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Estimated Air Quality Impacts on Surrounding Communities of PM2.5 and SO_2 Emissions Resulting From Maritime Operations at Elizabeth Port Authority Marine Terminal and Port Newark

EXECUTIVE SUMMARY

New Jersey is the most densely populated state in the country and home to major elements of the busiest port on the eastern seaboard. Two of these elements are the marine terminals at Port Newark and Elizabeth Port Authority Marine Terminal. Moving goods to, from, and through the port requires a multitude of equipment, almost all powered by diesel engines. These include the ships, harbor craft, trucks, trains, and cargo handling equipment that work on or in the waters around the port property. Diesel engines emit a variety of pollutants, with diesel particulate matter having the greatest impact. Diesel particulate matter is linked to cancer, asthma, premature death, and other adverse effects, including reduced visibility. Health studies have shown that there is no clear threshold below which adverse effects are not experienced by at least some segments of the population. As the port grows and as regulations and advancements in technology combine to reduce emissions from power plants, industry, motor vehicles and heating oil, emissions from port-related activities may be a bigger portion of the local and regional air pollution problem in the future, unless efforts continue to reduce port emissions.

METHODOLOGY
In order to better understand the potential impact that port-related emissions may have on local and regional air quality, as well as on local residents, the New Jersey Department of Environmental Protection (NJDEP) undertook a risk modeling analysis. NJDEP extracted data from the Port Authority of New York and New Jersey, Port Commerce Department 2006 Baseline Multi-facility Emissions Inventory on the emissions of fine particulate matter and sulfur dioxide from diesel engines operating in and around the port. These data points were then inserted into the AERMOD Dispersion Model (version 07026), and NJDEP was then able to predict the concentrations of these pollutants at various locations, including Bayonne, Newark, Elizabeth, Staten Island and Jersey City. (NJDEP recognizes that additional work is necessary to more accurately quantify air emissions resulting from truck and container moves both on and off the port property. Specifically, emissions from trucks traveling on local roads and the NJ Turnpike, as well as secondary container moves both on and off the port property, were not included). Note: Some uncertainty remains regarding the accounting of On-terminal truck moves.

The predicted concentrations were compared to NJDEP's "Significant Impact Levels" which help gauge whether the impact from an emissions source (such as the port) may significantly affect air quality on a long-term basis (annual significant impact level) or on a short-term basis (24-hour significant impact level).

The predicted concentrations were then added to "background" concentrations of emissions. Background concentrations are quantities of pollutants measured at monitors located throughout the state and reflect the emissions from motor vehicles, power plants, industrial sources, and pollution from nearby states. The combination of the port-specific emissions and the background concentrations was then compared with the USEPA's National Ambient Air Quality Standards (NAAQS).

HEALTH RISK ASSESSMENT

NJDEP then performed a health risk assessment to evaluate the potential for these levels of diesel particulate matter to cause cancer and other adverse health effects. Health scientists use risk assessments to estimate the increased risk of health problems in people who are exposed to different amounts of toxic air pollutants, such as diesel particulate matter. Health risk assessments generally do not gather information or health data on specific individuals, but instead provide estimates of the potential health risk impacts to a hypothetical individual exposed to the predicted off-site concentration over a 70 year period, which tends to result in overestimates of the actual risk. The prediction of cancer risk for diesel particulate matter was taken from values published by the California Air Resources Board. (A more detailed discussion of the cancer risk factor is discussed in Appendix C). Using the US EPA Integrated Risk Information System (IRIS), NJDEP also predicted whether the estimated concentrations of diesel particulates from the port could be continuously inhaled over a lifetime without an appreciable risk of adverse non-cancerous health effects

RESULTS

The modeling predicts that:

- The predicted concentrations of diesel particulate are below the levels that would cause non-cancerous health effects based on IRIS.
- Emissions from port activities do not cause a violation of the annual PM2.5 NAAQS at any modeled location.
- Emissions from port activities contribute significantly to an existing violation of the 24-hour NAAQS for PM2.5 in Bayonne, Newark, Elizabeth, Staten Island and Jersey City.
- Emissions from port activities are above New Jersey's interim significant impact levels (SIL's) for annual PM2.5 in Bayonne, Staten Island and Jersey City.
- Emissions from port activities are above New Jersey's interim SIL for 24-hour PM2.5 in Bayonne, Elizabeth, Jersey City and Staten Island.
- The incremental cancer risk at residences in the western part of Bayonne is of most concern. The prediction is that port related emissions result in an increased risk to a maximally exposed individual of 150 chances in a million,

assuming constant exposure to the highest predicted concentration for 70 years. This prediction justifies short-term efforts to reduce risk.

- The cancer risk predicted at residences in Elizabeth, Newark, Staten Island and Jersey City is lower (between 10 and 100 in a million), but high enough to justify long term efforts to further reduce cancer risk.
- Port-related SO_2 emissions do not violate the annual, 24 hour or 3 hour NAAQS. They do exceed the annual SIL in Bayonne, Newark, Staten Island and Jersey City. The 24 hour SIL is exceeded in these cities, as well as in Elizabeth.

NJDEP also individually analyzed the various categories of diesel goods movement equipment (i.e., trucks, ships, locomotives, and cargo handling equipment) and found that:

- There is no one source category primarily responsible for the risks identified in nearby residential areas: each of the main emission sources has some contribution.
- Emissions from trucks and rail at the Port, resulting in a cancer risk of between 0 and 10 in a million, posed negligible risk to areas currently used for residential purposes.
- Emissions from oceangoing vessels, tugboats and cargo handling equipment (CHE), resulting in a cancer risk of between 10 and 100 in a million, justify long term efforts to further reduce cancer risk.

EMISSION REDUCTION STRATEGIES

Since 2006, when the emissions data was collected, the Port Authority of New York and New Jersey and its tenants at Port Newark and the Elizabeth PA Marine Terminal have implemented actions to reduce diesel emissions. Accomplishments include:

- installing 39 electric wharf cranes and electronic terminal gates;
- modernizing all Cargo Handling Equipment (CHE) with on-road engines that meet tighter emission standards than the non-road engines that would typically be used;
- using ultra low sulfur fuel in all CHE prior to the mandatory switchover in 2010;
- investing over $600 million in expanding the ExpressRail. Established on-dock rail at all container terminals. Achieved 358,000 rail lifts in 2007, displacing over 537,000 truck trips;
- implementing infrastructure improvements to support expansion of rail volume and reduce dependency on trucks;
- extending gate hours to reduce congestion and idling.

In addition, NJDEP has been involved with the following emission reduction strategies:

- NJDEP supported the Port Authority's application for a $7 million grant from USEPA to help fund the Port Authority's Truck Replacement Program to modernize the drayage truck fleet that calls at the Port Authority's New York and New Jersey Marine Terminals, which includes Port Newark and the Elizabeth PA Marine Terminal.

- A project is underway, with enforcement settlement money, which was not associated with the Port Authority's or its tenants' activities, to upgrade two diesel switch locomotives that operate on the port property.
- NJDEP passed along funding from USEPA to the NJ Turnpike Authority for installation of truck stop electrification technology at the Vince Lombardi truck stop near the port. This infrastructure will help truckers comply with NJDEP's stringent idling rules.
- NJDEP has advocated for the establishment of "sulfur emission control areas" in US waterways so that only low sulfur fuel can be used by oceangoing vessels, thereby reducing diesel particulate formation.
- NJDEP has expressed support for USEPA's proposed rulemaking that would establish new NO_x limits for engines used in oceangoing vessels.

Also, the Port Authority of New York and New Jersey, working in voluntary partnership with USEPA; the New Jersey Department of Environmental Protection; the New York State Department of Environmental Conservation; the New York City Economic Development Corporation; the New York City Mayor's Office of Operations; and the New York Shipping Association has drafted a Clean Air Strategy for the Port of New York and New Jersey that identifies additional actions to reduce diesel emissions from all port-related sources. The anticipated future actions are not included in this baseline evaluation, but will be evaluated for their impact on reducing emissions once they have been quantified and selected for potential implementation.

In addition to implementing strategies to reduce diesel emissions, it may be useful to undertake a local ambient air monitoring study. Ambient air monitoring requires a long-term investment of resources and the results will not be definitive in pinpointing exact sources of diesel emissions, in part because there is no direct way to distinguish diesel exhaust from other particles in the ambient air.

INTRODUCTION

I. Background

This memo describes the modeling of the estimated actual emissions and the predicted impacts of fine particulates (PM2.5) and SO_2 from operations at the roughly 2300 acres of marine terminals at the Elizabeth Port Authority Marine Terminal and Port Newark. This report incorporates all of the concerns of the parties involved.

II. Modeling Methodology and Assumptions:

<u>Dispersion Model</u> - AERMOD Version (07026).

<u>Meteorological Data/Land Use</u> – The nearest meteorological site is less than one mile away at Newark International Airport. The most reliable measurements available are from 1991-1995. It is NJDEP policy to use worst-case annual meteorological conditions from a five year period to provide conservative estimates of air quality impacts. Therefore, the year with the highest predicted concentrations is used to define the source

impact. Impacts from an average meteorological year would be less. The meteorological data from the airport site includes hourly wind direction, wind speed, and atmospheric temperature. Upper air data from Atlantic City and Brookhaven was also used. For the AERMOD air quality model, urban dispersion coefficients are used because the area at the impacted receptors is comprised of industrial, commercial and compact residential land uses.

Emissions. Starcrest Consulting Group prepared an actual emission inventory for all port-related sources at all Port Authority Marine Terminal facilities using 2006 as the baseline year[1]. The inventory uses an activity-based approach and focuses on emissions of criteria air pollutants, diesel particulate matter and greenhouse gases for all port-related sources. NJDEP separated out from the Starcrest inventory those diesel particulate and sulfur dioxide emissions related to Port Newark and Elizabeth Port Authority Marine Terminal and used them as the basis for the air quality modeling. In addition to these on-terminal activities, emissions from trucks transporting port cargo on nearby roads between the port and the N.J. Turnpike were estimated by NJDEP.

PM2.5

- Emissions from all port operations are included [ocean-going vessels (OGV), locomotives, cargo handling equipment (CHE) and port-related truck traffic only] (see Table 1);
- Dwelling, transit and boiler emissions from ocean going vessels are included. Transit emissions are the engine emissions occurring while the ocean going vessels destined for berths at Port Newark and Elizabeth Port Authority Marine Terminal travel from the Lower New York Bay through the Newark Bay to dock at the Port.
- 365 days/year activity was assumed for all emission sources, except for truck-related activity, which operated on 250 days per year; Operating hours per year are taken from the 2006 inventory (e.g. Table 2:12, p.50). These hours were equally divided up into 365 days, since any piece of equipment could potentially be used on any day. Port-related truck emissions are restricted to the opening times of the port gates (i.e. 6am-6pm - obtained from terminal operators). Idling truck emissions are confined to the same period. Port-related truck activity is restricted to 250 days/year, which correlates to the number of days/year the marine terminals are open.
- The estimated PM2.5 emission rate for ocean-going vessels was 4.3 grams/sec. The estimated emission rate for the truck traffic was 0.04 grams/mile and 3.38 grams/hour[2] per idling truck.
- All ship, locomotive, cargo handling, and truck diesel particulate emissions used in this modeling effort are assumed to be PM-2.5.

SO_2

- The days of operation per year assumed were the same as for PM2.5. Operating hours per year were also the same as assumed for PM2.5. These

[1] Starcrest Consulting Group LLC, 2006 Baseline Multi-Facility Emissions Inventory, 2008
[2] Starcrest Consulting Group LLC, 2006 Baseline Multi-Facility Emissions Inventory, 2008, p87

hours were equally divided up into 365 days, since any piece of equipment could potentially be used on any day.

- Sulfur content of diesel fuel for ocean-going vessels is assumed to be 2.7%
- No secondary formation of particulates (sulfates) from sulfur dioxide emissions is considered in this modeling evaluation, which focuses on local effects rather than longer range transport of air pollution.

Table 1: PM2.5 and SO_2 Emissions for Port Newark and Elizabeth (2006)

Operation	PM2.5 (tpy)	SO_2 (tpy)
Cargo Handling Equipment	74.0	194
Ocean-going Vessels (OGV-Dwelling)	49.4	1184.2
Ocean-going Vessels (OGV-Transit)	67.3	735.7
Ocean-going Vessels (OGV-Boilers)	25.0	663.0
Ocean-going Vessels (OGV-Tugboats)	10.4	21.5
Locomotives	4.13	11.6
Trucks – idling	11.9	2.9
Trucks – on terminal	1.29	4.2
Trucks – Port roads	3.2	1.9

Source characterization - All of the port-related emission sources are mobile sources and are characterized as area sources, except for ocean-going vessels dwelling at berth ("hotelling") and the wharf cranes, which are modeled as individual point sources. Model parameters for area sources include emission rate, release height, lengths of X and Y sides of rectangular areas or vertices for polygons, and the initial vertical (σ_{zo}) dimensions of the area source plume. Model parameters for point sources include estimates of emission rate, stack height, stack diameter, stack exhaust temperature, and stack exhaust exit velocity.

The ocean-going vessel (OGV) transit emissions are simulated as area sources using values from Tables 5.5 and 5.9 of the Starcrest inventory, which apportion emissions by county. A 1000ft (305m) shipping lane[3] was assumed from the Lower New York Bay, through the Narrows and Kill van Kull, to Newark Bay. The hotelling emissions from ship auxiliary engines are simulated as individual point sources at the berths together with emissions from the ships' boilers. Because stack information was not available for individual engines, the average stack height (43 meters) obtained from the Port of Los Angeles Starcrest[4] inventory report was applied to all dwelling engines. The modeling parameters for each of the emission source categories are summarized in Table 2.

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[3] Transportation Safety Board, Office of Marine Safety, http://www.ntsb.gov/publictn/2007/MAB0702.pdf, p5
[4] Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, ARB, 2006

Commercial harborcraft (tugboat) emissions are generated in a similar fashion to the OGVs. The links are identical to those of OGVs, except that they only extend from the port to the anchorage channel (between The Narrows and Upper New York Bay). Cargo handling equipment (CHE) emissions are simulated as area sources with the polygon features of the dispersion model.[5]

Table 2: Emission Source Model Parameters

Model parameter	OGVs	Tugboats	CHE	Rail	Truck	OGV Dwelling	Wharf Cranes
Release height (m)	50	6	2.1-11.5	5	3.7	Ht=43m Temp=618K Vel=16m/s Diam=0.5m	Ht= 38m Temp=644K Vel=20m/s Diam=0.1m
Shipping lane width (m)	305	305	-	-	-		
σ_{zo} (m)	7 (transit)	2.7	0.3-1.8	2.6	1.8		

Locomotive emissions for idling and line haul are simulated as area sources, respectively. The links were estimated by NJDEP staff and extended from Bay Avenue 3000m north to Port Street. The line haul link width is estimated to be 20m.

The on-terminal and off-terminal heavy-duty truck traffic is simulated as area sources; the link width is assumed to be 18m (two lanes in each direction – no allowance for wake width was made due to their slow traveling speeds). The off-terminal truck emissions are represented as line sources along the Port approach roads.

Starcrest provided the annual operating hours for the cargo handling equipment and locomotives. NJDEP staff temporally allocated all the emission sources at both ports based on discussions with terminal operators. The assumptions for the temporal distribution of the emissions are listed in Table 3; further details are provided in Appendices A and B.

Number of trucks – Approximately 2.8 million visits per year were used in the modeling (11,164 trucks per operating day)[6]. The idle time used for each truck was 1.4 hours per day at the port[7]. Emissions are also included from the trucks traveling on roadways from the Port to the two closest intersections with the New Jersey Turnpike (a total of 5.9 miles combined).

Background

PM-2.5 Monitor – The 98th percentile 24-hour concentration and annual PM2.5 background values are based on the average values measured at the Elizabeth Lab.

[5] Emission release heights for CHE were not measured, but estimated during a DEP site visit

[6] Starcrest Consulting Group LLC, 2006 Baseline Multi-Facility Emissions Inventory, 2008, p85

[7] Starcrest Consulting Group LLC, 2006 Baseline Multi-Facility Emissions Inventory, 2008, p85

monitor from 2006-2008. The monitor is located approximately three miles southwest of the Port. By adding the 98th percentile background 24-hour concentration to the modeled impact we have adopted a more conservative approach since it assumes that this relatively high value occurred on the same day (in the worst case year) as the modeled impact.

Table 3: Temporal distribution of Diesel PM2.5 emissions at Elizabeth Port Authority Marine Terminal/Port Newark

Category	Time Period	Hours Per Day	Days Per Year
Ocean-going vessel (OGV) Transit	Midnight – midnight	24	365
OGV Dwelling	Midnight – midnight	24	365
OGV - Tugboats	Midnight – midnight	24	365
Cargo handling Equipment	6am – 9am/6pm	3-12	365
Trucks	6am – 6pm	12	250
Locomotives	6am – 8pm	14	365

SO_2 Monitor – The 3-hour, 24-hour and annual SO_2 background values were also based on values measured at the Elizabeth Lab. monitor (2006-2008).

<u>Receptors</u> – Two receptor networks were used, both Cartesian grids. The inner receptor grid covers an area approximately 5 ½ x 5 ½ miles centered on the port and includes residences to the east in Bayonne, and residences to the south in Elizabeth (Figure 1). The regional grid (29 x 38 points) had a 2000m resolution, whereas the inner network (19 x 22 points) had a 500m resolution. The latter does not represent a dense receptor grid. A 100m grid would lead to higher model predictions. Discrete receptors were also placed in Bayonne along the boundary with Newark Bay.

III. Impacts of the Port's Diesel Emissions on Nearby Air Quality - Fine Particulate Model Predictions – PM-2.5 National Ambient Air Quality Standards (NAAQS)

The predicted concentrations due to diesel emissions were compared to the PM-2.5 National Ambient Air Quality Standards (NAAQS). In Table 4, the maximum predicted annual PM-2.5 concentrations combined with representative PM-2.5 background levels (Elizabeth Lab) are compared to the existing PM-2.5 NAAQS.

This table shows that the region's annual background levels are close to the NAAQS. The Ports impacts, when added to the monitored background levels, do not exceed the annual NAAQS. The impact of the port activities on residential areas is greatest in the western portion of the City of Bayonne where emissions from port activities are above New Jersey's annual interim significant impact levels (SILs) for PM2.5. Impacts on residential areas in Staten Island and Jersey City also exceed the SIL, whereas impacts in Elizabeth and Newark residential areas are below the SIL. Figure 2 shows the spatial distribution of the maximum annual PM-2.5 concentrations. Table 5 shows the predicted eighth-high 24-hour concentrations with associated background levels compared to the existing PM-2.5 NAAQS. The eighth high modeled 24-hour concentration represents the 98th percentile concentration for that year. The 24-hour background level at the monitor

Table 4: Maximum Predicted Annual PM2.5 Impacts for 2006 near the Port of Elizabeth and Newark due to Ship, Cargo Handling Equipment, Truck and Locomotive Emissions at the Port

Location	Maximum Predicted Impact of Port (μg/m^3)	Interim Significant Impact Level[a] (SIL) (μg/m^3)	Background Air Quality (μg/m^3)[b,c]	Total Concentration (μg/m^3)	NAAQS (μg/m^3)
Bayonne (max. impact)	0.69	0.3	13.4	14.1	15.0
Elizabeth (max. impact)	0.22	0.3	13.4	13.6	15.0
Newark (max. impact)	0.10	0.3	13.4	13.5	15.0
Staten I. (max. impact)	0.34	0.3	13.4	13.7	15.0
Elizabeth Lab. Monitor	0.08	0.3	13.4	13.5	15.0
Jersey City	0.43	0.3	13.4	13.8	15.0

[a]The SIL is considered a de minimis pollutant impact. The interim PM-2.5 SILs are based on the existing SILs for PM-10. The PM-10 SILs have been scaled by the ratio of the PM-2.5 NAAQS to the PM-10 NAAQS. This was done for both the 24-hour and annual PM-2.5 SILs. The PM-2.5 SILs represent approximately 2% of annual PM-2.5 NAAQS and 3% of the 24-hour PM-2.5 NAAQS. Because EPA has not yet promulgated SIL's for fine particulate matter, NJDEP and other states in the region are using interim levels.
[b]Average annual concentration measured at Elizabeth Lab from 2006 to 2008
[c]The 0.08 μg/m^3 is subtracted from the Elizabeth Lab. monitored value to avoid double counting the Port's contribution.

nearest to the Port exceeds the NAAQS. Impacts in Bayonne, Elizabeth, Staten Island and Jersey City exceed the interim SIL. Figure 3 shows the spatial distribution of the maximum eighth-high 24-hour PM-2.5 concentrations. While the Port does not by itself cause an exceedance of the 24 hour NAAQS, its significant impacts on the existing exceedance justifies measures to reduce PM2.5 emissions from the Port.

NJDEP Risk Management Procedures for Facility-Wide Risk from Existing Sources[8]

Risk management guidelines are designed to interpret the results of risk assessments and determine which risks are generally considered high. The NJDEP has used risk management for about 20 years to make decisions about whether or not to issue a permit, based on risk, and to determine conditions that should be included in a permit, on a case-by-case basis, to minimize risk. More recently, NJDEP has used risk management as a

Table 5: Maximum Predicted 24-Hour PM2.5 Impacts for 2006 near the Port of Elizabeth and Newark due to Ship, Cargo Handling Equipment, Truck and Locomotive Emissions

Location	Maximum Predicted Impact of Port (µg/m^3)	Interim SIL (µg/m^3)	Background Air Quality (µg/m^3)^{a,b}	Total Concentration (µg/m^3)	NAAQS (µg/m^3)
Bayonne (max. impact)	2.8	1.2	35.3	38.1	35.0
Elizabeth (max. impact)	1.4	1.2	35.3	36.1	35.0
Elizabeth Lab. Monitor	0.5	1.2	35.3	35.8	35.0
Newark (max. impact)	0.6	1.2	35.3	35.9	35.0
Staten Is. (max. impact)	2.2	1.2	35.3	37.5	35.0
Jersey City	1.6	1.2	35.3	36.9	35.0

[a]Average annual concentration measured at Elizabeth Lab. from 2006 to 2008.
[b]The 0.5 µg/m^3 is subtracted from the Elizabeth Lab. monitored value due to the Port's contribution.

tool to identify strategies to reduce risk from concentrated sources of diesel emissions from mobile sources, such as train yards, truck terminals, and with this evaluation, the mobile sources operating at or near the marine terminals at Port Newark and the Elizabeth Port Authority Marine Terminal. The most recent version of the risk assessment technical manual is a draft document that will be finalized after the public

[8] January 27, 2009 NJDEP Technical Manual 1003 "Guidance on Risk Assessment for Air Contaminant Emissions", which provides information for carrying out a risk assessment in conjunction with applying for an air pollution control permit from a stationary source.

comment period closes on July 17, 2009 (see NJ Register notice dated May 18, 2009). As of the date of this modeling report, the risk assessment manual has not been finalized. NJDEP uses the following risk management guidelines for facility-wide risk:

- Cancer risk greater than 1000 in a million – unacceptable risk. Take immediate action to reduce risk; pursue enforcement action for existing facilities.
- Cancer risk greater than 100 in a million but less than 1000 in a million - implement short-term risk minimization strategy.
- Cancer risk greater than 10 in a million but less than 100 in a million greater than 10 in a million - implement long-term risk minimization strategy.
- Cancer risk less than 10 in a million – negligible risk; a formal risk minimization strategy is not required but continue efforts to minimize risk.

Note: *For individual, new and modified equipment*, the NJDEP considers a risk of greater than 1 in a million to be significant, justifying risk minimization, and a risk greater than 100 in a million to be unacceptable.

Model Predictions – Carcinogenic and Non-Carcinogenic Health Effects

Table 6 lists the predicted incremental cancer risk due to the estimated emissions from ships, cargo handling equipment, locomotives and trucks. It should be noted that emissions from the ship boilers are composed of non-diesel particulate matter. By omitting their emissions from this analysis the cancer risk is lower than if they were included. The values range from about 30 in a million at the residential area in Newark to the north to 150 in a million in the residential area in Bayonne to the east (see Figure 4). While some of these areas are not currently used for residential purposes, Figure 4 can also be used as a general tool to show areas of potential cancer risk outside the boundary of the Port. According to NJDEP's Risk Management Guidelines for the Air Quality Program, risks between 100-1000 in a million justify short-term efforts to further reduce cancer risk from sources at the Port (predicted for Bayonne). The incremental cancer risks predicted at residences in Elizabeth, Newark, Jersey City and Staten Island are between 10 and 100 in a million justifying long term efforts to further reduce cancer risk from sources at the Port. Figure 5 shows the predicted incremental cancer risk on a more regional scale showing an extensive area of risk above 10 in a million. The incremental cancer risk is an estimate that assumes a lifetime exposure and uses a unit risk factor, which estimates the carcinogenic potency of a chemical. The unit risk factor incorporates conservative assumptions to account for uncertainty, as described in the following sections and discussed in greater depth in Appendix C.

What are the uncertainties associated with the predicted risk?

The estimates provided by risk assessments are not exact. They help scientists and the public evaluate and place into perspective the risks associated with emissions of toxic air pollutants. Due to uncertainties in each of the variables that go into a health risk assessment, there is uncertainty in estimating the risk to a specific individual or at a specific location. Because of the conservative nature of the risk assessment process, these

Table 6: Predicted Incremental Cancer Risk at Residential Locations attributed to Diesel Particulate Emissions from OGV, Cargo Handling Equipment, Trucks and Locomotives Operating At or near Port Newark and Elizabeth

Receptor	Annual Impact (ug/m^3)	Unit Risk Factor [a] (ug/m^3)$^{-1}$	Incremental Cancer Risk [b]
Bayonne	0.50	3 E-04	150
Elizabeth	0.14	3 E-04	42
Newark	0.10	3 E-04	30
Staten Island	0.21	3 E-04	63
Jersey City	0.26	3 E-04	78

a. Unit risk factor from California EPA (2002)
b. Assumes 70 year inhalation exposure; 150= 150 in a million risk

assumptions typically overestimate the risk. The risk estimates provide guidance to agencies and emission sources to inform decisions on where to focus efforts to reduce exposure. Some of the more important uncertainties include the following:

- The predicted incremental cancer risk produced for this report assumes a continual lifetime inhalation exposure to the modeled diesel particulate concentration. This risk is most relevant for residential exposure and sensitive groups or populations, including schools, day care centers and hospitals in neighboring areas. Workers on the site of the emission sources used in this modeling are not exposed to the same levels of port-related diesel particulate emissions for 24 hours a day for a lifetime. Hence, the onsite risk levels in this report are informational for comparison to offsite risks, but are not directly relevant to the exposure and risk levels for the workers at the port.
- The cancer risk prediction also assumes that diesel emissions from Port-related activities will remain constant for the next 70 years. Activity is expected to grow and emissions per engine will decline as engines are replaced or rebuilt to cleaner standards and other emission reduction strategies are implemented, such as cleaner fuel and idle reduction.
- The unit risk factor used in estimating cancer risk is a value published and used by the California Air Resources Board. In order to be protective of public health, NJDEP uses this unit risk factor to estimate risk in the absence of a USEPA published unit risk factor. NJDEP acknowledges that the health studies upon which the number is based have limitations. (See Appendix C for further discussion.)
- The cancer and non-cancer risk predictions only include emissions from port-related activity in Port Newark and at the Elizabeth Port Authority Marine Terminal. Risk from exposure to background air contaminant levels from other sources is not included, and therefore the cumulative risk is not estimated.

- The model predictions presented here only include diesel emissions from Port Authority-owned terminals in New Jersey; other terminals have not been included. Truck emissions include only idling and transit emissions from trucks while inside the port gates, and emissions from truck transit along the approach roads to the port. Truck diesel particulate emissions on the New Jersey Turnpike and most local roads are not included.
- Since the workers on industrial sites such as the port property are typically present for about eight hours a day they are therefore exposed to the predicted levels of diesel particulate less than those living in nearby residences.

Culpability Analyses
In Appendix D we present isopleth maps to illustrate the predicted cancer risk based on actual or potential residential exposure resulting from emissions from each source category. These figures are intended to allow the identification and prioritization of emission sources that can be targeted for risk reduction strategies. These figures show that there is no one source primarily responsible for the cancer risks identified in nearby residential areas (Figure 4) and that each of the emission source categories has some contribution. Taken individually, rail and trucks had sufficient risk off-site to warrant long-term risk minimization (10 to 100 in a million); and ocean-going vessels, tugboats and cargo handling equipment had higher risk levels off-site justifying short-term risk minimization (100-1000 in a million). While not all of the off-site areas are currently used for residential purposes, the maps are a conservative approach to showing areas of actual and potential cancer risk.

Predicted Hazard Index (non-cancer risk) – The USEPA has an Integrated Risk Information System that provides estimates of the concentrations of specific pollutants that can be continuously inhaled over the duration of a lifetime without an appreciable risk of adverse non-cancerous health effects (referred to as a Reference Concentration). A source's impact divided by the reference concentration is the hazard index. A hazard index below 1 indicates a negligible health risk. The predicted exposure from Port sources alone does not exceed a hazard index of 1 in any of the residential areas of Elizabeth, Bayonne, Newark, Staten Island or Jersey City. Table 7 lists the predicted annual concentration of diesel particulates emitted from port operations and the calculated hazard index in these residential areas. Because diesel particulates from other sources in the region are not included in the modeling, no conclusion can be made whether the combined diesel concentration due to all sources exceeds the reference concentration in these neighborhoods.

Table 7: Predicted Hazard Index (non-cancer risk) at Residential Locations due to the Ports' OGV, Cargo Handling Equipment, Truck and Locomotive Diesel Particulate Emissions

Receptor	Annual Impact of Port (ug/m^3)	Reference Concentration (ug/m^3) [a, b]	Hazard Index[c]
Bayonne	0.50	5.0	0.10
Elizabeth	0.14	5.0	0.03
Newark	0.10	5.0	0.02
Staten Island	0.21	5.0	0.04
Jersey City	0.26	5.0	0.05

a. Estimate of a continuous inhalation exposure for a given duration to the human population that is likely to be without an appreciable risk of adverse non-cancerous health effects (from IRIS)
b. Assumes annual exposure
c. Hazard index below 1 indicates negligible incremental health risk.

IV. Impacts of Diesel Emissions From Operations at Port Newark and Elizabeth on Nearby Air Quality: Model Predictions – SO_2 NAAQS

The predicted concentrations of SO_2 emissions were compared to the SO_2 NAAQS. In Tables 8, 9 and 10 the respective maximum predicted annual, 24-hour (second-high) and 3-hour (second-high) SO_2 concentrations combined with representative SO_2 background levels (Elizabeth Lab) are compared to the existing SO_2 NAAQS. The region's background levels are well below the NAAQS. Impacts from the port activities with background are not predicted to cause violations of the NAAQS. Figures 6, 7 and 8 show the spatial distribution of the maximum annual, 24-hour and 3-hour SO_2 concentrations, respectively.

Table 8: Maximum Predicted Annual SO_2 Impact of Emissions from Operations at Port Newark and Elizabeth for 2006

Location	Annual Impact (µg/m^3)	SIL (µg/m^3)	Background-Air Quality (µg/m^3)[a,b]	Total Concentration (µg/m^3)	NAAQS (µg/m^3)
Bayonne (max. impact)	5.6	1	9.9	15.5	80
Elizabeth (max. impact)	0.8	1	9.9	10.7	80
Elizabeth Lab. Monitor	0.6	1	9.9	10.5	80
Newark (max. impact)	1.4	1	9.9	11.3	80

Staten Is. (max. impact)	2.7	1	9.9	12.6	80
Jersey City	2.8	1	9.9	12.7	80

[a]The 0.5 ug/m^3 impact due to port activities is not subtracted from the background

[b]Average annual concentration measured at Elizabeth Lab. from 2006 to 2008.

Table 9: Maximum Predicted 24-hour SO_2 Impact of Emissions from Operations at Port Newark and Elizabeth for 2006

Location	**24-hour Impact (2nd highest) (µg/m^3)**	**SIL (µg/m^3)**	**Background Air Quality (µg/m^3)[a]**	**Total Concentration (µg/m^3)**	**NAAQS (µg/m^3)**
Bayonne (max. impact)	23.2	5	22.8	46.0	365
Elizabeth (max. impact)	6.9	5	22.8	29.7	365
Elizabeth Lab. monitor	3.7	5	22.8	26.5	365
Newark (max. impact)	5.6	5	22.8	28.4	365
Staten Is. (max. impact)	14.8	5	22.8	37.6	365
Jersey City	12.2	5	22.8	35.0	365

[a]The 3.7 µg/m^3 due to port activities is not subtracted from the background

V. Discussion of Results

The modeling predicts that:

- Emissions from port activities when added to background concentrations do not cause a violation of the annual PM2.5 NAAQS at any modeled location.
- The predicted concentrations of fine particulates from Port operations, not including background concentrations, are below the levels that would cause non-cancerous health effects.
- Emissions from port activities contribute to an existing violation of the 24-hour NAAQS for PM2.5 in Bayonne, Newark, Elizabeth, Jersey City and Staten Island.

Table 10: Maximum Predicted 3-hour SO_2 Impact of Emissions From Operations at Port Newark and Elizabeth for 2006

Location	3-hr Impact (2nd highest) (µg/m^3)	SIL (µg/m^3)	Background Air Quality (µg/m^3)[a]	Total Concentration (µg/m^3)	NAAQS (µg/m^3)
Bayonne (max. impact)	76.3	25	81.8	158.1	1300
Elizabeth (max. impact)	37.5	25	81.8	119.3	1300
Elizabeth Lab. monitor	28.2	25	81.8	110.0	1300
Newark (max. impact)	44.7	25	81.8	126.5	1300
Staten Is. (max. impact)	69.8	25	81.8	151.6	1300
Jersey City	40.3	25	81.8	122.1	1300

[a]The 28.2 µg/m^3 due to port activities is not subtracted from the background

- Emissions from port activities are above New Jersey's 24-hour interim significant impact level (SIL) for PM2.5 in Bayonne, Staten Island, Elizabeth and Jersey City.
- The incremental cancer risk at residences in the western part of Bayonne is of most concern. The prediction is that port related emissions result in an increased risk to a maximally exposed individual of about 150 chances in a million, assuming constant exposure to the highest predicted concentration for 70 years. This prediction justifies short-term efforts to reduce risk.
- The incremental cancer risk predicted at residences in Elizabeth, Staten Island, Jersey City and Newark is not as elevated (between 10 and 100 in a million) and justifies long-term efforts to further reduce cancer risk.
- Port-related SO_2 emissions when added to the background concentrations do not violate the annual, 24 hour or 3 hours NAAQS.

VI. Emission Reduction Measures

The Port Authority of New York and New Jersey has drafted a Clean Air Strategy for the Port of New York and New Jersey that identifies additional actions to reduce diesel emissions from all port-related sources. The future actions are not included in this baseline evaluation, but will be evaluated for their impact on reducing emissions once they have been quantified and selected for potential implementation.

cc: Peg Hanna (Diesel Section)
Melinda Dower (Diesel Section)
Chris Salmi (Air Quality Management)
Peter Mayes (Bureau of Technical Services)
Alan Dresser (Bureau of Technical Services)

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APPENDIX A: ASSUMPTIONS MADE CONCERNING PM2.5 EMISSIONS[A]										
Main Source Type	**Subcategory**	**Location/Source Type**	**Stack Height (m)**	**Annual Emission rate (tpy)**	**Emission rate (g/s)**	**Value used in model ($g/s/m^2$) if area source, g/s if point source**	**Hours of operation (Annual)**	**Approx. hours of operation (daily)[b]**	**Reference for stack height**	**Notes**
CMV	OGV – Transit	1000ft. channel from 3 mile mark to Port; Area	50	65.3	1.88	1.47E-07	8760	24[c]	Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, Final Report, 2006, CalEPA, ARB James Corbett, pers. comm.. Feb. 2009	Breakdown of OGV into dwelling, transit and boilers from Table 5.5; breakdown of county emissions from Table 5.9 including Starcrest email dated 9/9/09
CMV	OGV - Dwelling	Dwelling at two points next to Maher and PNCT Terminals Point	43 SZINIT=7	49.4	1.42	0.68 PN 0.74 PE	8760	24[c]	As above	As above
CMV	OGV – Boilers	As above, Transit Dwelling:	As above	2.27 22.7	0.06 0.65	5.11E-09 0.28 PN 0.36 PE	8760	24[c]	As above	As above
CMV	OGV- Tugboats	1000ft. channel from The Narrows to Port; Area	6	10.4	0.299	4.00E-08	8760	24[c]	Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, Final Report, 2006, CalEPA, ARB	
CHE	Straddle	Port-wide Area	11.5	30.98	2.18	6.00E-07	3578	6am-4pm[c]	Field trip estimate at Maher terminal (02/10/09)	CHE emissions were split into each type of equipment by allocating county emissions (see Tables 2.1 and 2.3 of 2006 inventory) The total emission was divided proportionally for each port by area (88% PE, 11% PN)
CHE	Tractor	Port-wide Area	2.9	20.65	2.92	8.02E-07	1783	6am-11am[c]	As above	As above
CHE	Fork lift	Port-wide Area	2.1	3.70	0.63	1.73E-07	1481	6am-10am[c]	As above	As above

Main Source Type	Subcategory	Location/Source Type	Stack Height (m)	Annual Emission rate (tpy)	Emission rate (g/s)	Value used in model (g/s/m^2) if area source, g/s if point source	Hours of operation (Annual)	Approx. hours of operation (daily)[b]	Reference for stack height	Notes
CHE	Top Loader	Port-wide Area	3.15	3.96	0.35	9.69E-08	2829	6am-2pm[c]	Average value taken from Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, Final Report, 2006, CalEPA, ARB	As above
CHE	Container Handler	Port-wide Area	3.15	1.89	0.22	5.94E-08	2205	6am-12pm[c]	Average value taken from ARB report above	As above
CHE	Other Primary Equipment	Port-wide Area	3.15	2.07	0.20	5.36E-08	2674	6am-1pm[c]	Average value taken from ARB report above	As above (average hours from Table 2.12 – not including cranes)
CHE	Ancillary	Port-wide Area	3.15	1.63	0.38	1.06E-07	1067	6am-9am[c]	Average value taken from ARB report above	As above (average hours from Table 2.18)
CHE	Wharf Crane	Dockside –distributed around 7 miles of dock. Point	38	1.72	0.39	0.39 spread between 14 cranes (0.028)	1102	6am-9am[c]	Field trip measurement at Maher terminal (02/10/09)	Specific locations were taken from NJDEP's 2007 GIS aerial photographs.
CHE	Rubber-tired Gantry Crane	Port-wide Area	19.2	4.30	0.23	0.23	4596	6am-6pm[c]	Field trip estimate at Maher terminal (02/10/09)	Contact with each terminal confirmed their use at APM only
CHE	Other Crane	Port-wide Area	38	3.44	0.48	1.32E-07	1799	6am-11am[c]	As above	Stack parameters were estimated during a DEP site visit
LOCO	Switch (idling)	ExpressRail between Maher and APM terminals Area	4.6	4.0	0.19	5.73E-07	5110 (estimate from M. Dower)	6am-8pm[c]	Diesel Particulate Matter Health Risk Assessment for the West Oakland Community, 2008, ARB, CalEPA Appendix B	
LOCO	Line Haul	Area	4.6	0.13	0.01	1.07E-07	As above	6am-8pm[c]	Diesel Particulate Matter Health Risk Assessment for the West Oakland Community, 2008, ARB, CalEPA Appendix B	

Main Source Type	Subcategory	Location/Source Type	Stack Height (m)	Annual Emission rate (tpy)	Emission rate (g/s)	Value used in model ($g/s/m^2$) if area source, g/s if point source	Hours of operation (Annual)	Approx. hours of operation (daily)[b]	Reference for stack height	Notes
					24-hour	**Annual**				
Trucks	Idle	APM, Maher,PNCT Area	3.66	11.93	1.0 divided amongst the three terminals by area: 2.61E-06 $g/s/m^2$ (APM) 2.61 E-06 g/s/ m^2 (Maher) 2.61E-06 g/s/ m^2 (PNCT)	0.686 divided amongst the three terminals by area: 1.79E-06 $g/s/m^2$ (APM) 1.79 E-06 g/s/ m^2 (Maher) 1.79E-06 g/s/ m^2 (PNCT)	250 days	6am-6pm[d]		Port Authority of New York and New Jersey, 2006 Baseline multi-Facility Emissions Inventory, November 2008, p87
Trucks	On-terminal	Port-wide Area	3.66	1.29	0.108 Divided amongst the two Ports 1.98E-08 $g/s/m^2$ (Elizabeth) 1.98E-08 g/s/ m^2 (Newark)	0.074 Divided amongst the two Ports 1.36E-08 $g/s/m^2$ (Elizabeth) 1.36 E-08 g/s/ m^2 (Newark)	250 days	6am-6pm[d]		Proportional tpy divided by area; see spreadsheet Port truck emission calculations.xls; Emission rate from Port Authority of New York and New Jersey, 2006 Baseline multi-Facility Emissions Inventory, November 2008, p87
Trucks	Off-terminal	From the Port gates to the New Jersey Turnpike intersections 13A and 14. Area	3.66	7.87	Annual 0.23	Varying according to link length and width	250 days	6am-6pm[d]		

[a] Elizabeth Port Authority Marine Terminal = PE, Port Newark = PN
[b] Starting hour to Ending hour
[c] Based on 365 days per year;
[d] Based on 250 working days per year;

Ref A: Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, Final Report, CalEPA, ARB (2006)

Unitary emission rates for CHE were calculated for both ports based on the total area (3639210.657 $meters^2$).
Notes: Urban population used was 2,395,758 with a roughness length of 1.0m.

APPENDIX B: ASSUMPTIONS MADE CONCERNING SO2 EMISSIONS[A]										
Main Source Type	**Subcategory**	**Location/ Source Type**	**Stack Height (m)**	**Annual Emission rate (tpy)**	**Emission rate (g/s)**	**Value used in model (($g/s/m^2$) if area source, g/s if point source)**	**Hours of operation (Annual)**	**Approx. hours of operation (daily)** [b]	**Reference for stack height**	**Notes**
CMV	OGV - Transit	1000ft. channel from 3 mile mark to Port; Area	50	735.7	21.1	1.65E-06	8760	24[c]	Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, Final Report, 2006, CalEPA, ARB James Corbett, pers. comm.. Feb. 2009	Breakdown of OGV into dwelling and transit from Table 5.5; breakdown of county emissions from Table 5.9
CMV	OGV - Dwelling	Dwelling at two points next to Maher and PNCT Terminals Point	43 SZINIT=7	1184.2	34.0	15.5 PN 18.5 PE	8760	24[c]	As above	As above
CMV	OGV -Tugboats	1000ft. channel from The Narrows to Port; Area	6	21.5	0.61**	8.27E-08	8760	24[c]	Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, Final Report, 2006, CalEPA, ARB	
CHE	Straddle	Port-wide Area	11.5	73.5	5.18	1.42E-06	3578	6am-4pm[c]	Field trip estimate at Maher terminal (02/10/09)	CHE emissions were split into each type of equipment by allocating county emissions (see Tables 2.1 and 2.3 of 2006 inventory) The total emission was divided proportionally for each port by area (88% PE, 11% PN)
CHE	Tractor	Port-wide Area	2.9	59.3	8.39	2.3E-06	1783	6am-11am[c]	As above	As above
CHE	Fork lift	Port-wide Area	2.1	7.97	1.36	3.73E-07	1481	6am-10am[c]	As above	As above

Main Source Type	**Subcategory**	**Location/ Source Type**	**Stack Height (m)**	**Annual Emission rate (tpy)**	**Emission rate (g/s)**	**Value used in model (g/s/m^3) if area source, g/s if point source**	**Hours of operation (Annual)**	**Approx. hours of operation (daily)[b]**	**Reference for stack height**	**Notes**
CHE	Top Loader	Port-wide Area	3.15	15.06	0.43	3.69E-07	2829	6am-2pm[c]	Average value taken from Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, Final Report, 2006, CalEPA, ARB	As above
CHE	Container Handler	Port-wide Area	3.15	7.97	0.22	2.50E-07	2205	6am-12pm[c]	Average value taken from ARB report above	As above
CHE	Other Primary Equipment	Port-wide Area	3.15	5.67	0.16	1.47E-07	2674	6am-1pm[c]	Average value taken from ARB report above	As above (average hours from Table 2.12 – not including cranes)
CHE	Ancillary	Port-wide Area	3.15	2.3	0.06	1.49E-07	1067	6am-9am[c]	Average value taken from ARB report above	As above (average hours from Table 2.18)
CHE	Rubber-tired Gantry Crane	Port-wide Area	19.2	13.29	0.38	1.11E-05	4596	6am-6pm[c]	Field trip estimate at Maher terminal (02/10/09)	Contact with each terminal confirmed their use at APM only
CHE	Other Crane	Port-wide Area	38	8.86	0.25	3.41E-07	1799	6am-11am[c]	As above	Stack parameters were estimated during a DEP site visit
LOCO	Switch (idling)	ExpressRail between Maher and APM terminals Area	4.6	4.0	0.19	5.73E-07	Estimate from PA 2006 inventory 34,744; 11 shifts	6am-8pmc	Diesel Particulate Matter Health Risk Assessment for the West Oakland Community, 2008, ARB, CalEPA Appendix B	
LOCO	Line Haul	Volume	4.6	0.13	0.01	1.05E-07	As above	6am-8pmc	Diesel Particulate Matter Health Risk Assessment for the West Oakland Community, 2008, ARB, CalEPA Appendix B	
Trucks	Idle	APM, Maher,PNCT Area	3.66	2.95	1.0 divided amongst the three terminals by area: 6.48E-07 g/s/m^2 (APM) 6.48E-07 g/s/m^2 (Maher) 6.48E-07 g/s/m^2 (PNCT)	0.686 divided amongst the three terminals by area: 4.44E-07 g/s/m^2 (APM) 4.44 E-07 g/s/m^2 (Maher) 4.44E-07 g/s/ m^2 (PNCT)	250 days	6am-6pm	Trucks	Trucks

Main Source Type	Subcategory	Location/Source Type	Stack Height (m)	Annual Emission rate (tpy)	Emission rate (g/s)	Value used in model (g/s/m3) if area source, g/s if point source	Hours of operation (Annual)	Approx. hours of operation (daily) [b]	Reference for stack height	Notes
					24-hour	**Annual**				
Trucks	On-terminal	Port-wide Area	3.66	1.29	0.108 Divided amongst the two Ports 1.98E-08 g/s/m^2 (Elizabeth) 1.98E-08 g/s/ m^2 (Newark)	0.074 Divided amongst the two Ports 1.36E-08 g/s/m^2 (Elizabeth) 1.36 E-08 g/s/ m^2 (Newark)	250 days	6am-6pmd		Proportional tpy divided by area; see spreadsheet Port truck emission calculations.xls;
Trucks	Off-terminal	From the Port gates to the New Jersey Turnpike intersections 13A and 14. Area	3.66	4.60	Annual 0.13	Varying according to link length and width	250 days	6am-6pmd		

[a] Elizabeth Port Authority Marine Terminal = PE, Port Newark = PN
[b] Starting hour to Ending hour
[c] Based on 365 days per year;
[d]Based on 250 working days per year;

Ref A: Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, Final Report, CalEPA, ARB (2006)

Unitary emission rates for CHE were calculated for both ports based on the total area (3639210.657 meters^2).
Notes: Urban population used was 2,395,758 with a roughness length of 1.0m.

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FIGURE 1: MODEL RECEPTOR INNER GRID AND LOCATION OF RESIDENTIAL NEIGHBORHOODS NEAR TO THE PORT

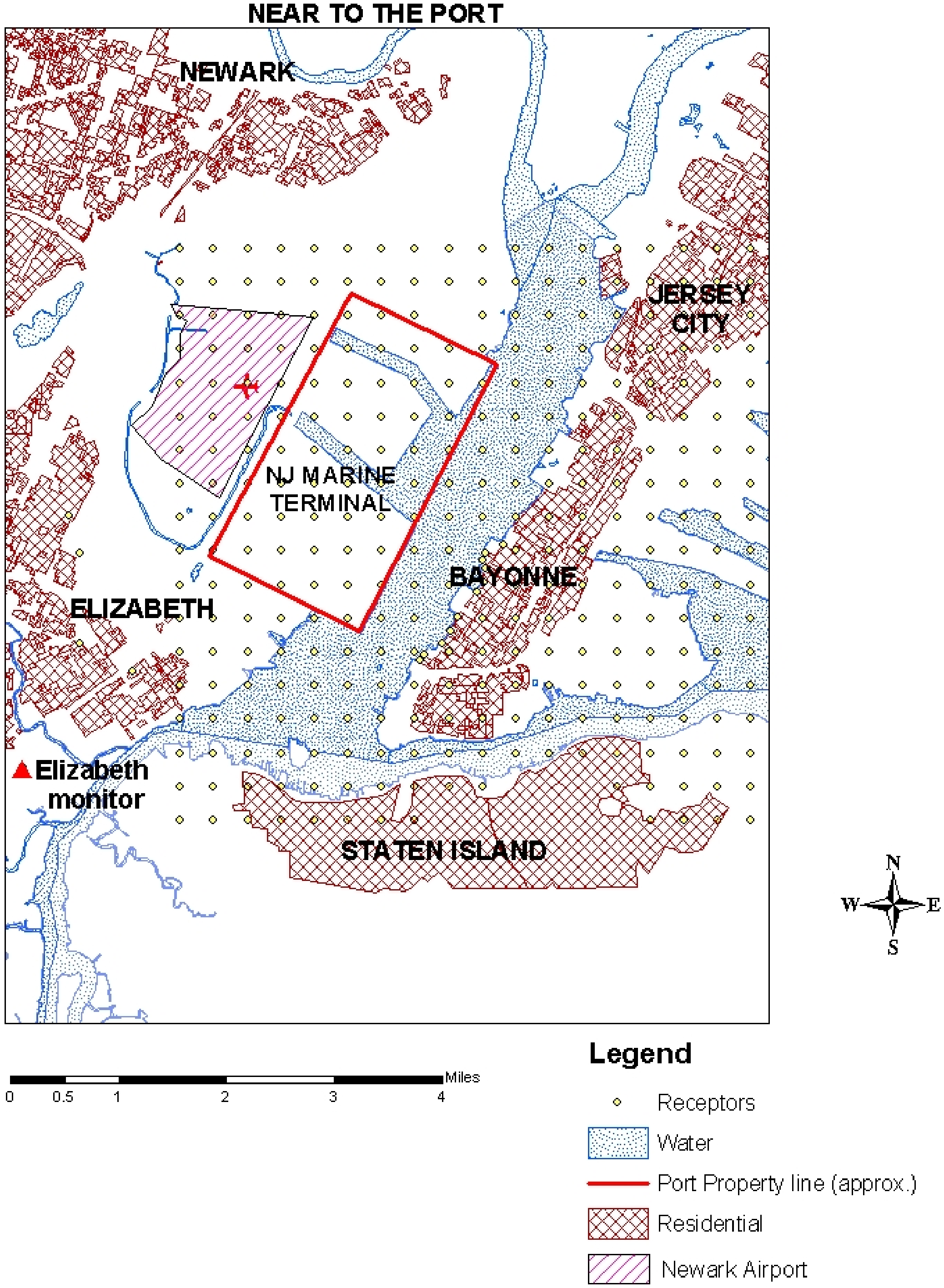

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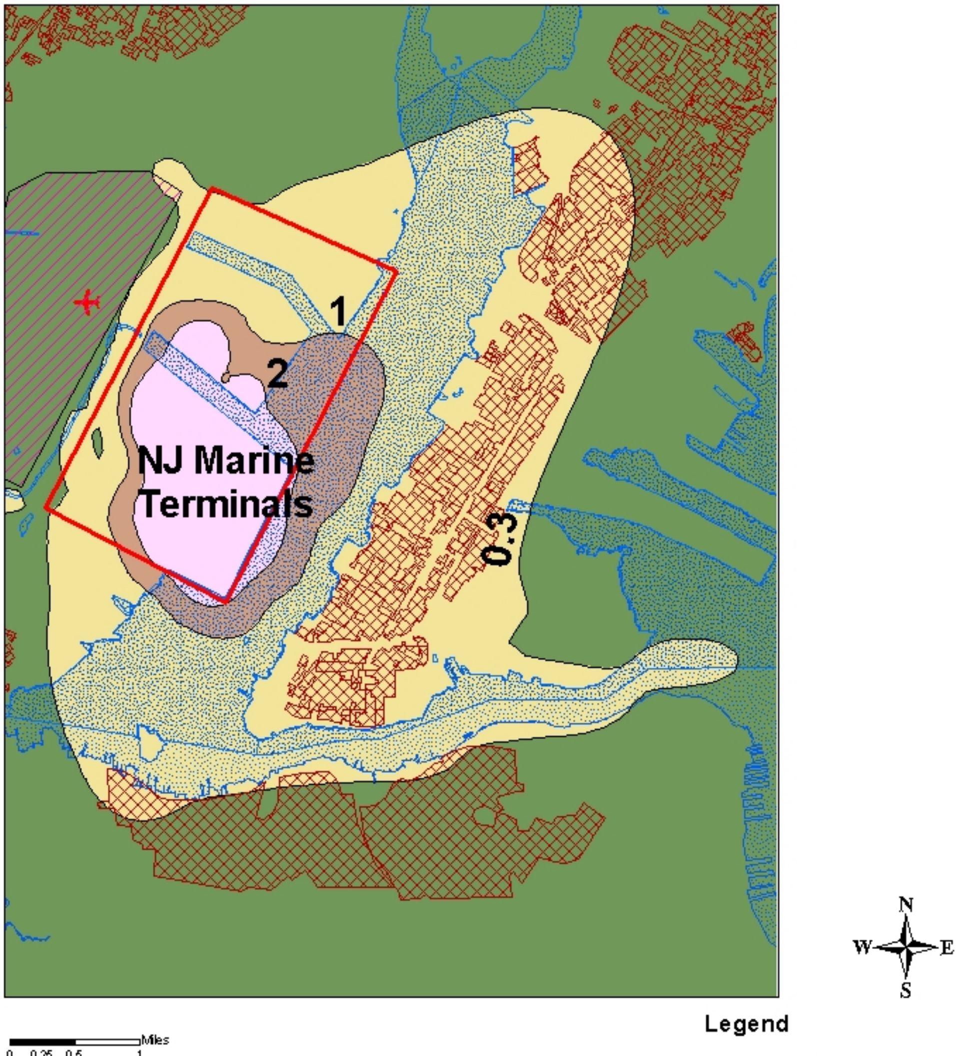
FIGURE 2: MAXIMUM PREDICTED ANNUAL PM2.5 CONCENTRATIONS DUE TO ALL PORT ACTIVITIES (not including background)



Adjusted background PM2.5 at Elizabeth Lab = 13.4 ug/m^3 (2006-2008 average)
Significant Impact Level = 0.3ug/m^3
NAAQS = 15.0ug/m^3

Legend

- Property line
- 0 - 0.3 ug/m^3 (below SIL)
- 0.3 - 1 ug/m^3 (above SIL)
- 1 - 2 ug/m^3
- Greater than 2.0 ug/m^3
- Residential
- Newark Airport

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FIGURE 3: MAXIMUM PREDICTED 24-HOUR PM2.5 CONCENTRATIONS DUE TO ALL PORT ACTIVITIES (not including background)

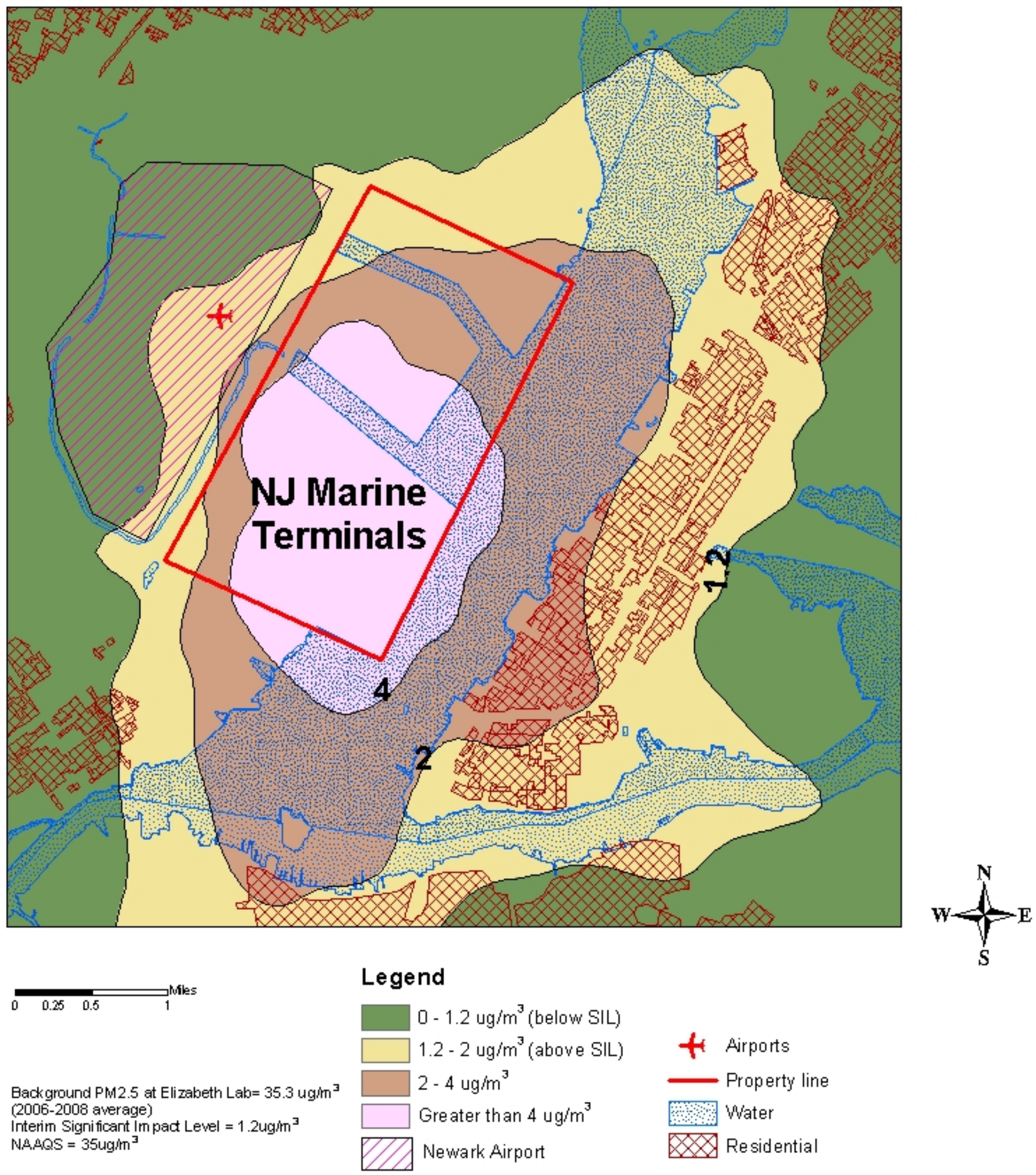

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FIGURE 4: MAXIMUM PREDICTED 70-YEAR LIFETIME CANCER RISK DUE TO PORT-RELATED DIESEL PARTICULATE EMISSIONS (not including background)

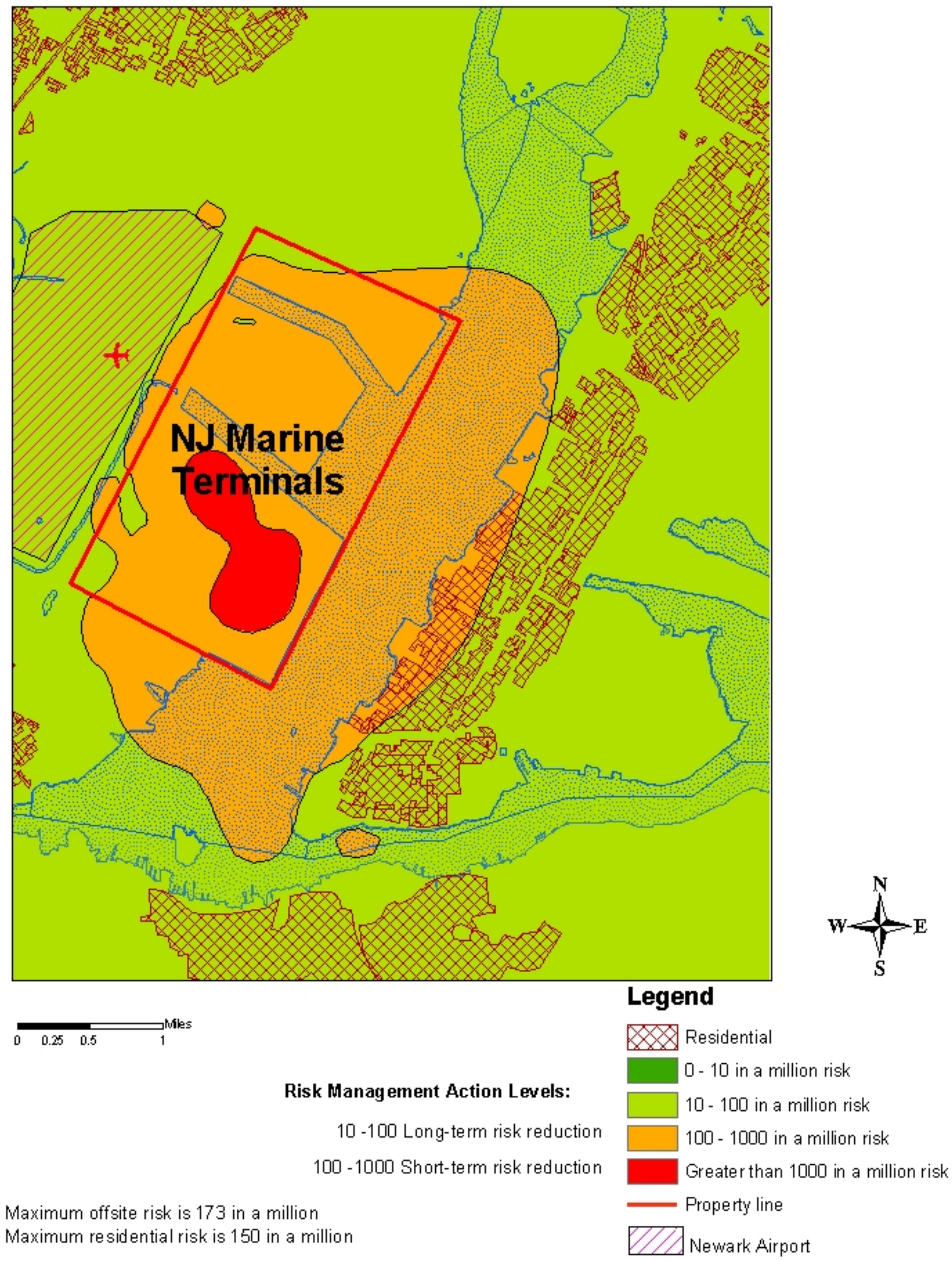

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FIGURE 5: MAXIMUM PREDICTED 70-YEAR LIFETIME CANCER RISK DUE TO PORT-RELATED DIESEL PARTICULATE EMISSIONS (not including background)

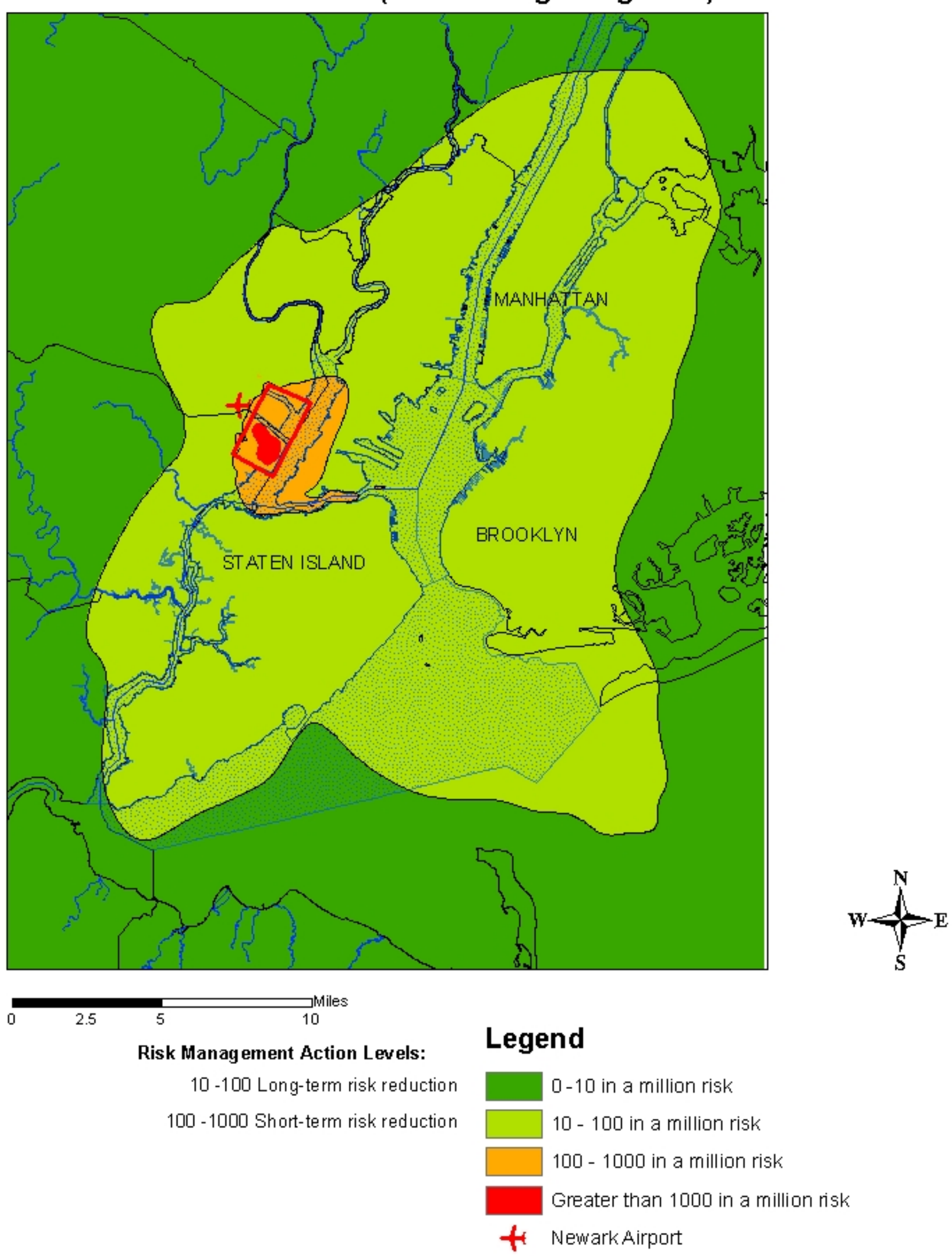

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FIGURE 6: MAXIMUM PREDICTED ANNUAL SO2 CONCENTRATIONS DUE TO ALL PORT ACTIVITIES (not including background)

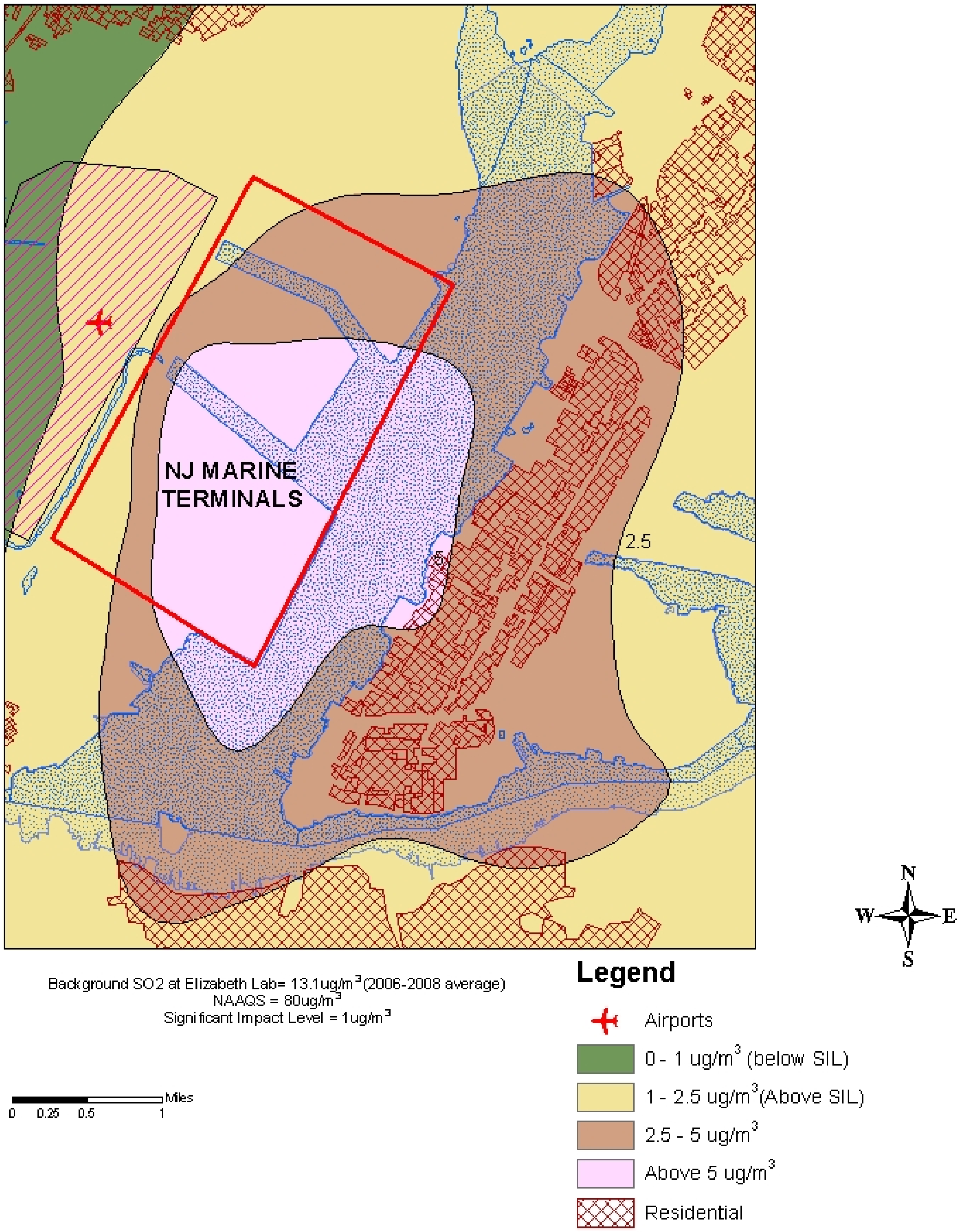

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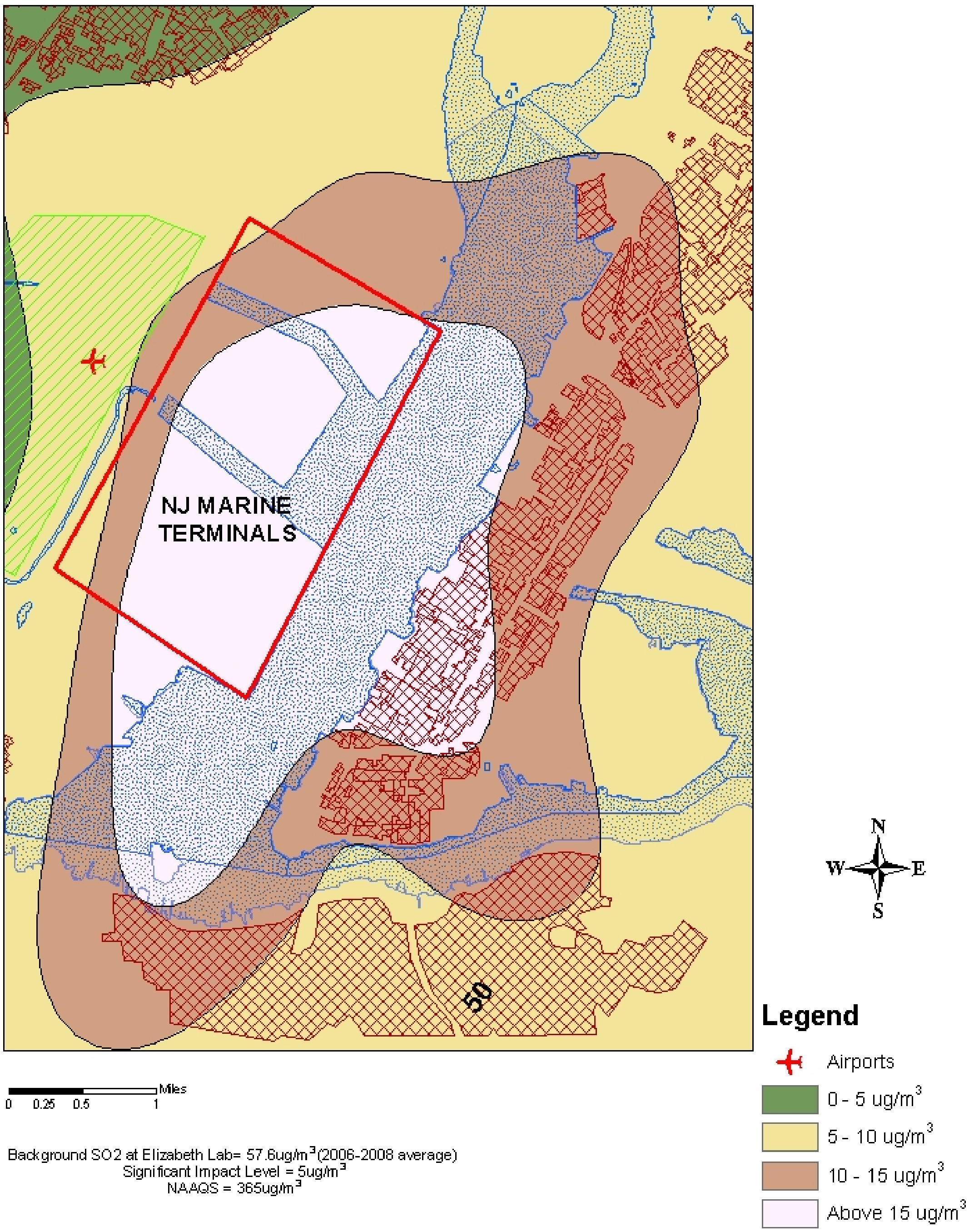
FIGURE 7: MAXIMUM PREDICTED 24-HOUR SO2 CONCENTRATIONS DUE TO ALL PORT ACTIVITIES (not including background)



Background SO2 at Elizabeth Lab= 57.6ug/m^3(2006-2008 average)
Significant Impact Level = 5ug/m^3
NAAQS = 365ug/m^3

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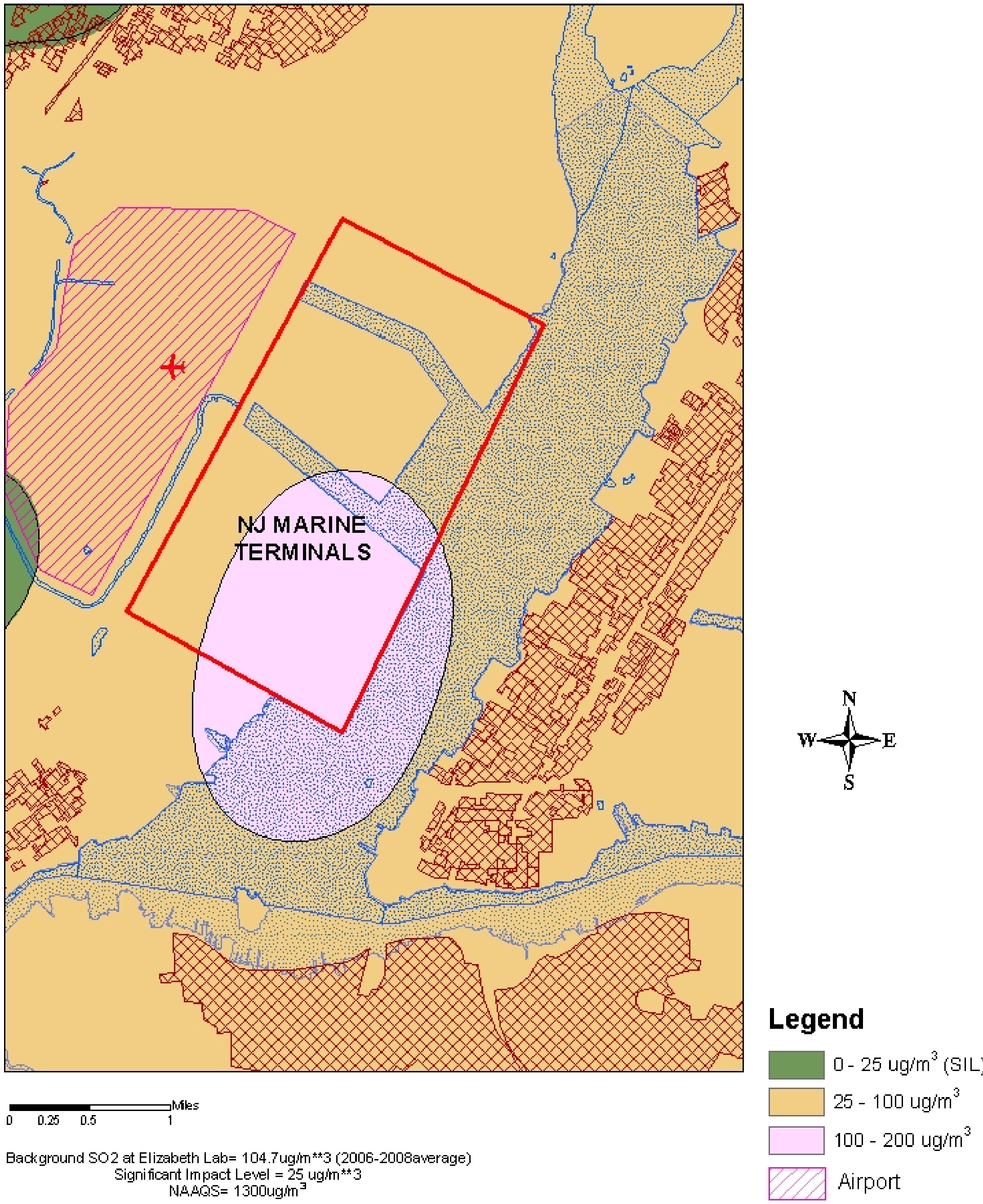
FIGURE 8 : MAXIMUM PREDICTED 3-HOUR SO2 CONCENTRATIONS DUE TO ALL PORT ACTIVITIES (no background included)



Background SO2 at Elizabeth Lab= 104.7ug/m**3 (2006-2008average)
Significant Impact Level = 25 ug/m**3
NAAQS= 1300ug/m3

Appendix C

Use of California's Unit Risk Factor for Diesel Exhaust in Risk Assessment

New Jersey Department of Environmental Protection
Division of Air Quality
Bureau of Technical Services
9/30/2009

Executive Summary

Introduction & Background

The NJDEP Division of Air Quality (DAQ) has been using unit risk factors (URF) to evaluate cancer risk from emission sources since the late 1980s. The URF is a numerical dose-response factor that characterizes the relationship between the exposure to a substance, or dose, and the increased risk in developing cancer. These are developed from the review of toxicological and epidemiological studies by various governmental agencies and are published after a thorough review. Two primary sources of URF numbers are the USEPA's Integrated Risk Information System (IRIS) and the California Office of Environmental Health Hazard Assessment (OEHHA). Other sources of numerical dose responses may be used that meet the peer review criteria or have been evaluated in a public participation process. This document provides the reader with a summary of issues associated with diesel exhaust particulate matter emissions and the uncertainties inherent in the URF.

California's Position

California has listed diesel exhaust as a "Toxic Air Contaminant" (TAC) subject to risk assessment and risk management under California's Toxics Air Contaminant Program (Health & Safety Code section 39660). The process of adding a substance to the list of TACs is rigorous, involves public input, and approval by a Scientific Review Panel. The California Scientific Review Panel concluded that a reasonable estimate of the cancer unit risk is 3E-4/(ug/m^3).

USEPA's Position

In the *Health Assessment Document for Diesel Engine Exhaust* (May 2002), USEPA concludes that Diesel Exhaust (DE) is "likely to be carcinogenic to humans by inhalation," and that this hazard applies to environmental exposures. However, the document states, "human exposure-response data (for DE) are considered too uncertain to derive a confident quantitative estimate of cancer unit risk, and with the chronic rat inhalation studies not being predictive for environmental levels of exposure, EPA has not developed a quantitative estimate of cancer unit risk."

New Jersey's Position

The DAQ recognizes that there is always uncertainty in trying to quantify risk from exposure to a carcinogen. This is particularly true for exposure to DE. Emissions vary based on type, size, and age of engines, fuel type and operating conditions. Engines have become more efficient and less polluting, and are expected to continue this trend in the future. The DAQ also recognizes the scientific uncertainties associated with epidemiological and toxicological studies. The DAQ has reviewed the California and USEPA documentation describing how each agency arrived at their conclusion. What is clear is that the potential exposure to DE is relatively high, there is consensus it is probably carcinogenic, and that studies have shown there to be a dose-response relationship. The DAQ agrees that it meets the criteria of an air contaminant, and the risk should be evaluated in accordance with 7:27-8.5(c). The DAQ finds that in order to conduct an Air Quality Impact Analysis the best numerical value to determine risk is to use the California URF of 3E-4/(ug/m^3).

Technical Summary

Exposure

The 1996 National Air Toxics Assessment (NATA), released in 2002, was the first attempt by the USEPA to quantify the magnitude of exposure to diesel particulate matter (PM). It included estimates of ambient concentrations of diesel PM, averaged at the state, county, and census tract level. These concentrations were all attributed to emissions from mobile sources, both on-road and off-road. The contribution from stationary sources and even "non-point" sources was not included. It did not address diesel PM cancer risk.

The California Air Resources Board (CARB) estimated that the average annual ambient concentration of DE in California is 1.54 ug/m^3 (both indoor & outdoor).

In New Jersey, the estimated statewide annual average ambient concentrations of diesel PM are decreasing somewhat. It was modeled by the USEPA in the 1999 NATA to be 2 ug/m^3 (ranging from 0.82 in Cape May County to 4.65 Hudson County). The 2002 NATA modeled average ambient concentration of for NJ was 1.6 ug/m^3 (ranging from 0.7 in Cape May County to 3 in Hudson County).

Using the California URF to estimate cancer risk, a statewide exposure to diesel particulate at a concentration of 1.6 ug/m^3 gives a risk of 475 in a million.

The overall risk of developing cancer in the U.S. over a lifetime from all exposures, including air pollution, is 1 in 2 for males and 1 in 3 for females, and the risk for lung cancer is about 1 in 15. In other words, the risk for males is 500,000 in a million, the risk for females is 333,000 in a million, and the risk for lung cancer is 70,000 in a million.

Carcinogenicity of Diesel PM

There seems to be consensus that DE is human carcinogen. USEPA classifies it as "likely to be carcinogenic to humans by inhalation." The International Agency for Research on Cancer (IARC) classifies it a Group 2A carcinogen, "probably carcinogenic to humans." Numerous epidemiological studies have reported an increased cancer risk, particularly lung cancer, in populations that have been exposed to high levels of DE, such as truckers and railroad workers. Animal studies have also shown a positive association.

DE contains many gaseous and particulate compounds that are considered to be carcinogens, including known human carcinogens benzene, arsenic, and nickel. A number of hydrocarbons and PAHs, which are classified as "possibly" or "probably" carcinogenic, are adsorbed onto the particles.

It has been surmised that the total carcinogenic effect estimated for the many carcinogens identified in DE does not account for the carcinogenic effect of the whole DE. However, several animal studies have found tumors only from exposure to diesel PM. This and other considerations led California to have the particle mass serve as a surrogate measure for the whole DE exposure. Virtually all DE PM is less than 2.5 um in size.

Quantifying Cancer Risk

Unit risk is defined as the probability of contracting cancer from a lifetime (70-year) exposure to a unit concentration (1 ug/m^3) of a specific compound. A unit risk factor (URF) allows for the estimation of an increase in cancer risk in relation to exposure to an ambient air concentration. The unit risk factor yields a health risk expressed fractionally as "the chance" in a million, or 100,000, etc. of developing cancer. In the DAQ, URFs are used to estimate the magnitude of the cancer risk which may be attributable to a specific source of emissions.

To develop a URF, exposure (concentration) data is related (fitted linearly) to a specific health outcome, such as lung cancer. In general, the greater the exposure, the higher the cancer incidence, resulting in a potency slope. The confidence, and associated uncertainty, of this relationship is evaluated with statistical models that fill in data gaps, often at the lower end of the exposure range.

California's Process

California has listed diesel exhaust as a "Toxic Air Contaminant" (TAC) under California's Toxics Air Contaminant Program (Health & Safety Code section 39660). The listing process involves the production of technical support documents, conferences, public workshops, public hearings, public comment periods, and approval by a Scientific Review Panel.

Documentation of the process of listing DE as a TAC (and development of the associated URF) can be found at www.arb.ca.gov/regact/diesltac/diesltac.htm. This includes the

California Environmental Protection Agency (CalEPA) “Report to the Air Resources Board on the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant” (Part A: Exposure Assessment, April 22, 1998; Part B: Health Risk Assessment for Diesel Exhaust, May 1998; and comments and responses from three comment periods, (June 1994, May 1997, and February 1998). A summary on development of the URF can be found in the *Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II – Technical Support Document for Describing Available Cancer Potency Factors*, CalEPA, December 2005, in the chapter titled "Particulate Matter from Diesel-Fueled Engines."

Development of the California URF

Human epidemiological studies (usually occupational) and animal studies can be used to develop a URF. Epidemiological studies are often retrospective, in that they look back at past exposure and relate that to health outcomes that appear later. Actual measured exposures are often not available. The advantage of animal studies is that they allow for animals to be exposed to specific measured concentrations for a specific amount of time, with specific health outcomes observed. Extrapolating those results to humans is a major source of uncertainty.

The unit risks ultimately derived by California’s Office of Environmental Health Hazard Assessment (OEHHA) for the general population were derived from two case studies of railroad workers. Included in the studies was the assumption that the mass concentration of particles governs the risk of DE, regardless of the particular type of diesel engine or fuel. The DE URFs are in units of “per ug/m^3 of diesel particulate matter.”

California primarily used two studies in development of its URF:

- Garshick E, Schenker M, Munoz A, Segel M, Smith T, Woskie S, Hammond S and Speizer F. 1987. A case-control study of lung cancer and DE exposure in railroad workers. Am Rev Respir Dis 135:1242-1248.
- Garshick E, Schenker M, Munoz A, Segel M, Smith T, Woskie S, Hammond S and Speizer F. 1988. A retrospective cohort study of lung cancer and DE exposure in railroad workers. Am Rev Respir Dis 137:820-825.

These two studies are among a number that establish excess relative risk for lung cancer among workers exposed to DE. According to OEHHA, these two studies were specifically selected for the quantitative risk assessment because of their general excellence, their apparent finding of a relationship of cancer rate to duration of exposure, and because of the availability of measurements of DE among such railroad workers from the early 1980s in other studies. The case-control study had better information on smoking rates, while the cohort study had smaller confidence intervals of risk estimates. Neither study contained direct measurements of exposure concentrations over time. The resulting risk entails uncertainties due mostly to the limited exposure information and to the choice of models and data used in the analysis.

The effective dose was estimated to be cumulative atmospheric exposure to DE. Since direct measurements of exposure concentrations over the follow-up time of the study were not available, the exposure history had to be reconstructed. This was done using personal exposure measurements on railroad workers just after the end of the follow-up period in the study, historical data on dieselization of locomotives in the U.S., and other information. Also, data from a different study was used that estimated exposure to respirable PM for different job groups. Adjustments were made using estimated national average concentrations of PM, and for the PM attributable to environmental tobacco smoke.

For the cohort study, assumptions were made about nationwide concentrations breathed by workers. A linear rise in train dieselization was incorporated, producing a linear rise of the national average exposure concentrations around trains. Overall average cumulative exposure for the cohort for each year of follow-up (1959-1980) was quantified. There was an adjustment (intermittency correction) for non-continuous exposure. A calculation was made of the relationship between relative risk of lung cancer from DE exposure divided by the background incidence of lung cancer in the general population. Relative risks were fitted linearly to the duration of exposure, resulting in a slope. The unit risk was reported as the 95% upper confidence limit of the mathematical model.

The result that OEHHA gives is actually a range of lifetime unit risks, from 1.3E-4 to 2.4E-3/(ug/m^3), concluding that "the more scientifically valid unit risk values are near the lower end of the range." The California Scientific Review Panel concluded that a reasonable estimate of the cancer unit risk is 3E-4/(ug/m^3).

Comparisons With Other Data

A meta-analysis (a systematic combination of the results of numerous studies that generates a quantitative summary of variability) of 30 studies was used to bracket the carcinogenic potency of DE. None of the studies in the meta-analysis provided direct measurements of exposure concentration; this had to be reconstructed. The range of plausible exposures for the various populations in the studies ranged from 5 to 500 ug/m^3, resulting in risk ranging from 1.3E-4/ug/m^3 to 1.3E-2/ug/m^3. These were the extreme bounds of probable exposures. The 90% confidence interval range of the risks was calculated to be 1.6E-4 to 1.2E-3 per ug/m^3.

Available rat studies were not directly used to develop the range of URFs because of the uncertainties of extrapolating from rats to humans. However, URF values were calculated for comparison with the results of the human data. Rat data ranges were slightly within or below the bottom of the range of values based on human data.

Recognized Uncertainties Associated with the California Derived URF

Some of the significant issues in using these studies for development of a URF include:
- Lack of knowledge of actual exposure history, including possible exposure to unknown confounders;

- Historical reconstruction of exposure based on another study's exposure data for railway workers and the rate of dieselization for US railroads;
- Representativeness of railroad workers for the general population;
- Choice of analytical model.

There was considerable uncertainty in the slope in the relationship between cumulative exposure to DE & lung cancer. The 1988 cohort study states that the lack of a positive slope between cumulative exposures does not imply the study is negative, but is due to weakness in exposure assignment, changing exposures over time, and the lack of exposure data pre-1959.

There was a debate over inclusion of workers assumed to be "unexposed" to DE (clerks, signalmen) and the assumption that their exposure is background-level, and equivalent to zero. This assumption influences the slope, giving a positive result when set at zero and compared to those workers exposed to locomotive exhaust.

The studies did not include exposure prior to 1959, which could have added 10 to 15 years to exposure. This could bias the slope upward by attributing cancer incidence to the shorter exposure period. High estimates of exposure influence the estimated potency downward. Lower exposure concentrations would indicate a higher potency.

The duration of follow-up of exposed workers was relatively short. The latency for most human carcinogens is generally 20 years or more.

There were numerous programs and models available to analyze and interpret data. Their selection is discussed in detail in the OEHHA documents, and in their responses to comments.

Improvements in engines will have led to a decline in exposure to PM from the 1970s to the 1980s. Patterns of exposure would have changed because of a decline in emissions from newer engines. This could not be accounted for in the analysis.

Responses to the Issues

OEHHA: OEHHA believes that their use of a large range of risk estimates encompasses the uncertainty introduced by the limited exposure information. They state that the overall magnitude of the associated uncertainty is not unduly large. The greater than usual uncertainty in the exposure estimates is substantially offset by the much smaller than usual range of extrapolation from the occupational exposures of interest to ambient levels of concern. The extrapolation range was about 50 to 100 from the occupational exposure levels to ambient levels. OEHHA's range of risks attempts to scope out the uncertainty. The use of human data obviates the large uncertainty of extrapolating from animal data. Relative to other identified toxic air contaminants, OEHHA felt that there was a large amount of data to work with, including both noncancer and cancer studies, animal and human studies. There is less uncertainty about the range of risks from DE than about the range of risks from other identified California toxic air contaminants.

OEHHA actually presented a range of risks based on a range of exposure estimates. These exposure estimates included those provided by engine manufacturers (the high end of the range) and those estimated from lower range study data. OEHHA considered that the range could not be much broader than estimated (40 - 500 ug/m^3 with a likelier level of 50 - 240 ug/m^3). OEHHA acknowledged the uncertainty in the exposure estimates in the document, but concluded that their range of reconstructed doses is reasonable.

STAPPA/ALAPCO (now NACAA) used CalEPA's recommended URF of 3E-4/(ug/m^3) in its report on "Cancer Risk from Diesel Particulate: National and Metropolitan Area Estimates for the United States" (March 15, 2000).

Study Author's (Garshick) Comments: Eric Garshick, the primary author of the studies used in OEHHA's risk assessment, submitted comments during the public review period on how the data from his studies was used. He does stand by his study as showing an association between DE exposure and lung cancer risk in railroad workers. However, he stated that "[I]t is not possible to use the human epidemiologic data that was reanalyzed to assign a unit risk with confidence due to the uncertainty of the exposure data." OEHHA acknowledged that, given limitations in the available exposure information, it was not possible to derive a single unit risk value with confidence. However, OEHHA developed a range of upper bound unit risk values based upon a wide range of plausible exposure patterns. OEHHA also revised its analyses to include more recent information provided by the Engine Manufacturers Association with respect to diesel engine emissions and the potential magnitude of the past exposures of railroad workers.

USEPA Position and Arguments: In the *Health Assessment Document for Diesel Engine Exhaust* (May 2002), USEPA concludes that DE is "likely to be carcinogenic to humans by inhalation," and that this hazard applies to environmental exposures. However, the document also states that the DE "human exposure-response data are considered too uncertain to derive a confident quantitative estimate of cancer unit risk, and with the chronic rat inhalation studies not being predictive for environmental levels of exposure, EPA has not developed a quantitative estimate of cancer unit risk."

Kenny Crump Analysis & Comments: Crump, an independent consultant who also represents the automotive industry, was involved in analyzing data for USEPA to develop a quantitative risk assessment. In comments to OEHHA, he argued that his analysis of the cohort study shows no evidence to support an exposure-response trend. Relative risk of lung cancer decreased with increasing duration of exposure. OEHHA says there is no statistical support for these claims. They state that Crump's analyses did not use the clerks and signalmen as a control group, as they were assigned in the Garshick papers. Rather, they were treated as exposed to DE. OEHHA believes that this is a major reason that Crump does not get statistically significant exposure-response slopes in his exposure-response analyses. They disagreed with Crump's conclusions that there is no association between DE exposure and cancer because he could not find a positive dose-response trend in his analysis. Their analysis of evidence from 30 epidemiological studies indicated that DE exposure to workers is associated with an increased risk of lung cancer and that this risk is still significant after controlling as best as possible for smoking. OEHHA's meta-analysis indicates a significant exposure duration-response trend.

Miscellaneous Technical Arguments

Selection of Model: OEHHA chose a linear non-threshold model to estimate human cancer risk from DE on the theory that carcinogenesis is a result of DNA mutation from the constituents of DE. Animal and cellular studies demonstrate that DE is mutagenic. There may be other mechanisms working in concert with each other. DE is not treated as a threshold carcinogen, because there is insufficient data supporting a threshold hypothesized mechanism such as that involving lung overload.

Causal Relationship: OEHHA has stated that a causal relationship between DE exposure and human lung cancer risk is reasonable and very likely based on analysis of the epidemiological studies in the literature of exposed workers. OEHHA assessed causal inference using standard criteria. These criteria included: 1) the consistency of the findings; 2) the strength of the associations; 3) the possibility that the findings were due to bias; 4) the probability that the findings were due to chance; 5) evidence of exposure-response relationships; 6) temporality of the associations; and 7) biological plausibility of the associations. The great majority of the epidemiological studies find an association. The small magnitude of the relative risk increases the potential for confounding. However, the number and diversity of the occupations studied, and the various analyses of sources of confounding (e.g., smoking, ETS exposure, recall bias, informational bias) do not indicate that confounding or chance accounts for the observed results. While limited exposure information was available, based upon duration of exposure there was evidence of an exposure response trend.

Biological plausibility: Although this is not required for causal inference, there is biological evidence to support the association: 1) DE contains many mutagens; 2) DE causes lung cancer in animal studies; 3) DE contains many substances which occur in other complex mixtures which are respiratory carcinogens in humans; and 4) DE contains known and probable human carcinogens.

OEHHA has not shown a mechanism or even established the existence of a causal link between ambient exposures to DE and lung cancer in humans. Studies examining the association of long-term ambient exposures to DE and the incidence of lung cancer have not been done. Therefore, OEHHA has principally relied upon the available occupational exposure studies to assess the potential cancer risk. Because the range of extrapolation from the occupational exposures to the ambient exposures of concern is not large, it adds confidence to the extrapolation of findings at occupational exposures to ambient levels of exposure. With respect to the possible mechanisms of carcinogenesis, OEHHA has reviewed them, including evidence bearing on the genotoxicity of DE. The related evidence includes the presence of known genotoxins and carcinogens in DE, the bioavailability of various DE constituents, and the effects of DE or its constituents in various in vitro and in vivo test systems for genotoxicity.

Newer engines: There is very little information on the specific constituents of PM in new vs. old engines or using new vs. old fuels. Preliminary information indicates a reduction in PM, but the chemical composition of the exhaust appears to be similar between new and old exhaust. However, because distributed electrical generation may become more prevalent, the number of stationary diesel sources may increase and subsequent exposure to emissions may be increasing.

New Information: New studies will contribute to a future re-evaluation of a URF for DE. One of the most recent studies is "Lung Cancer and Vehicle Exhaust in Trucking Industry Workers" (October 2008; Eric Garshick, F. Laden, J.E. Hart, B. Rosner, M. E. Davis, E.A. Eisen, T.J. Smith. Environmental Health Perspectives, 116:1327-1332). The study established a large retrospective cohort of trucking company workers to assess the association of lung cancer mortality and measures of vehicle exhaust exposure. Adjusting for age and a healthy-worker survivor effect, lung cancer hazard ratios were elevated in workers with jobs associated with regular exposure to vehicle exhaust. Mortality risk increased linearly with years of employment and was similar across job categories despite different current and historical patterns of exhaust-related PM from diesel trucks, city and highway traffic, and loading dock operations. Smoking behavior did not explain variations in lung cancer risk. The authors concluded that trucking industry workers who have had regular exposure to vehicle exhaust from diesel and other types of vehicles on highways, city streets, and loading docks have an elevated risk of lung cancer with increasing years of work.

APPENDIX D

CULPABILITY ANALYSES

(following pages)

The following isopleth maps show the maximum predicted 70-year lifetime cancer risk based on actual or potential exposure resulting from diesel particulate emissions from each of the main sources. The marine terminals at Port Newark and Elizabeth Port Authority Marine Terminal and the waters approaching these facilities are not used for residential purposes, so these areas may have lower risks proportional to the 8 hour or similar length work days that occur there. These figures are intended to allow the identification of risk reduction strategies by identifying certain emission sources. However, no one source appears to be dominant or primarily responsible. These figures also reflect the location of those sources with relation to the closest area of residences, e.g., the ocean-going vessels and tugboats operate in Newark Bay at a closer distance to Bayonne than the locomotives.

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FIGURE 9: MAXIMUM PREDICTED 70-YEAR LIFETIME CANCER RISK DUE TO DIESEL PARTICULATE EMISSIONS FROM OCEAN-GOING VESSELS (not including background)

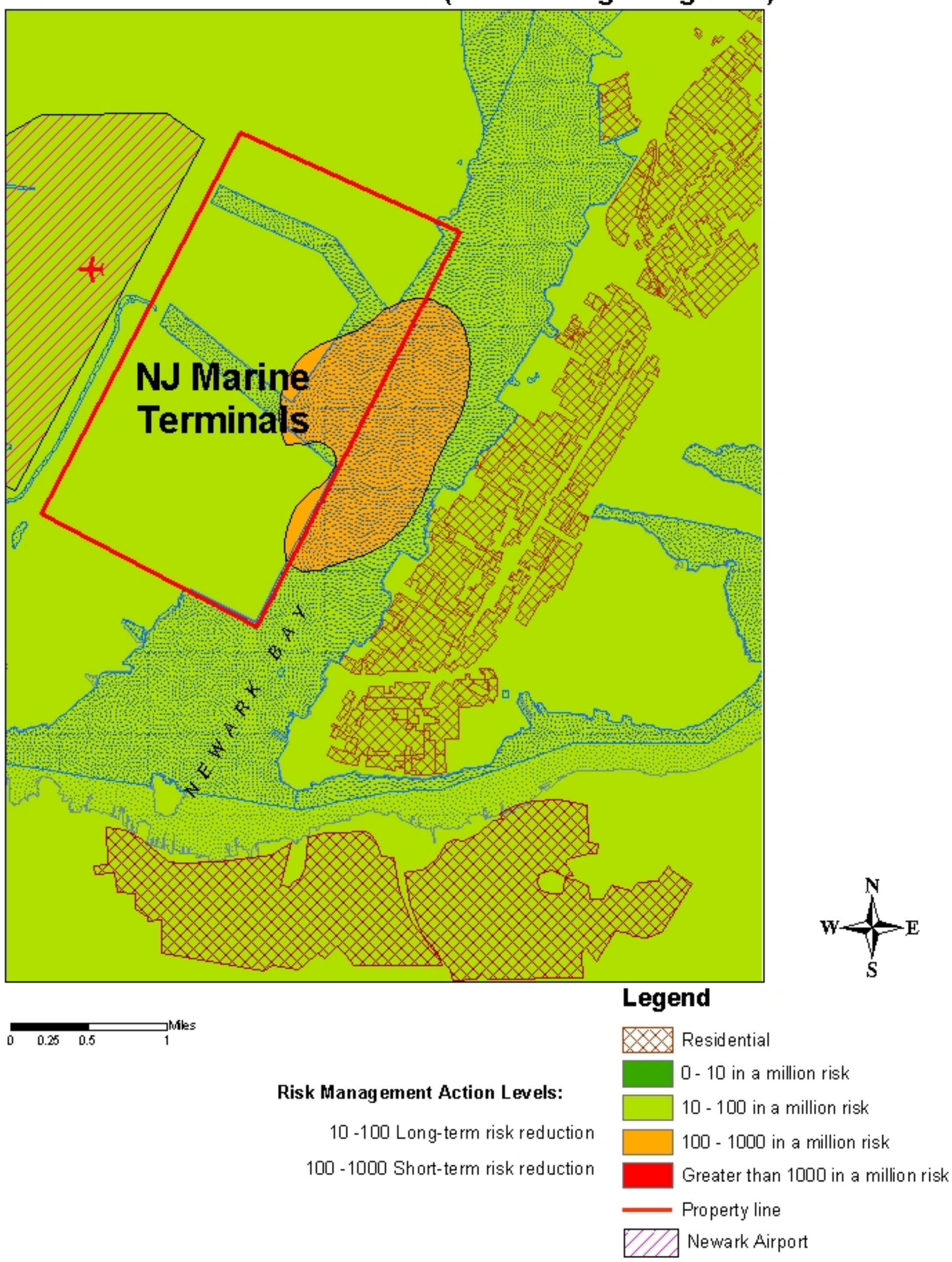

FIGURE 10: MAXIMUM PREDICTED ANNUAL PM2.5 CONCENTRATIONS DUE TO TUGBOATS AT THE PORT (not including background)

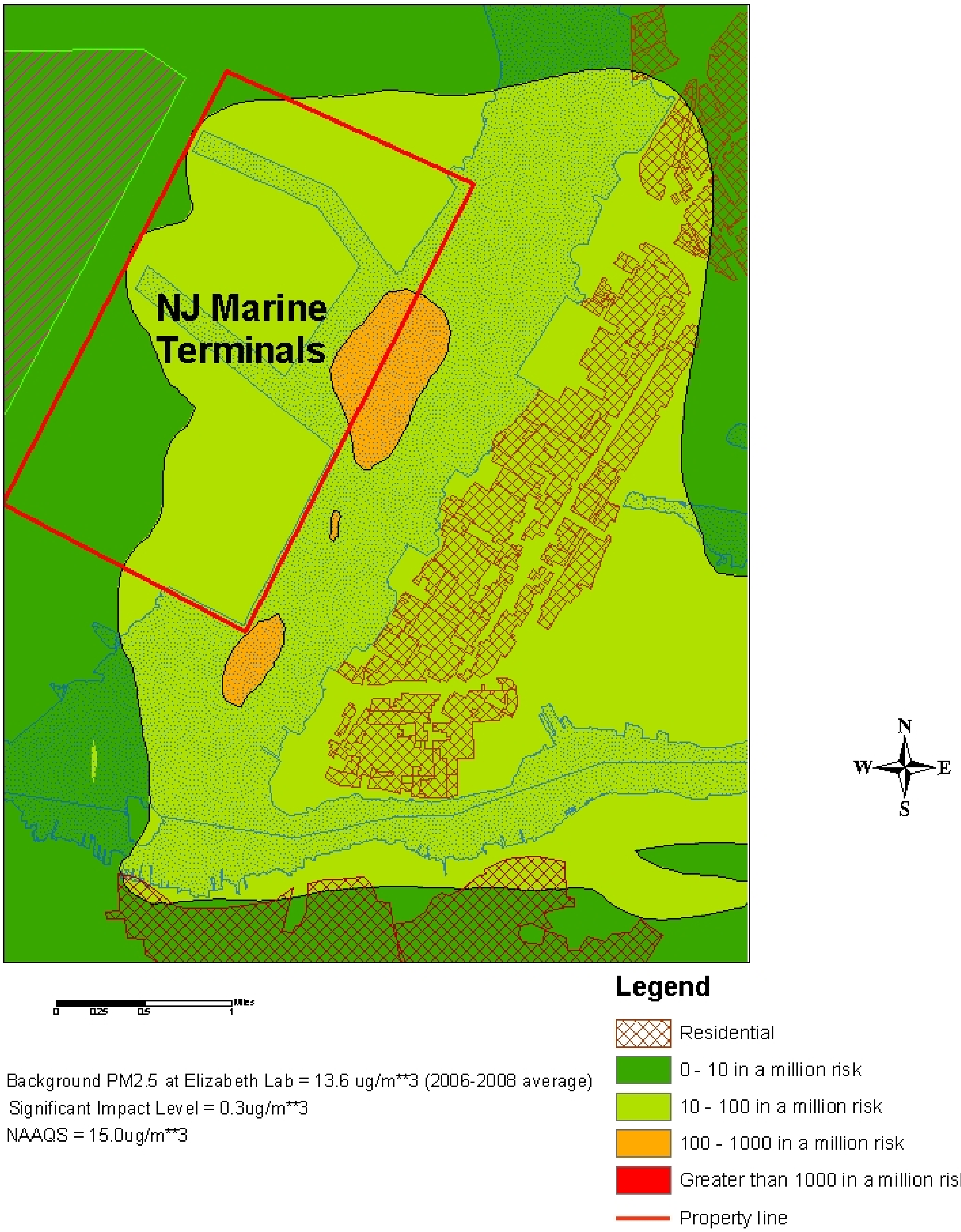

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FIGURE 11: MAXIMUM PREDICTED 70-YEAR LIFETIME CANCER RISK DUE TO DIESEL PARTICULATE EMISSIONS FROM CARGO HANDLING EQUIPMENT (not including background)

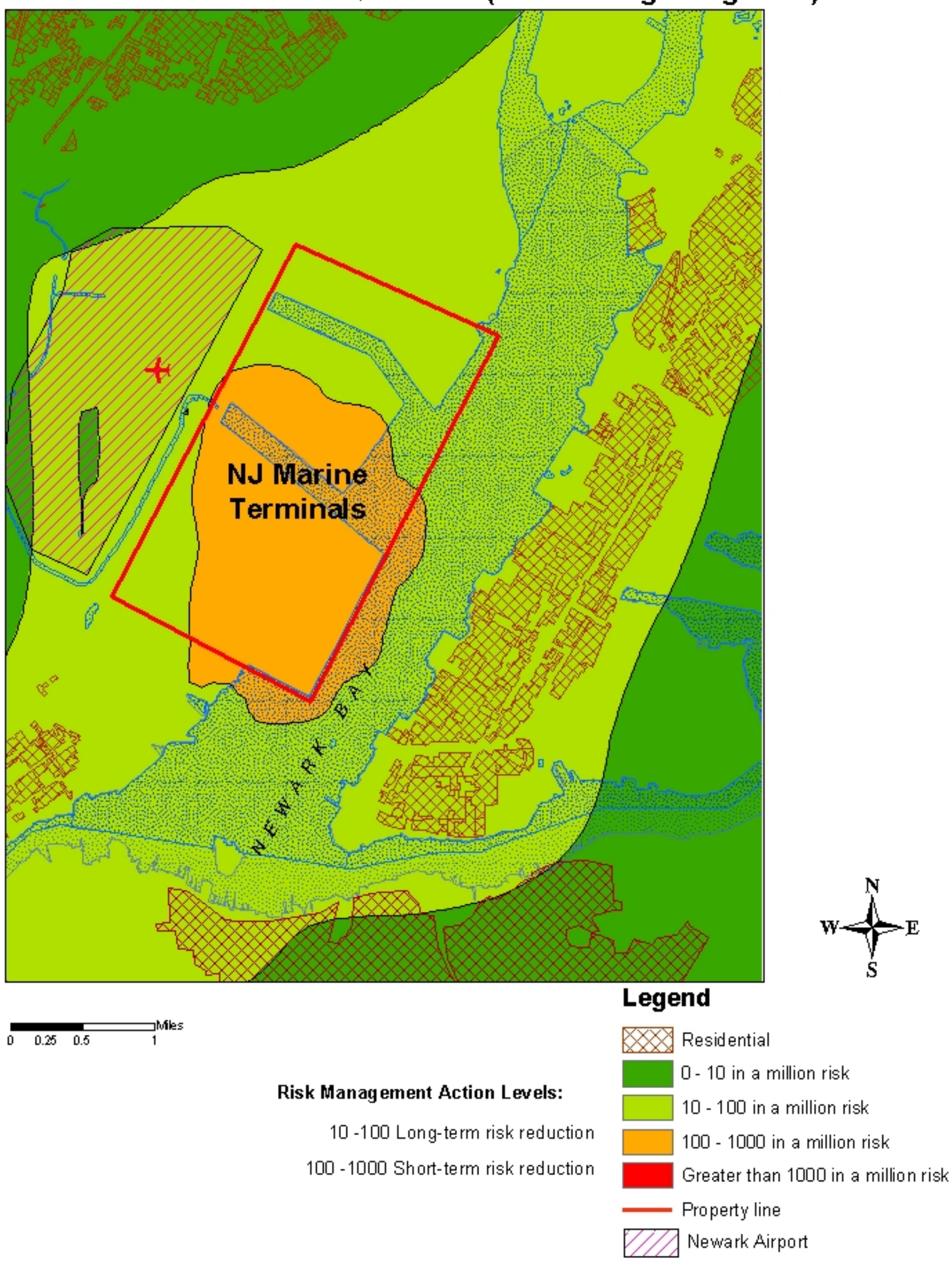

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FIGURE 12: MAXIMUM PREDICTED 70-YEAR LIFETIME CANCER RISK DUE TO DIESEL PARTICULATE EMISSIONS FROM LOCOMOTIVES (not including background)

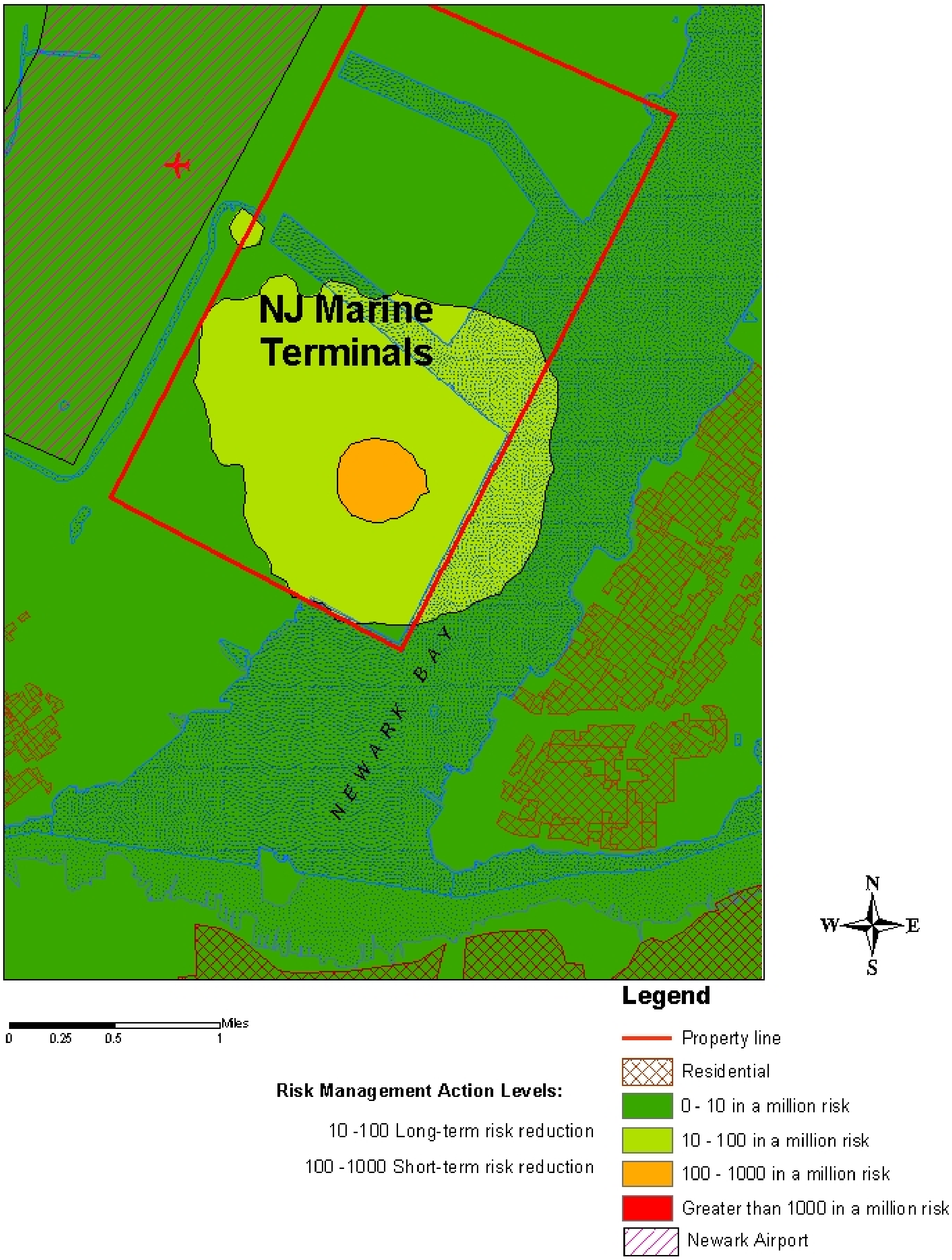

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FIGURE 13: MAXIMUM PREDICTED 70-YEAR LIFETIME CANCER RISK DUE TO DIESEL PARTICULATE EMISSIONS FROM TRUCKS (not including background)