship Identification Number	9316660	9274915
Number of Auxiliary Engines	3	3
Auxiliary Engine Model	Yanmar 6N21L	Daihatsu 3DK-20
Auxiliary Engine Type	Four-stroke	Four-stroke
Number of Cylinders	6	3
Rated Power Output (kW)	615	440
Engine Speed (rpm)	720	900
Test Date	May 26, 2008	July 16, 2008
Engines on During Test	2	1
Ave. Power During Test	88 and 151 kW	210 kW

Repeated attachment and detachment of the ECS to the Queen Lily (Figure 14), the Angela (Figure 15), and the Ginga Merlin (Figure 7) was successfully demonstrated. Deployment and recovery of the ECS had proven to not interfere with normal Metropolitan Stevedore operations. Robert Waterman, Assistant Vice-President of Bulk Operations for Metropolitan Stevedore, stated that he had not heard of nor saw any adverse affects to their normal operations during AMECS operation. There had been a total of at least 20 separate attachments and detachments of AMECS to various vessels during the demonstration period without any adverse affect on Metropolitan Stevedore operation.[4] There was no noted damage or adverse effect on the vessels, the auxiliary engines, nor the auxiliary boilers due to the operation of AMECS. ACTI personnel were present in the ship's engine control room throughout all the tests. The ship's engineer did not report any observable effect (from available instrumentation) due to ECS attachment, operation of AMECS, and ECS detachment.

Figure 14. Emission Capture System Attached to the Queen Lily

[4] Communication with Robert Waterman, Assistant Vice-President of Bulk Operations for Metropolitan Stevedore, on November 17, 2008

Figure 15. Emission Capture System Attached to the Angela

3.3 Emission Measurements

The emissions testing were performed by Professional Environmental Services, Inc. of Irwindale. Simultaneous emissions measurement of NOx, CO, SO_2, PM, VOC, CO_2, and O_2 were conducted at the inlet and outlet of the ETS of AMECS. Ammonia (NH_3) slip from the SCR was only tested at the outlet of the ETS. Duplicate test runs were conducted at the inlet and outlet locations while the auxiliary engines on the vessels were running. Table 7 summarizes the test methods, number of test runs, and duration of tests performed by Professional Environmental Services. Due to the scheduling difficulties, the triplicate runs in the testing protocol were reduced to duplicate runs. There was insufficient time to conduct the third set of tests.

Table 7. Test Methods, Number of Tests, and Duration of Tests per Vessel

	Test Method	Test Runs/Duration
Volumetric Flow Rates	SCAQMD Methods 1.1-4.1	Continuous
NOx, CO, CO_2, O_2	SCAQMD Methods 100.1	2 runs – 60 minutes each
SO_2	SCAQMD Methods 6.1	2 runs – 60 minutes each
NH_3 (outlet only)	SCAQMD Methods 207.1	4 runs – 30 minutes each
PM	SCAQMD Methods 5.2	2 runs – 60 minutes each
VOC	SCAQMD Methods 25.1 & 25.3	2 runs – 60 minutes each

4. Test Results

The NOx, PM, VOC, SO_2, CO, and NH_3 test results are presented here. The full emission source test reports are presented in the appendices. The emission source test report for the Queen Lily is presented in Appendix B. Appendix C contains the emission source test report for the Angela.

4.1 Emissions Results

South Coast Air Quality Management District's (SCAQMD) Source Test Engineering evaluated the emission source test reports and concluded that the results required some corrections and clarifications. The SCAQMD memorandum (documented in Appendix D) concluded:

- Recalculations performed by SCAQMD and the results presented in the SCAQMD's memorandum should supersede the original emission source test reports.
- Testing did not include quantification of the small amount of visible fugitive emissions observed to be coming from the vessel stack to bonnet interface.
- PM deposition on the inner surfaces of the bonnet and ducting were not quantified.
- The reported control efficiencies only represent AMECS' control efficiencies, and do not represent the percentage reduction over uncontrolled emissions from the vessel stack (which may be higher if the PM deposits were disposed in a manner that prevented discharge to the atmosphere).

Table 8 presents the inlet and outlet emission results to the Emissions Treatment System of AMECS for the Queen Lily (tested on May 26, 2008) and the Angela (tested on July 16, 2008). A urea pump failed during the second run for the Queen Lily. This invalidated the NOx measurement on the outlet. A broken trap in the testing laboratory using SCAQMD Method 25.1 for the Angela's first run on the ETS inlet and having a greater than 20% difference between the paired sample results (one is a quality assurance duplicate) invalidated the VOC measurement.

The overall emission control efficiencies of the major pollutants of interest are presented in Table 9. The CO reduction efficiency for the Angela was not determined because the measurements for both runs for the inlet and outlet were below the detection limit. The overall control efficiency for NOx was reduced by 1.5% (for this report's analysis) to account for the degradation of the SCR Catalyst over time.

The ammonia slip from the use of urea in the SCR system was low. Measurements for NH_3 were only conducted on the outlet of the ETS. The failing of the urea pump during the second run for the Queen Lily invalidates the NH_3 measurement. The three remaining NH_3 measurements (corrected to 15% O2) are 8.4 ppm (Queen Lily run 1), 0.5 ppm (Angela run 1), and 4.0 ppm (Angela run 2). This results in an average NH_3 slip of 4.3 ppm (@ 15% O2).

Table 8. AMECS Inlet/Outlet Emissions

	Inlet Emissions (lbs/hr)					Outlet Emissions (lbs/hr)				
	NOx	PM	VOC	SO_2	CO	NOx	PM	VOC	SO_2	CO
QUEEN LILY										
Run 1	5.63	1.39	1.32	5.65	0.76	< 0.02	0.025	0.053	0.009	0.39
Run 2	7.04	0.54	1.49	5.49	0.70	*	0.011	0.064	0.005	0.43
Average	6.34	0.97	1.41	5.57	0.73	< 0.02	0.018	0.0585	0.007	0.41
ANGELA										
Run 1	3.02	0.864	N/A	3.11	< 0.27	0.073	0.072	0.11	0.006	< 0.28
Run 2	4.91	0.925	3.11	3.01	< 0.27	< 0.04	0.074	0.09	0.007	< 0.28
Average	3.97	0.895	3.11	3.06	< 0.27	< 0.06	0.073	0.10	0.007	< 0.28

* Data not included due to urea pump failure (NOx was non-detect until the urea pump failed)
N/A = Not Available due to broken trap and >20% difference between paired sample results

Table 9. Average AMECS Control Efficiencies

	NOx	PM	VOC	SO_2	CO
QUEEN LILY	>99.7%	98.1%	95.9%	99.9%	43.8%
ANGELA	>98.6%	91.8%	96.8%	99.8%	ND
Average Control Efficiency	>99.1%	95.0%	96.3%	99.8%	43.8%
Adjusted Average Control Efficiency[1]	>97.6%	95.0%	96.3%	99.8%	43.8%

ND = Not Determined
[1] Assumed 1.5% reduced NOx control efficiency to allow for SCR catalyst degradation over time

VOC reduction was found to occur primarily in the hot sections of the ETS (heat-exchanger, burner, ducting between the burner and the SCR Reactor, and the SCR Reactor portions of the ETS). ACTI performed an analysis on VOC destruction that can be found in Appendix E. Based on the collected data most of the measured VOC destruction is occurring in the burner section of the ETS (forty foot ducting connecting the burner with the SCR Reactor) and in the SCR Reactor.

4.2 Utility, Energy, and Chemical Consumption Rates

ACTI collected operating process data on the AMECS and provided the estimates shown in Table 10 on the utility, energy, and chemical consumption rates per hour of operation treating the exhaust volume of 12,500 scfm (capacity of one ETS). Propane was the fuel used for reheating the exhaust prior to the SCR in the demonstration, but natural gas or electrical power is expected to be available in a permanent installation of the AMECS. The amount of natural gas required to heat the 12,500 scfm of exhaust is 1.01 million Btu/hr. Also, in the demonstration test, portable diesel engine generators were used to produce the electricity needed, but electricity from the local utility will be used in normal operation. The diesel engine generators and propane were used due to the temporary AMECS installation for the demonstration.

Table 10. AMECS Utility, Energy, and Chemical Consumption Rates

Consumables	Quantity	Units
Electricity	350	kWh/hr
Natural Gas	1.01	MMBtu/hr
Water	310	gal/hr
Aqueous Urea (40%)	0.38	gal/kg NOx
Sodium Hydroxide (30%)	0.82	gal/kg SOx

4.3 Waste Generation

Liquid and solid waste (PM) is produced by the Preconditioning Chamber and the Cloud Chamber discharge of the AMECS.

Solid waste accumulated from the ETS was estimated to be produced at a peak rate of 2.2 lb/hr. This estimate is based upon data collected by ACTI during the demonstration testing. Captured solid waste was stored in drums that hold around 400 pounds of material each.

Liquid wastewater was being produced at a rate of 2.7 gallons per hour. Analysis of ALECS wastewater showed it could be considered safe enough to be discharged to a publicly owned treatment system, but local policies specific to each location will need to be identified (TIAX, 2007).

4.4 Overall System Evaluation

Conventional stationary emission control technology has been demonstrated to be very effective in treating emissions from ocean-going vessel sources. The Dock-Based ECS demonstrated the ability to capture emissions from single vessels. The demonstration at the POLB utilized a system that was installed to handle a single vessel at a time; a simultaneous multi-vessel emissions capture system with multiple vessels was not tested. The Barge-Based ECS was not tested at the POLB.

5. Life Cycle Cost Analysis

5.1 Methodology

The life cycle cost analysis estimates the total cost of the AMECS incurred over the life of the system and is used along with the emission estimates to determine the system cost effectiveness per ton of pollutant reduced. The life cycle cost analysis entails Cost Element Definition, Data Collection, and Evaluation.

5.2 Cost Element Definition

Cost elements are broken down into Initial Capital Costs, Operating and Maintenance Costs including Utility/Energy Costs, Repair and Replacement Costs, Downtime Costs, Environmental Costs, and Salvage Value.

A) Initial Capital Costs include engineering and design (drawings and regulatory issues), bidding process, purchase order administration, hardware capital costs, testing and inspection, inventory of spare parts, foundations (design, preparation, concrete and reinforcing), installation of equipment, connection of process piping, connection of electrical wiring and instrumentation, one-time licensing/permitting fees, and the start up (check out) costs.

B) Operating and Maintenance Costs include items such as labor costs of operators, inspections, insurance, warranties, recurring licensing/permitting fees, and all maintenance (corrective and preventive maintenance). Also included are yearly costs of consumables such as the utility/energy costs (electricity, natural gas, and water) and chemical costs (such as sodium hydroxide and urea).

C) Repair and Replacement Costs are the costs of repairing and replacing equipment over the life of the AMECS. These costs are included in the operation and maintenance costs.

D) Port impact costs include estimates of costs incurred by the Port of Long Beach due to the operation or non-operation of the AMECS. AMECS is not expected to affect the normal operations of ocean-going vessels hotelling.

E) Environmental Costs are associated with the disposal of wastewater and solid waste.

F) The Salvage Value of the system would be the net worth of the AMECS in its final year of the life cycle period. If the system can be moved and salvaged for useful parts/purposes, there would be a reduction in life cycle costs.

The estimates in this report are based upon data and observations taken during the operation and demonstration testing of the AMECS.

5.3 Data Collection and Assumptions

Data for this evaluation was provided by ACTI based upon the data collected from the demonstration at the Port of Long Beach. Accuracy of input data is important to improve the certainty of the life cycle cost prediction. The data obtained are the most accurate information available. Where actual data were not available, literature searches, theoretical calculations, and engineering estimates were utilized. The ETS would be common among installations at different berths, however, the ECS would need to be tailored to each specific installation dependent upon the size and activity of ocean-going vessels at each berth (multiple vessels could be treated simultaneously). ACTI has also designed a barge based ECS (which uses an ETS installed on the dock or on the barge, depending upon the specific application) that has not been demonstrated on an ocean-going vessel yet.

ACTI provided information on the initial capital costs (see Table 11). The ETS (12,500 scfm capacity) in the POLB demonstration is the full size design (there is no scaling required for production units sold by ACTI). However, ACTI also states that the current standard ETS design of 12,500 scfm could be scaled up to a maximum of 27,000 scfm for a single ETS unit. For this analysis, if more than 12,500 scfm needs to be treated, a second (or more) 12,500 scfm unit is added. The costs include burden and markup. The costs include the proprietary direct and indirect capital costs which include items such as shipping, engineering support, construction & field expenses, contractor fees, start-up, performance test, and contingencies. Assumptions of reduced prices from multiple production runs of around 20 units, split between rail and marine applications were included based upon the experience of demonstrating the ALECS at Union Pacific Railroad's J. R. Davis Rail Yard in Roseville, California, and the AMECS for this POLB demonstration.

Table 11. AMECS Initial Capital Costs

Dock-Based Initial Capital Costs	Cost/Unit
Emissions Treatment System (ETS)	$ 4,215,596
Emissions Treatment System Installation	$ 954,525
Exhaust Capture System (ECS)	$ 1,672,188
Exhaust Capture System Manifold	$ 318,989
Exhaust Capture System Installation	$ 1,240,883

The recurring operation and maintenance (O&M) costs are presented in Table 12. The consumables and utilities are based upon the AMECS demonstration experience. The electricity and natural gas prices are based upon the Energy Information Administration's forecasted 2008 Industrial prices for the California/Pacific region[5]. The SCR catalyst is estimated to be replaced every six years. The 6 year life of the catalyst is based upon the removal of sulfur and PM prior to the SCR which extends the life of the catalyst. The SCR catalyst replacement cost is included in the maintenance costs. It is assumed that there will not be a salvage value of the AMECS at

[5] The 2006$ were converted to 2008$ based upon the estimated 2008 Consumer Price Index (CPI) (average of monthly CPI through September 2008).

the end of its useful life and any salvage value would be offset by any costs associated with shutting down the AMECS.

AMECS will be staffed 24 hours a day, 365 days a year by full time fully trained personnel with labor rates ranging from $75/hr to $115/hr.

Table 12. AMECS Recurring Operation and Maintenance Costs

Dock-Based Recurring Operating Costs	Cost/Unit
Full Time Personnel	$ 1,283,696 /ETS/year
Service Personnel (ECS)	$ 88.20 /hour
Maintenance	$ 70,177 /ETS/year
Insurance	$ 39,875 /ETS/year
Sodium Hydroxide (30%)	$ 1.75 /gal
Urea (40%)	$ 2.18 /gal
Solid Waste Disposal	$ 1.15 /pound
Liquid Waste Disposal	$ 0.25 /gal
Water	$ 0.0038 /gal
Electricity	$ 0.11 /kWh
Heat (Natural Gas)	$ 8.24 /MMBtu
Central Facility	$ 364,062 /ETS/year

Table 13, Table 14, and Table 15 presents the auxiliary engine and boiler emission factors, rated power, load factors, operating loads, and fuel distribution (CARB, June 2008). Auxiliary engines primarily use heavy fuel oil with almost a third using distillate (0.5% sulfur marine distillate). It is assumed that all auxiliary boilers use heavy fuel oil.

The auxiliary engine load represents the total average auxiliary engine power used per vessel (combining multiple engines if there were operating simultaneously). The auxiliary boiler fuel use rates were converted to equivalent kilowatts (CARB, June 2008). Estimated Average and Peak exhaust flows for vessels from ACTI are based upon auxiliary engine and boiler loads. Appendix F presents an ACTI analysis on auxiliary boiler emissions and exhaust flow rates.

Table 13. Auxiliary Engine & Boiler Emission Factors, g/kWh

FUEL	PM g/kWh	NOx g/kWh	SOx g/kWh	VOC g/kWh	CO g/kWh
Engine[1]: Heavy Fuel Oil (HFO)	1.5	14.7	11.1	0.46	1.1
Engine[1]: Marine Distillate (0.5% S)	0.38	13.9	2.1	0.52	1.1
Boiler: Heavy Fuel Oil (HFO)	0.8	2.1	16.5	0.11	0.2

[1] Medium speed auxiliary engine

Table 14. Auxiliary Engine Power, Load Factor, and Fuel

Vessel Type	Rated Power kW	Load Factor %	Hotelling Load kW	Fuel Share HFO %	Fuel Share Distillate %
Auto Carrier	2,999	26%	780	71%	29%
Bulk	2,459	10%	246	71%	29%
Container Ship	8,156	18%	1468	71%	29%
General Cargo	1,799	10%	180	71%	29%
Passenger	44,042	16%	7047	92%	8%
Reefer	3,605	32%	1154	71%	29%
Roll-on/Roll-off	2,605	26%	677	71%	29%
Tanker	2,339	26%	608	71%	29%

Table 15. Auxiliary Engine & Boiler Hotelling Loads and Flow Rates per Vessel

Vessel Type	Auxiliary Engine(s)			Auxiliary Boiler		
	Ave. Load kW	Ave. Flow scfm	Peak Flow scfm	Ave. Load kW	Ave. Flow scfm	Peak Flow scfm
Auto Carrier	780	2,339	4,139	278	1,112	1,668
Bulk	246	738	3,393	82	328	492
Container Ship	1,468	4,404	11,255	380	1,520	2,280
General Cargo	180	540	2,483	99	396	594
Passenger	7,047	21,140	60,778	750	3,000	4,500
Reefer	1,154	3,461	4,975	348	1,392	2,088
Roll-on/Roll-off	677	2,032	3,595	82	328	492
Tanker	608	1,824	3,228	1,593	6,372	9,558

Table 16 presents the total auxiliary engine and boiler exhaust flow rates. Estimates are based upon the ECS capturing all of the exhaust with 5% excess ambient air (vessel exhaust represents 95% of total volume of gases being treated by the ETS). The number of vessels serviced by each ETS is based upon the total peak flow rate (which is not normally expected in hotelling mode) and the ETS capacity of 12,000 scfm (which can treat up to 12,500 scfm). The vessels/ETS ratio was adjusted such that the fraction of vessels less than 0.5 vessels was adjusted down to a whole vessel. In the Auto Carrier example, the 2.1 vessels/ETS was adjusted to 2.0. This analysis is based upon a per vessel cost basis, which means although the ETS can process 2.1 vessels, it will only be given credit for processing 2.0 vessels and half of the ETS costs will be attributed to a single vessel instead of only 48% of the ETS cost (if the 2.1 vessels/ETS were used in the calculations). If the fractional part of the vessels/ETS ratio was greater than or equal to 0.5 vessels, the value remained unchanged. This has the effect of applying a premium on the ETS cost to accommodate the estimated peak flow rate. In the Container ship example, the ETS is estimated to only process 0.9 vessels (based upon the peak flow rate), which will have the effect of putting an extra 11% premium on the ETS cost to accommodate the excess in peak flow rate (a single ETS could accommodate 2 vessels running at the estimated average flow rate of the Container vessel). These assumptions are considered conservative.

Table 16. Total Auxiliary Engine & Boiler Flow Rates

Vessel Type	Total Average Flow Rate scfm	Adjusted Total Average Flow scfm	Total Peak Flow Rate scfm	Number of Vessels per ETS	Adjusted Number of Vessels per ETS
Auto Carrier	3,451	3,633	5,807	2.1	2.0
Bulk	1,066	1,122	3,885	3.1	3.0
Container Ship	5,924	6,236	13,535	0.9	0.9
General Cargo	936	985	3,077	3.9	3.9
Passenger	24,140	25,411	65,278	0.2	0.2
Reefer	4,853	5,108	7,063	1.7	1.7
Roll-on/Roll-off	2,360	2,484	4,087	2.9	2.9
Tanker	8,196	8,628	12,786	0.9	0.9

The pollutant emission rates for the auxiliary engine and auxiliary boiler for each vessel type are presented in Table 17 and Table 18. They were calculated from the hotelling loads of the auxiliary engine/boiler and their respective emission factors. The auxiliary engines are assumed to run on a mix of heavy fuel oil and marine distillate (see Table 14). The auxiliary boilers are assumed to burn only heavy fuel oil continuously while hotelling (CARB, June 2008).

Table 17. Auxiliary Engine Emissions per Vessel Type, lb/hr

Vessel Type	PM lb/hr	NOx lb/hr	SOx lb/hr	VOC lb/hr	CO lb/hr
Auto Carrier	2.02	24.87	14.59	0.82	1.89
Bulk	0.64	7.84	4.60	0.26	0.60
Container Ship	3.80	46.83	27.48	1.55	3.56
General Cargo	0.47	5.74	3.37	0.19	0.44
Passenger	21.91	227.38	161.26	7.22	17.09
Reefer	2.99	36.80	21.59	1.21	2.80
Roll-on/Roll-off	1.75	21.60	12.68	0.71	1.64
Tanker	1.58	19.40	11.38	0.64	1.47

Table 18. Auxiliary Boiler Emissions per Vessel Type, lb/hr

Vessel Type	PM lb/hr	NOx lb/hr	SOx lb/hr	VOC lb/hr	CO lb/hr
Auto Carrier	0.49	1.29	10.11	0.07	0.12
Bulk	0.14	0.38	2.98	0.02	0.04
Container Ship	0.67	1.76	13.82	0.09	0.17
General Cargo	0.17	0.46	3.60	0.02	0.04
Passenger	1.32	3.47	27.28	0.18	0.33
Reefer	0.61	1.61	12.66	0.08	0.15
Roll-on/Roll-off	0.14	0.38	2.98	0.02	0.04
Tanker	2.81	7.38	57.95	0.39	0.70

The average California hotelling times for each vessel call are given in Table 19 (CARB, June 2008). It is expected that AMECS will be installed in a location with a high berth occupancy rate to fully utilize AMECS' capacity. "Maximum calls to berth" are the theoretical maximum if the berth has 100% occupancy (full utilization). Both the Barge-Based and the Dock-Based ECS design utilize the same ETS that would be installed on the dock. It is possible that the Barge-Based ECS would have a higher utilization rate than the Dock-Based ECS due to the Dock-Based ECS being limited to only treating vessels moored next to the dock. The Barge-Based ECS has not been demonstrated yet.

Table 19. Hotelling Time and Utilization

Vessel Type	Average Hotelling Time hours/call	Maximum Calls to Berth calls/year	Dock Utilization %	Dock Usage calls/year
Auto Carrier	18.4	476	65%	310
Bulk	64.5	136	65%	88
Container Ship	34.9	251	65%	163
General Cargo	46.1	190	65%	123
Passenger	11.7	751	20%	150
Reefer	41.9	209	65%	136
Roll-on/Roll-off	28.4	308	65%	200
Tanker	33.5	262	65%	170

For this analysis, the Dock-Based ECS utilization (AMECS utilization assumed to be equal to dock occupancy) is assumed to conservatively be 65% (90% is also considered possible) (Environ, 2006). The exception is the estimated 20% dock utilization for the passenger/cruise vessels which is based upon ACTI's research and observations.

The resulting estimated emissions per vessel call to a berth are given in Table 20 with the annual emissions in Table 21.

Table 20. Auxiliary Engine & Boiler Emissions per Vessel, tons/call

Vessel Type	PM ton/call	NOx ton/call	SOx ton/call	VOC ton/call	CO ton/call
Auto Carrier	0.023	0.240	0.227	0.008	0.019
Bulk	0.025	0.265	0.245	0.009	0.020
Container Ship	0.078	0.847	0.720	0.029	0.065
General Cargo	0.015	0.143	0.161	0.005	0.011
Passenger	0.136	1.347	1.100	0.043	0.102
Reefer	0.075	0.804	0.717	0.027	0.062
Roll-on/Roll-off	0.027	0.312	0.222	0.010	0.024
Tanker	0.073	0.448	1.160	0.017	0.036

Table 21. Auxiliary Engine & Boiler Emissions per Vessel, tons/year

Vessel Type	PM ton/yr	NOx ton/yr	SOx ton/yr	VOC ton/yr	CO ton/yr
Auto Carrier	7.1	74.5	70.3	2.5	5.7
Bulk	2.2	23.4	21.6	0.8	1.8
Container Ship	12.7	138.3	117.6	4.7	10.6
General Cargo	1.8	17.6	19.8	0.6	1.4
Passenger	20.4	202.2	165.2	6.5	15.3
Reefer	10.3	109.3	97.5	3.7	8.4
Roll-on/Roll-off	5.4	62.6	44.6	2.1	4.8
Tanker	12.5	76.2	197.4	2.9	6.2

6. Cost Effectiveness

The cost effectiveness of the AMECS is determined by dividing the total AMECS life cycle cost by the total weighted emissions reduced by AMECS over the life of the system. The use of weighted reduced emissions is based upon the Carl Moyer Memorial Air Quality Standards Program. The Carl Moyer program was established in 1998 to offer monetary incentives to encourage the voluntary purchase of cleaner-than-required engines, equipment, and emission reduction technologies (CARB, April 2008). The Carl Moyer program considers NOx, VOC and PM_{10} emission reductions in one calculation where weighting factors are applied. For NOx and VOC emission reductions, a weighting factor of one is used. CARB has identified particulate emissions from diesel-fueled engines as toxic air contaminants, and believes emission reductions of PM_{10} should carry additional weight in the calculation because, for an equivalent weight, these emissions are more harmful to human health. CARB uses a PM weighting factor of 20. The Carl Moyer method utilizes the Annualized Cash Flow method which multiplies the initial capital cost by a capital recovery factor to obtain an equivalent end of year annual capital cost payment (but not the recurring annual operation and maintenance costs).[6] This report estimates the Total Life Cycle Costs (2008$) by combining the annualized initial capital costs adjusted for the time value of money (Annualized Cash Flow method) and the discounted annually recurring future costs which is calculated by determining the present value of the costs from buying, operating, and maintaining the equipment over the life of the equipment (Discounted Cash Flow method).

The weighted cost effectiveness formula for AMECS analysis is:

$$\frac{\text{Total Life Cycle Cost (2008\$)}}{\text{(NOx + VOC + 20*PM) (weighted tons reduced over life of AMECS)}}$$

Table 22 summarizes the weighted emissions reduced based upon the AMECS control efficiencies (with the 1.5% reduction in NOx control efficiency to account for the SCR degradation over time). The total pollutants reduced do not include the SOx emissions (Moyer methodology).

The initial capital costs in Table 23 are on a costs per vessel basis. The ETS per vessel percentage calculates the fraction of the capital costs attributed to a single vessel (note that this is based upon the peak exhaust flow rate, not the average exhaust flow rate). It is expected for AMECS to be installed such that the optimum amount of treatable exhaust would be available. For example, the Auto Carrier berth that has one ETS would not be installed in an area that only has one ECS installed because it would only be capable of using about 50% of the ETS' capacity when the auxiliary engine and boiler are running at full load. The Auto Carrier berth should be installed with two ECS for each ETS installed to optimally utilize AMECS' ETS capacity.

[6] The Moyer method does not consider annual operating and maintenance costs.

Table 22. Emissions Reduced per Vessel

Vessel Type	PM[1] ton/yr	NOx ton/yr	VOC ton/yr	TOTAL[2] ton/yr	SOx[3] ton/yr
Auto Carrier	135.8	72.7	2.4	210.9	70.2
Bulk	42.3	22.9	0.8	65.9	21.6
Container Ship	242.0	135.0	4.5	381.5	117.4
General Cargo	34.7	17.2	0.6	52.5	19.8
Passenger	386.7	197.4	6.2	590.3	164.9
Reefer	194.8	106.8	3.6	305.2	97.3
Roll-on/Roll-off	102.7	61.1	2.0	165.8	44.5
Tanker	237.2	74.4	2.8	314.4	197.0

1 Moyer weighting factor of 20 was applied to the PM emissions reduced.
2 Total emissions only include PM, NOx, and VOC for cost effectiveness calculations.
3 SOx emissions reduced is provided in this table for informational purposes only.

Table 23. ETS per Vessel and Initial Capital Costs per Vessel

Vessel Type	ETS per Vessel	ETS Costs/Vessel		ECS Costs/vessel (Dock-Based)			TOTAL COSTS $/VESSEL
		Equipment	Install	Tower	Manifold	Install	
Auto Carrier	50%	2,107,798	477,263	1,672,188	318,989	1,240,883	5,817,120
Bulk	33%	1,391,147	314,993	1,672,188	318,989	1,240,883	4,938,200
Container Ship	113%	4,763,624	1,078,613	1,889,573	360,457	1,402,197	9,494,465
General Cargo	26%	1,096,055	248,177	1,672,188	318,989	1,240,883	4,576,291
Passenger	544%	22,932,845	5,192,616	9,096,703	1,735,300	6,750,401	45,707,865
Reefer	59%	2,487,202	563,170	1,672,188	318,989	1,240,883	6,282,431
Roll-on/Roll-off	34%	1,433,303	324,539	1,672,188	318,989	1,240,883	4,989,901
Tanker	107%	4,510,688	1,021,342	1,789,241	341,318	1,327,744	8,990,334

Table 24 contains the Dock-Based capacity factor, consumables and utilities usage rate. These usage rates are based upon the average exhaust flow rates of each vessel type and the fraction of AMECS 12,000 scfm capacity that each vessel utilizes.

Table 24. ETS Capacity Factor, Consumables, and Utilities Usage Rate per Vessel

Vessel Type	%ETS Exhaust Capacity	Liquid Waste gal/hr	Solid Waste lb/hr	Urea gal/hr	NaOH gal/hr	Water gal/hr	Electric Power kW	Heating MMBTU/Hr
Auto Carrier	30%	0.83	0.66	4.51	9.24	90.1	106	0.29
Bulk	9%	0.26	0.20	1.42	2.84	27.8	33	0.09
Container Ship	52%	1.42	1.14	8.38	15.44	154.6	182	0.50
General Cargo	8%	0.22	0.18	1.07	2.61	24.4	29	0.08
Passenger	212%	5.80	4.64	39.80	70.51	630.2	741	2.05
Reefer	43%	1.17	0.93	6.62	12.81	126.7	149	0.41
Roll-on/Roll-off	21%	0.57	0.45	3.79	5.86	61.6	72	0.20
Tanker	72%	1.97	1.57	4.62	25.93	214.0	252	0.70

The berth utilization (AMECS utilization) in Table 25 determines the amount of consumable and utility costs per year for each vessel.

Table 25. Dock-Based Berth Utilization, Consumables, and Utilities Cost

Vessel Type	Berth Utilization %	Liquid Waste $/year	Solid Waste $/year	Urea $/year	NaOH $/year	Water $/year	Electric Power $/year	Heating $/year
Auto Carrier	65%	1,882	6,924	89,292	146,845	1,968	67,734	13,743
Bulk	65%	581	2,138	28,070	45,083	608	20,915	4,244
Container Ship	65%	3,230	11,886	165,850	245,472	3,379	116,269	23,591
General Cargo	65%	510	1,877	21,152	41,417	534	18,364	3,726
Passenger	20%	4,050	14,903	242,465	344,790	4,236	145,777	29,579
Reefer	65%	2,646	9,737	131,104	203,569	2,768	95,241	19,325
Roll-on/Roll-off	65%	1,287	4,735	75,040	93,074	1,346	46,316	9,398
Tanker	65%	4,469	16,445	91,390	412,058	4,674	160,863	32,640

The ETS per Vessel percentage in Table 26 affects the labor, maintenance, insurance and central facility costs per year. The consumables and utilities in Table 25 are summarized in Table 26. Burden and markup have been applied to all costs except for the utilities (e.g. electricity, natural gas, and water), as these will be supplied by the port. Maintenance and labor will supplied by a third party operator/owner. AMECS will be staffed 24 hours a day, 365 days a year.

Table 26. Annual Operation and Maintenance Cost

Vessel Type	ETS per Vessel %	Labor Cost $/year	Maintenance & Insurance $/year	Consumables & Utilities $/year	Central Facility $/year	Total Cost $/year
Auto Carrier	50%	990,391	55,026	328,389	182,031	1,555,836
Bulk	33%	522,972	36,317	101,639	120,140	781,069
Container Ship	113%	1,467,444	124,358	569,678	411,390	2,572,870
General Cargo	26%	472,744	28,613	87,580	94,656	683,594
Passenger	544%	1,452,704	598,681	785,799	1,980,498	4,817,682
Reefer	59%	910,504	64,931	464,389	214,797	1,654,620
Roll-on/Roll-off	34%	662,098	37,418	231,195	123,781	1,054,492
Tanker	107%	1,475,272	117,755	722,539	389,546	2,705,113

The total life cycle cost of the AMECS is based upon the discounted cash flow of costs in the future (which brings the costs to their present value), and the annualized payments of the initial capital costs to account for the time value of money. The costs are summed to produce the total life cycle cost of the AMECS. The interest (discount rate) is assumed to be 4 percent based upon the value used in the Carl Moyer program (CARB, April 2008). The system is designed and projected to have a life of 20 years (the EPA Air Pollution Control Cost Manual uses a 20 year economic lifetime for a SCR system) (EPA, January 2002). Table 27 summarizes the fully loaded (with burden and markup) cost elements. In the Auto Carrier example, $5.8 million capital is annualized with an adjustment for the time value of money (4 percent interest for 20 years) to be $0.4 million per year with a cumulative 20 year cost of $8.6 million. The net present value (NPV), which accounts for the changes in value of money over time, of the annually recurring operation and maintenance cost ($1.6 million) over the life of AMECS is $22 million. Figure 16 graphically shows the total project life costs with the capital cost and O&M cost components (per vessel basis).

Table 27. Annual Cost and Total Project Life Cost (2008$) per Vessel

Vessel Type	Berth Utilization	Initial Capital Cost	Yearly Cost Element		20 Year Total	
			Annualized Capital Cost	O&M Cost	Annualized Capital Cost	NPV O&M Cost
Auto Carrier	65%	5,817,120	428,034	1,555,836	8,560,678	21,990,095
Bulk	65%	4,938,200	363,361	781,069	7,267,227	11,039,575
Container Ship	65%	9,494,465	698,619	2,572,870	13,972,386	36,364,790
General Cargo	65%	4,576,291	336,732	683,594	6,734,630	9,661,879
Passenger	20%	45,707,865	3,363,265	4,817,682	67,265,294	68,092,826
Reefer	65%	6,282,431	462,272	1,654,620	9,245,446	23,386,299
Roll-on/Roll-off	65%	4,989,901	367,166	1,054,492	7,343,313	14,904,121
Tanker	65%	8,990,334	661,524	2,705,113	13,230,490	38,233,901

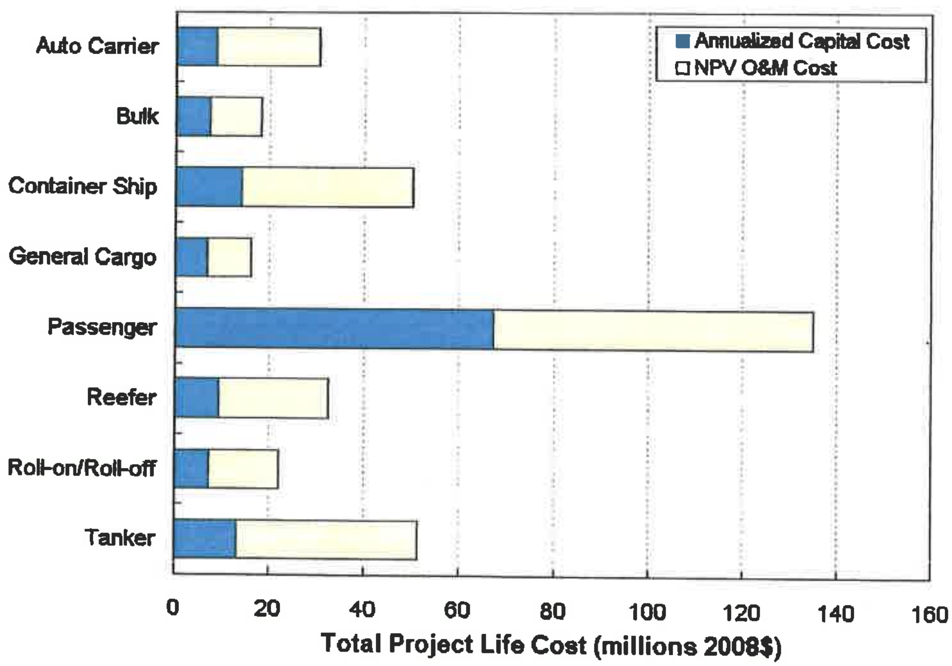

Figure 16. Total Project Life Cost (per Vessel)

Table 28 presents the total project cost over the estimated 20 year AMECS life and the adjusted controlled emissions weighted with the factor of 20 applied to the PM emissions reduced. The total cost and emissions reduced are on a per vessel basis.

Table 28. Cost Effectiveness Over 20 Year AMECS Life, per Vessel

Vessel Type	Total Cost 2008$	Weighted Emissions Reduced, tons	Cost Effectiveness 2008$/ton
Auto Carrier	30,550,773	4,218	7,242
Bulk	18,306,802	1,318	13,890
Container Ship	50,337,176	7,630	6,597
General Cargo	16,396,509	1,049	15,627
Passenger	135,358,120	11,807	11,465
Reefer	32,631,744	6,103	5,347
Roll-on/Roll-off	22,247,434	3,317	6,707
Tanker	51,464,390	6,288	8,184

To estimate the costs of a total AMECS installation that will utilize the ETS capacity (for a minimum of one vessel), Table 29 was created to summarize the initial capital costs (ECS and ETS) and recurring annual O&M costs for AMECS installations based upon the ETS per OGV factor (which was based upon the peak exhaust flow rate and the single ETS unit capacity of 12,000 scfm). The number of ECS units is also the number of vessels that the AMECS can service simultaneously.

Table 29. Total AMECS Installation for Full ETS Utilization (2008$)

Vessel Type	ETS per OGV	Number of ECS units	Number of ETS units	Total ECS Cost/AMECS	Total ETS Cost/AMECS	Total O&M Cost/year per AMECS
Auto Carrier	50%	2	1	6,464,119	5,170,121	3,111,672
Bulk	33%	3	1	9,696,178	5,118,420	2,343,206
Container Ship	113%	1	1	3,652,227	5,842,237	2,572,870
General Cargo	26%	4	1	12,928,238	5,376,926	2,734,377
Passenger	544%	1	5	17,582,404	28,125,461	4,817,682
Reefer	59%	2	1	6,464,119	6,100,743	3,309,240
Roll-on/Roll-off	34%	3	1	9,696,178	5,273,524	3,163,475
Tanker	107%	1	1	3,458,304	5,532,030	2,705,113

Table 30 presents the total project cost over the estimated 20 year AMECS life and the adjusted controlled emissions weighted with the factor of 20 applied to the PM emissions reduced. The total cost and emissions reduced are on a total AMECS installation basis. The cost effectiveness is the same as the cost effectiveness presented in Table 28 (per vessel basis). Figure 17 graphically shows the cost effectiveness of the AMECS for the various vessel types.

Table 30. Cost Effectiveness Over 20 Year AMECS Life, Total AMECS Installation

Vessel Type	Annualize Capital Cost 2008$	Present Value O&M Cost 2008$	Total Cost 2008$	Weighted Emissions Reduced tons	Cost Effectiveness 2008$/ton
Auto Carrier	17,121,356	43,980,190	61,101,546	8,437	7,242
Bulk	21,801,682	33,118,725	54,920,407	3,954	13,890
Container Ship	13,972,386	36,364,790	50,337,176	7,630	6,597
General Cargo	26,938,521	38,647,516	65,586,036	4,197	15,627
Passenger	67,265,294	68,092,826	135,358,120	11,807	11,465
Reefer	18,490,891	46,772,598	65,263,489	12,206	5,347
Roll-on/Roll-off	22,029,938	44,712,363	66,742,301	9,951	6,707
Tanker	13,230,490	38,233,901	51,464,390	6,288	8,184

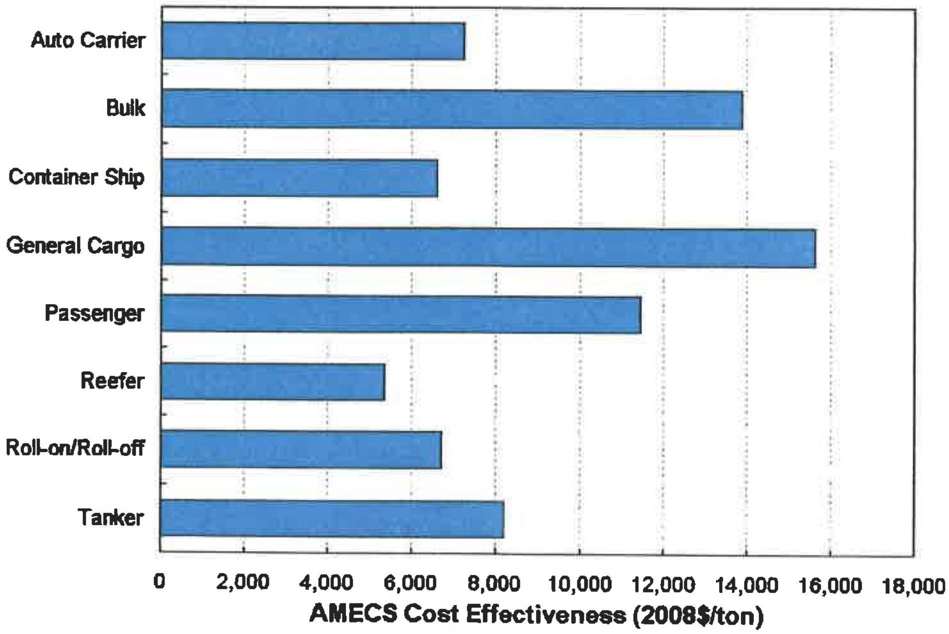

Figure 17. AMECS Cost Effectiveness

If AMECS were to be Barge-Based deployed, which could potentially treat any type of vessel, a weighted average calculation could give more relevance to vessels that hotel longer. The California and POLB weighting factors are based upon the vessel port visits and average hotelling time per visit in 2006 (CARB, June 2008). ACTI developed weighting factors based upon the relative applicability/marketability of AMECS to the various vessel types. Table 31 shows the weighting factor profiles for the California average, POLB average, and ACTI weighting factor profiles for each vessel type.

Table 31. Weighting Factor Profiles

Vessel Type	CA Port Visits in 2006	CA Ave. Hotelling Time hrs/visit	CA Average Weighting Factor	POLB Port Visits in 2006	POLB Hotelling Time hrs/visit	POLB Weighting Factor	ACTI Weighting Factor
Auto Carrier	1,006	18.4	4.9%	247	17.7	3.6%	15%
Bulk	983	64.5	16.7%	290	55.9	13.4%	33%
Container Ship	5,038	34.9	46.2%	1,445	49.5	59.2%	4%
General Cargo	371	46.1	4.5%	142	44.4	5.2%	5%
Passenger	770	11.7	2.4%	133	11.0	1.2%	3%
Reefer	315	41.9	3.5%	28	24.4	0.6%	5%
Roll-on/Roll-off	112	28.4	0.8%	52	34.5	1.5%	10%
Tanker	2,391	33.5	21.0%	536	34.5	15.3%	25%

Table 32 presents the simple average and various weighted averages. The simple average of \$9,382/ton assumes that each of the cost effectiveness values for each vessel type is of equivalent importance. The California and POLB weighted average cost effectiveness are lower than the simple average with the ACTI weighted average having the highest cost effectiveness of \$10,043/ton of weighted emissions reduced by AMECS.

Table 32. Average Cost Effectiveness

	Cost Effectiveness 2008$/ton
Simple Average	9,382
California Weighted Average	8,658
POLB Weighted Average	8,366
ACTI Weighted Average	10,043

Averaging the different cost effectiveness of the various vessel types may not be appropriate for the Dock-Based design because a single berth does not service all vessel types. The Barge-Based design would cost more, but it would also have an increased AMECS utilization due to not being constrained to only treating vessels berthed next to the AMECS and it would be able to service different vessels. The Barge-Based design (not demonstrated yet) is beyond the scope of this report. However, a single average value allows for a general examination of the sensitivity of the average cost effectiveness of all the various vessel types resulting from varying various input/assumptions.

Sensitivity analysis was performed on the higher ACTI weighted average cost effectiveness of \$10,043/ton according to the hypothetical base case parameters listed in Table 33. The results are graphed in the tornado chart in Figure 18.

Table 33. Parameters Used for the Cost Effectiveness Sensitivity Analysis

	Better Cost Effectiveness	ACTI Weighted Midpoint Case	Worse Cost Effectiveness
Berth/AMECS Utilization Rate[1]	90%	65%	40%
Peak Exhaust Flow Rates	-25%	—	+25%
AMECS Lifetime	25 years	20 Years	15 years
Water/Electricity/NG Rates	-50%	—	+200%
Interest (Discount Rate)	6%	4%	3%

[1] Passenger vessels were kept constant at 20% berth utilization.

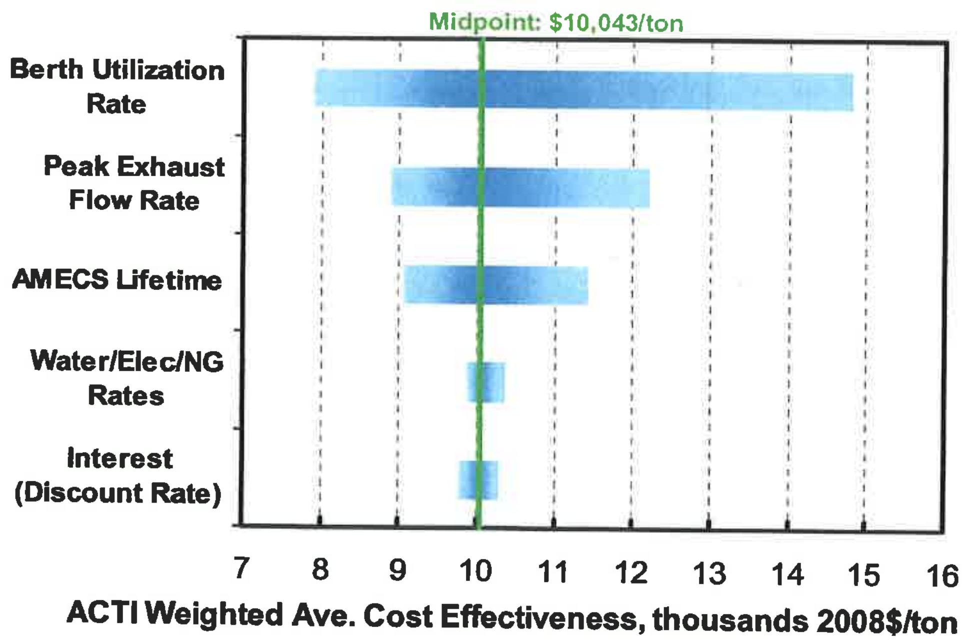

Figure 18. Cost Effectiveness Sensitivity on ACTI Weighted Average

Figure 18 highlights the importance of installing the AMECS on a berth with a high occupancy which would allow AMECS the opportunity to be utilized thereby improving its cost effectiveness. The midpoint/default scenario for the analysis was set at 65% (except for passenger vessels which were kept at a constant 20%). The maximum (worst) cost effectiveness ($14,831/ton) is based upon a berth utilization of 40% with the minimum (better) cost effectiveness ($7,916/ton) due to a 90% berth utilization/occupancy rate. The 25% drop in berth utilization produced a 48% increase in cost effectiveness value (worst), but a 25% increase in berth utilization produced a 21% improvement (decrease) in cost effectiveness.

A 25% increase in estimated peak exhaust flow rate (auxiliary engine and boiler) produced a 22% increase in cost effectiveness ($12,205/ton). A 25% decrease in peak exhaust flow rates for each vessel type produced an average 11% reduction ($8,905).

If the 20 design life of AMECS could be extended to 25 years, the cost effectiveness would improve by 10% ($9,061/ton). But if the AMECS life was reduced to 15 years, the cost effectiveness would increase by 14% ($11,417/ton).

The change in water/utility costs didn't make as much of an impact on the cost effectiveness of AMECS. Doubling the water/utility rates only increased the cost effectiveness by 3% ($10,358/ton) and cutting the rates in half only improve the cost effectiveness by 2% ($9,886/ton).

The cost effectiveness calculations based upon annualized capital costs which effectively increases the total project costs due to the interest rate is countered by the reduction in total operation and maintenance costs for the project over the AMECS life due to the discount rate bringing future O&M costs to the 2008 present value. Assuming that the interest rate and the discount rate remain equal, decreasing the rate to 3%, produced a 2% increase in cost effectiveness ($10,289/ton). However, increasing the interest/discount rate to 6% resulted in a 3% improvement in cost effectiveness ($9,780).

An additional benefit of AMECS that is not captured by the cost effectiveness analysis is the 99.8% reduction in SOx emissions and 34.8% reduction in CO emissions. Vessels not being required to be modified in order for AMECS to treat the exhaust emissions is also a benefit that is not examined by this cost effectiveness analysis.

7. Summary

The testing of AMECS at the POLB was to investigate the effectiveness of utilizing stationary air pollution control equipment to capture and treat hotelling emissions from vessels that were moored at berths. A major advantage of the AMECS is that no vessel modifications are required for AMECS to treat the exhaust emissions.

The objectives/criteria of the test program and its' accomplishments were:

Objective 1: To document the effectiveness of the AMECS system in reducing ocean-going vessel emissions of particulate matter (PM), oxides of nitrogen (NOx), volatile organic compounds (VOC) and other pollutants under typical at-berth operating conditions. The criterion for a successful demonstration will be no less than 90% reduction in PM, NOx, and VOC.

Objective 1 is accomplished by this report which documents and evaluates the AMECS pollutant control efficiencies and the AMECS costs effectiveness. The average PM, NOx, VOC, as well as SOx removal efficiencies of at least 95% from the vessel exhaust exceeds Objective 1 criteria for success.

Objective 2: To assure that the emission control equipment, process, and procedures do not interfere with normal Metropolitan Stevedore operations. This would include not affecting the loading/offloading operations of Metropolitan Stevedore as well as the auxiliary engine/boiler operation of the vessel

Objective 2 was accomplished. Robert Waterman, Assistant Vice-President of Bulk Operations for Metropolitan Stevedore, stated that there were no adverse affects to their normal operations during AMECS operation. There was no noted damage or adverse effect on the vessels, the auxiliary engines, nor the auxiliary boilers due to the operation of AMECS. ACTI personnel were present in the ship's engine control room throughout all the tests and confirmed with the ship's engineer that there were no observable effects due to AMECS' attachment, operation, and detachment from the ships.

Table 34 summarizes the overall average pollutant control efficiencies of the AMECS. The measured average control efficiencies are presented, but the adjusted average control efficiencies were used for this report's analysis to produce a more conservative analysis.

Table 34. Average AMECS Control Efficiency Summary

	NOx	PM	VOC	SO2	CO
Measured Average Control Efficiency	>99.1%	95.0%	96.3%	99.8%	43.8%
Adjusted Average Control Efficiency[1]	>97.6%	95.0%	96.3%	99.8%	43.8%

[1] Cost effectiveness analysis assumed 1.5% reduced NOx control efficiency to allow for SCR catalyst degradation over time

Table 35 presents the total 20 year AMECS cost effectiveness and the number of ECS installed for each AMECS installation (which is the same number of vessels that can be serviced by AMECS simultaneously). Figure 19 graphs the cost effectiveness for each vessel type (assumes a berth is dedicated to a specific vessel type). Sensitivity analysis showed that placement of the

AMECS in a berth with high occupancy is important in increasing the AMECS utilization rate and consequently improve the cost effectiveness.

Table 35. Cost Effectiveness Over 20 Year AMECS Life, Total AMECS Installation

Vessel Type	Maximum Number of Vessels Treated by AMECS Simultaneously	Total Life Cost 2008$	Weighted Emissions Reduced tons	Cost Effectiveness 2008$/ton
Auto Carrier	2	61,101,546	8,437	7,242
Bulk	3	54,920,407	3,954	13,890
Container Ship	1	50,337,176	7,630	6,597
General Cargo	4	65,586,036	4,197	15,627
Passenger	1	135,358,120	11,807	11,465
Reefer	2	65,263,489	12,206	5,347
Roll-on/Roll-off	3	66,742,301	9,951	6,707
Tanker	1	51,464,390	6,288	8,184

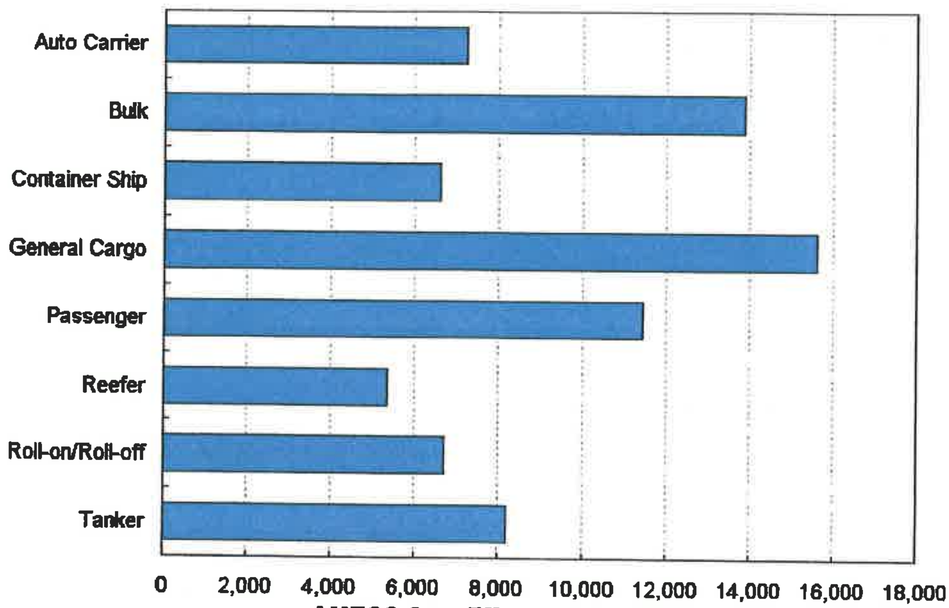

Figure 19. AMECS Cost Effectiveness

The successful capture efficiencies demonstrated by ALECS at the Union Pacific Railroad's J. R. Davis Rail Yard in Roseville, California, and AMECS at the Port of Long Beach resulted in a support letter from Barry Wallerstein, Executive Officer of the SCAQMD (Appendix G). The letter stated that the implementation of both systems could "provide large benefits to the South Coast Air Basin and, in particular, the communities adjacent to these sources."

8. List of Acronyms

ACTI	Advanced Cleanup Technologies, Inc.
ALECS	Advanced Locomotive Emissions Control System
AMECS	Advanced Maritime Emissions Control System
ARB	California Air Resources Board
Btu	British Thermal Unit
CA	California
CARB	California Air Resources Board
CCS	Cloud Chamber Scrubber (subsystem of ETS)
CEMS	Continuous Emission Monitoring System
CO	Carbon Monoxide
CO_2	Carbon Dioxide
dwt	Deadweight Tonnage
ECS	Emissions Capture System
EPA	U.S. Environmental Protection Agency
ETS	Emissions Treatment System
°F	degrees Fahrenheit
gal	Gallons
HFO	Heavy Fuel Oil
hr	Hour
ID	Induced Draft
kWh	Kilowatt Hours
lb	Pounds
MMBtu	Million British Thermal Units
NaOH	Sodium Hydroxide
NG	Natural Gas
NH_3	Ammonia
NO	Nitric Oxide
NO_x	Oxides of Nitrogen
O&M	Operation and Maintenance
O_2	Oxygen
OGV	Ocean-Going Vessel
PCC	Preconditioning Chamber (subsystem of the ETS)
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter less than or equal to 2.5 microns
PM_{10}	Particulate Matter less than or equal to 10 microns
POLB	Port of Long Beach
ppm	parts per million
S	Sulfur
SCAQMD	South Coast Air Quality Management District
scfm	Standard Cubic Feet per Minute
SCR	Selective Catalytic Reduction
SO_2	Sulfur Dioxide
SO_x	Oxides of Sulfur
VOC	Volatile Organic Compounds
yr	Year

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