California Environmental Protection Agency

Air Resources Board

Health Risk Assessment for the BNSF Railway Richmond Railyard

Stationary Source Division
November 20, 2007

California Environmental Protection Agency
Air Resources Board

Health Risk Assessment for the BNSF Railway Richmond Railyard

Principal Author
Eugene Yang, Ph.D., P.E.

Contributing Authors
Stationary Source Division:
Jing Yuan, Ph.D.
Chan Pham
Pingkuan Di, Ph.D., P.E.
Hector Castaneda

Planning and Technical Support Division:
Nicole Dolney
Beth Schwehr
Anthony Servin, P.E.
Stephen Zelinka
Johnnie Raymond

Reviewed by

ARB Executive Office:
Michael H. Scheible, Deputy Executive Officer

ARB Stationary Source Division:
Robert D. Fletcher, Chief, Stationary Source Division
Dean C. Simeroth, Chief, Criteria Pollutants Branch
Harold Holmes, Manager, Engineering Evaluation Section

The staff of the Air Resources Board has prepared this report. Publication does not signify that the contents reflect the views and policies of the Air Resources Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

This page left intentionally blank

Acknowledgements

Air Resources Board staff extends its appreciation to the representatives of BNSF Railway and their consultants for preparing the railyard emissions inventory data and conducting air dispersion model simulations.

BNSF Railway:
Mark Stehly, Michael Stanfill

Environ International, Inc.:
Dave Souten, Douglas Daugherty, Ph.D; Christian Lindhjem, Ph.D.; Robert Scofield, D. Env.; Till Stoeckenius

This page left intentionally blank

TABLE OF CONTENTS

I. INTRODUCTION 1
A. Why ARB is concerned about diesel PM emissions? 1
B. Why evaluate diesel PM emissions at the BNSF Richmond Railyard? 2
C. What are health risk assessments? 2
D. Who prepared the BNSF Richmond Railyard health risk assessment? 4
E. How is this report structured? 5

II. SUMMARY 6
A. General description of the BNSF Richmond Railyard 6
B. What are the primary facility operations at the BNSF Richmond Railyard? 6
C. What are the diesel PM emissions at and near the BNSF Richmond Railyard? 7
D. What are the potential cancer risks from the BNSF Richmond Railyard? 13
E. What are the estimated non-cancer chronic risks near the BNSF Richmond Railyard? 18
F. What are the estimated health risks from off-site (non-railyard) emissions? 20
G. Can study estimates be verified by air monitoring? 24
H. What activities are underway to reduce diesel particulate matter emissions and public health risks? 24

III. SUMMARY OF BNSF RICHMOND RAILYARD ACTIVITY AND EMISSIONS ... 28
A. BNSF Richmond Railyard facility 28
B. BNSF Richmond Railyard operations 28
C. BNSF Richmond Railyard emission inventory summary 31
D. Off-site non-railyard emission inventory 37
E. Current applicable diesel fuel regulations and their benefits to the railyards 41

IV. AIR DISPERSION MODELING OF BNSF RICHMOND RAILYARD 46
A. Air dispersion model selection 46
B. Source characterization and parameters 47
C. Meteorological data 48
D. Model receptors 52

E. Building wake effects 55

F. Model implementation inputs 55

V. HEALTH RISK ASSESSMENT OF BNSF RICHMOND RAILYARD 56

A. ARB railyard health risk assessment guidelines 56

B. Exposure assessment 57

C. Risk characterization 58

D. Risk characterization associated with on-site emissions 59

E. Risk characterization associated with off-site (non-railyard) emissions 68

F. Risks to sensitive receptors surrounding the BNSF Richmond Railyard 74

G. Uncertainty and limitations 74

LIST OF TABLES

Table II-1 Comparisons of diesel PM emissions (tons per pear) from three major source categories within eleven railyards.. 8
Table II-2 BNSF Richmond Railyard and off-site diesel PM emissions. 10
Table II-3 Cancer potency weighted toxic air contaminant emissions from significant off-site stationary sources surrounding BNSF Richmond Railyard 12
Table II-4 Major toxic air contaminants from gasoline-related sources in the San Francisco Bay Area Air Basin in 2005. 13
Table II-5 Estimated impacted areas and exposed population associated with different potential cancer risk levels for a 70-year exposure..... 15
Table II-6 Equivalent potential cancer risk levels of 70-, 30-, 9-, and 40-year exposure durations associated with on-site railyard diesel PM emissions..... 17
Table II-7 Area coverage and exposed population of impacted zones for cancer risk levels associated with the off-site diesel PM emissions (based on Tier-1 estimate and 80th percentile breathing rate for 70-year exposure). 22
Table III-1 Summary of diesel PM emissions at the BNSF Richmond Railyard..... 31
Table III-2 Diesel PM emissions by locomotive operation activity. 33
Table III-3 Diesel PM emissions by on-road truck operations. 34
Table III-4 Diesel PM emissions of off-road engines and equipment. 35
Table III-5 Non-diesel total organic gas emissions at the BNSF Richmond Railyard. .. 36
Table III-6 Summary of off-site stationary diesel PM emissions at one-mile off-site boundary from the railyard boundary..... 39
Table III-7 Significant toxic air contaminant emissions identified from off-site stationary sources within one-mile off-site boundary 39
Table III-8 Summary of off-site mobile diesel PM emissions within one-mile off-site boundary by vehicle classifications..... 40

Table III-9 Off-site mobile diesel PM emissions by traffic flows within one-mile off-site boundary. 40
Table III-10 California diesel fuel standards 41
Table III-11 U.S. EPA diesel fuel standards 42
Table III-12 Average 1999 properties of reformulated diesel fuel. 43
Table V-1 Estimated acreage and exposed population of different cancer risk zones associated with on-site railyard diesel PM emissions (based on Tier-1 estimate and 80th percentile breathing rate for 70-year exposure duration). 62
Table V-2 Equivalent potential cancer risk levels of 70-, 30-, 9-, and 40-year exposure durations associated with on-site railyard diesel PM emissions (based on Tier-1 methodology and 70-year exposure). 63
Table V-3 The impacted area of non-cancer chronic risks by estimated hazard indices associated with on-site railyard diesel PM emissions at the BNSF Richmond Railyard. 67
Table V-4 The estimated acreages of impacted zones and the associated exposed population, based on Tier-1 estimate and 80th percentile breathing rate for 70-year exposure duration. 70
Table V-5 Cancer potency weighted toxic air contaminant emissions from significant off-site non-railyard stationary sources surrounding BNSF Richmond Railyard. 71
Table V-6 Major toxic air contaminants from gasoline-related sources in San Francisco Bay Area Air Basin, based on 2005 emission inventory. 72
Table V-7 Numbers of sensitive receptors identified in different levels of estimated cancer risks (based on a 70-year exposure duration) associated with on-site railyard diesel PM emissions. 74

LIST OF FIGURES

Figure II-1 The geographical location of BNSF Richmond Railyard and the neighboring areas. 7

Figure II-2 Estimated potential cancer risks (chances per million) associated with diesel PM emissions at the BNSF Richmond Railyard (based on Tier-1 estimate and 80th percentile breathing rate for 70-year exposure). 16

Figure II-3 Comparison of estimated potential cancer risks associated with diesel PM emissions at the BNSF Richmond Railyard to the regional background cancer risk level ("*": Estimated exposed population within each cancer risk range). 18

Figure II-4 Estimated non-cancer chronic risks (indicated as Hazard Indices) associated with diesel PM emissions from the BNSF Richmond Railyard. 19

Figure II-5 Estimated cancer chronic risks (chances per million) associated with the off-site diesel PM emissions within the one-mile boundary (dashed line) around the BNSF Richmond Railyard (based on Tier-1 estimate and 80th percentile breathing rate for 70-year exposure). 21

Figure II-6 Estimated non-cancer chronic risks (indicated as Hazard Indices) associated with the off-site non-railyard diesel PM emissions within the one-mile boundary (dashed line) around the BNSF Richmond Railyard.... 23

Figure III-1 Locomotive operation activities and other stationary emission sources at the BNSF Richmond Railyard. 29

Figure III-2 Operation areas of on-road trucks and fleet at the BNSF Richmond Railyard. 30

Figure III-3 Off-site one-mile distance boundary (dashed line) from the BNSF Richmond Railyard (encompassed by solid lines). 38

Figure IV-1 Wind Rose Plot of Chevron Refinery Meteorological Station at Richmond for the year 2001–2005. 50

Figure IV-2 Wind class frequency distribution of Chevron Refinery meteorological station at Richmond for the year 2001–2005. 51
Figure IV-3 The Receptor Grid Networks of Air Dispersion Modeling at the BNSF Richmond Railyard Facility. 53
Figure IV-4 Model receptors and locations for air dispersion modeling at the BNSF Richmond Railyard. 54
Figure V-1 Estimated potential cancer risk (in a million) associated with on-site diesel PM emissions at the BNSF Richmond Railyard facility (based on Tier-1 estimate and 80th percentile breathing rate for 70-year exposure duration). 61
Figure V-2 Estimated non-cancer chronic risks (indicated as a Hazard Index) associated with the on-site diesel PM emissions at BNSF Richmond Railyard. 66
Figure V-3 Estimated potential cancer risks (as chances per million) from off-site stationary and mobile diesel PM emissions within the one-mile boundary (dashed line) around the BNSF Richmond Railyard (based on Tier-1 estimate and 80th percentile breathing rate for a 70-year exposure duration). 69
Figure V-4 Estimated non-cancer risks (indicated as hazard indices) associated with the off-site non-railyard diesel PM emissions within a one-mile off-site boundary (dashed line) around the BNSF Richmond Railyard. 73

APPENDICES

A. METHODOLOGY OF OFF-SITE DIESEL PM MOBILE SOURCE EMISSIONS

B. METHODOLOGY OF OFF-SITE DIESEL PM STATIONARY SOURCE EMISSIONS

C. SUMMARY OF AIR DISPERSION MODELING RESULTS FROM OFF-SITE DIESEL PM EMISSIONS

D. LOCOMOTIVE DIESEL PM EMISSION FACTORS

E. ESTIMATION OF DIESEL PM EMISSIONS FROM THE HHD DIESEL TRUCKS TRAVELING BETWEEN RAILYARD AND MAJOR FREEWAYS

F. SPATIAL ALLOCATIONS OF MAJOR DIESEL PM EMISSION SOURCES AT THE BNSF RICHMOND RAILYARD

G. AERMOD MODE SENSITIVITY ANALYSIS OF METEOROLOGICAL DATA

This page left intentionally blank

I. INTRODUCTION

The California Air Resources Board (ARB or Board) conducted a health risk assessment study (study) to evaluate the impacts associated with toxic air contaminants emitted in and around the BNSF Railway's (BNSF) railyard located in Richmond, California. The railyard is approximately 12 miles northeast of San Francisco. The study focused on the railyard property emissions from locomotives, on-road heavy-duty trucks, off-road vehicles, and equipment used to move bulk cargo. Also evaluated were mobile and stationary sources with significant emissions within a one-mile distance from the railyard. This information was used to evaluate the potential health risks associated with diesel particulate matter emissions to those living nearby the railyard.

A. Why ARB is concerned about diesel PM emissions?

In 1998, following a 10-year scientific assessment process, ARB identified particulate matter from diesel exhaust (diesel PM) as a toxic air contaminant based on its potential to cause cancer and other adverse health problems, including respiratory illnesses, and increased risk of heart disease. Subsequent to this action, research has shown that diesel PM contributions to premature deaths[1](ARB, 2002). The diesel PM particles are very small; moreover, by mass approximately 94 percent of these particles are less than 2.5 microns in diameter ($PM_{2.5}$). Because of their tiny size, diesel PM particles are readily respirable and can penetrate deep into the lung and enter the bloodstream, carrying with them an array of toxins. Exposure to diesel PM is a health hazard, particularly to children whose lungs are still developing and the elderly who may have other serious health problems. Population-based studies in hundreds of cities in the U.S. and around the world demonstrate a strong link between elevated PM levels and premature deaths (Pope et al., 1995, 2002 and 2004; Krewski et al., 2000), increased hospitalizations for respiratory and cardiovascular causes, asthma and other lower respiratory symptoms, acute bronchitis, work loss days, and minor restricted activity days (ARB, 2006a).

Diesel PM emissions typically are the dominant toxic air contaminants in and around a railyard facility. Diesel PM accounts for about 70 percent of the statewide estimated potential ambient air toxic cancer risks based on data from ARB's ambient monitoring network in 2000 (ARB, 2000). These findings were consistent with that of a study conducted in southern California*, Multiple Air Toxics Exposure Study in the South Coast Air Basin*, (SCAQMD, 2000). Based on scientific research findings and the dominance of diesel PM emissions, the health impacts in this study primarily focus on the risks from the diesel PM emissions.

[1] Premature Death: as defined by U.S. Centers for Disease Control and Prevention's Years of Potential Life Lost, any life ended before age 75 is considered as premature death.

B. Why evaluate diesel PM emissions at the BNSF Richmond Railyard?

In 2005, the ARB entered into a statewide railroad pollution reduction agreement (Agreement) with Union Pacific Railroad (UP) and BNSF Railway (BNSF). This Agreement was developed to implement near-term measures to reduce diesel PM emissions in and around railyards by approximately 20 percent.

The Agreement requires that health risk assessments be prepared for each of the 17 major or designated railyards in the State. The Agreement also requires the railyard health risk assessments to be prepared based on the experience of the UP Roseville Railyard Health Risk Assessment study in 2004 (ARB, 2004a) and the Health Assessment Guidance for Railyards and Intermodal Facilities (ARB, 2006b). The BNSF Richmond Railyard is one of the designated railyards subject to the Agreement and the health risk assessment requirements.

C. What are health risk assessments?

An exposure assessment is an analysis of amount (i.e., concentration in the air) of a pollutant that a person is exposed to a specific time period. This information is used in a risk assessment to evaluate the potential for an air pollutant to contribute cancer or other health effects. A health risk assessment uses mathematical models to evaluate the health impacts from exposure to certain chemical or toxic air contaminant released from a facility or found in the air. Health risk assessments provide information to estimate potential long-term cancer and non-cancer health risks. Health risk assessments do not gather information or health data on specific individuals, but are estimates for the potential health impacts on a population at large.

A health risk assessment consists of three major components: (1) the air pollution emission inventory, (2) the air dispersion modeling, and (3) an assessment of associated risks. The air pollution emission inventory provides an estimate of how air pollutants are generated from different emission sources. The air dispersion modeling incorporates the estimated emission inventory and meteorological data as inputs, then use a computer model to predict the distributions of air toxics in the air. Based on the modeling results, an assessment of the potential health risks from the air toxics to exposed population is performed. The results are expressed in a number of ways as summarized below.

- For potential cancer health effects, the risk is usually expressed as the number of chances in a population of a million people. The number may be stated as “10 in a million” or “10 chances per million”. The methodology used to estimate the potential cancer risks is consistent with the Tier-1 analysis of *Air Toxics Hot Spots Program*

Risk Assessment Guidelines (OEHHA, 2003). A Tier-1 analysis assumes that an individual is exposed to an annual average concentration of a given pollutant continuously for 70 years. The length of time that an individual is exposed to a given air concentration is proportional to the risk. During childhood, the impact from exposure to a given air concentration is greater. Exposure durations of 30 years or 9 years may also be evaluated as supplemental information to present the range of cancer risk based on residency period.

- For non-cancer health effects, a reference exposure level (REL) is used to estimate if there will be certain identified adverse health impacts, such as lung irritation, liver damage, or birth defects. These adverse health effects may happen after chronic (long-term) or acute (short-term) exposure. To calculate a non-cancer health risk, the reference exposure level (REL)[2] is compared to the concentration that a person is exposed to and a hazard index (HI) is calculated. The higher the hazard index is above 1.0, the greater the potential for possible adverse health impacts. If the hazard index is less than 1.0, then it is an indicator that adverse effects are less likely to occur.

- For premature deaths that linked to diesel PM in the San Francisco Bay Area Air Basin, ARB staff estimated about 410 premature deaths per year due to diesel PM emissions in 2000 (ARB Research Division, Lloyd and Cackette, 2001). The total diesel PM emissions from all sources in the San Francisco Bay Air Basin were estimated at about 4,840 tons per year in 2000 and 4,550 tons per year in 2005 (ARB, 2006a). During 2005, the diesel PM emissions from the BNSF Richmond Railyard was estimated at 4.63 tons, less than 0.2 percent of the total estimated air basin diesel PM emissions.

The potential cancer risk from known carcinogens estimated from the health risk assessment is expressed as the incremental number of potential cancers that could develop per million people, assuming population is exposed to the carcinogen at a defined concentration over a presumed 70-year lifetime. The ratio of potential number of cancers per million people can also be interpreted as the incremental likelihood of an individual exposed to the carcinogen developing cancer from continuous exposure over

[2] The Reference Exposure Level (REL) for diesel PM is essentially the U.S. EPA Reference Concentration first developed in the early 1990s based on histological changes in the lungs of rats. Since the identification of diesel PM as a Toxic Air Contaminant (TAC), California has evaluated the latest literature on particulate matter health effects to set the Ambient Air Quality Standard. Diesel PM is a component of particulate matter. Health effects from particulate matter in humans include illness and death from cardiovascular and respiratory disease, and exacerbation of asthma and other respiratory illnesses. Additionally, a body of literature has been published, largely after the identification of diesel PM as a TAC and adoption of the REL, which shows that diesel PM can enhance allergic responses in humans and animals. Thus, it should be noted that the REL does not reflect adverse impacts of particulate matter on cardiovascular and respiratory disease and deaths, exacerbation of asthma, and enhancement of allergic response.

a lifetime. For example, if the cancer risk were estimated to be 100 chances per million, then the probability of an individual developing cancer would not be expected to exceed 100 chances in a million. If a population (e.g., one million people) were exposed to the same potential cancer risk (e.g., 100 chances per million), then statistics would predict that no more than 100 of those million people exposed would be likely to develop cancer from a lifetime of exposure (i.e., 70 years) to diesel PM emissions from a facility.

The health risk assessment is a complex process that is based on current knowledge and a number of assumptions. However, there is a certain extent of uncertainty associated with the process of risk assessment. The uncertainty arises from lack of data in many areas, necessitating the use of assumptions. The assumptions used in the assessment are often designed to be conservative on the side of health protection in order to avoid underestimation of risk to the public. As indicated by the OEHHA Guidelines, the Tier-1 evaluation is useful in comparing risks among a number of facilities and similar sources. Thus, the risk estimates should not be interpreted as a literal prediction of disease incidence in the affected communities but more as a tool for comparison of the relative risk between one facility and another. Therefore, risk assessment results are best used for comparing potential risks to target levels to determine the level of mitigation needed. They are also an effective tool for determining the impact a particular control strategy will have on reducing risks.

OEHHA is in the process of updating the current health risk assessment guidelines, and the ARB and UP and BNSF agreed to evaluate the non-cancer health impacts using an interim methodology. This was used in the *Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach* (ARB, 2006d) to estimate PM mortality. This will serve as a short-term and interim effort until OEHHA can complete its update of the Guidelines.

As soon as the HRAs are final, both the ARB and Railroads in cooperation with the BAAQMD (Bay Area Air Quality Management District) staff, local citizens and others will begin a series of meetings to identify and implement measures to reduce emissions from railyard sources. Existing effects are detailed in Chapter III-C.

D. Who prepared the BNSF Richmond Railyard health risk assessment?

Under the Agreement, ARB worked with affected local air quality management districts, counties, cities, communities, and the two railroads to develop two guideline documents for performing the health risk assessments. The two documents, entitled *Health Risk Assessment Guidance for Railyard and Intermodal Facilities* (ARB, 2006b) and *Railyard Emissions Inventory Methodology* (ARB, 2006e), provide guidelines for the identification, modeling, and evaluation of the toxic air contaminants from designated railyards throughout California. Using the guidelines, the railroads developed the emission inventories based on the year 2005 activities and performed the air dispersion modeling for all operations that occur within each of the designated railyards.

ARB staff is responsible for reviewing and approving the railroads' submittals, identifying significant sources of emissions near the railyards and modeling the impacts of those sources, and preparing the railyard health risk assessments. ARB staff is also responsible for releasing the draft HRAs to the public for comment and presenting them at community meetings. After reviewing public comments on the draft HRAs, ARB staff made revisions as necessary and appropriate, and is now presenting the HRAs in final form. Ultimately, the information derived from the railyards HRAs is to be used to help identify the most effective mitigation measures that could be implemented to further reduce railyard emissions and public health risks.

E. How is this report structured?

The next chapter provides a summary of the BNSF Richmond Railyard operations, emissions, air dispersion modeling, and health risk assessment results. Following the summary, the next chapters present the details of the analyses of emission inventory, air dispersion modeling, and health risk assessment. The appendices present the technical supporting documents for the analysis discussed in the main body of the report.

II. SUMMARY

The study estimated the 2005 base-year diesel PM emissions generated from the BNSF Richmond Railyard and non-railyard (off-site) emission sources. The operation activities and emissions within the BNSF Richmond Railyard, the emissions within the area with a one-mile perimetric distance from the railyard, and the health risk assessment are summarized as below.

A. General description of the BNSF Richmond Railyard

The BNSF Richmond Railyard is located west of the City of Richmond, California, and is approximately 12 miles northeast of San Francisco (see Figure II-1). The railyard is bordered by commercial properties to the north, Interstate-580 (I-580) to the south, industrial properties to the west, and residential properties to the east. The San Francisco Bay and San Pablo Bay are located within a few miles from the western and southern boundaries of the railyard property. Interstate I-80 is located approximately three miles to the east of the railyard property. The railyard facility comprises about a quarter-mile wide by one and half a mile long strip of land encompassing about 150 acres. Areas with the greatest residential densities are located east and northeast of the railyard. The population surrounding the railyard facility within a 3-mile radius was estimated at about 76,000, according to the U.S. 2000 Census Bureau's Data.

The facility generally runs northeast and southwest. In 2005, the facility consisted of a locomotive staging area, locomotive fueling area, freight car repair building, a locomotive repair shop, train master facility, and administrative offices for the intermodal and mechanical areas of the facility.

B. What are the primary facility operations at the BNSF Richmond Railyard?

The major activities during 2005 were intermodal operations with trains arriving and originating from the railyard, including locomotive line haul, locomotive switching, and cargo handling operations. Some basic locomotive services and track maintenance were also conducted at the facility, including sanding, fueling, lubrication and scheduled mechanical inspections. The BNSF Richmond Railyard also supports operations at the BNSF Oakland International Gateway (OIG) railyard facility in Oakland, California.

Figure II-1 The geographical location of BNSF Richmond Railyard and the neighboring areas.

C. What are the diesel PM emissions at and near the BNSF Richmond Railyard?

In 2005, the combined diesel PM emissions, from the BNSF Richmond Railyard on-site emissions and other significant off-site non-railyard emission resources within a one-mile boundary (see Figure III-3), were estimated at about 25 tons per year. Off-site sources and activities, not generally related to railyard activities, includes both mobile

and stationary sources, and were estimated at about 20 tons per year, or about 80% of total diesel PM emissions. The diesel PM emissions at the BNSF Richmond Railyard are estimated at about 5 tons per year or 20% of the combined on-site and off-site (i.e., railyard and non-railyard) diesel PM emissions.

In comparison with other railyards in the State, Table II-1 summarizes three major diesel PM source categories within all designated railyards that the health risk assessments are scheduled to be completed in 2007.

Table II-1 Comparisons of diesel PM emissions (tons per pear) from three major source categories within eleven railyards..

Designated Railyards	Locomotives	Cargo Handling Equipment	On-road Trucks	Off-road and Stationary Sources	Total[§]
UP Roseville[*]	25.1[**]	N/A[‡]	N/A[‡]	N/A[‡]	**25.1**
BNSF Hobart	5.9	4.2[†]	10.1	3.7	**23.9**
UP Commerce	4.9	4.8[†]	2.0	0.4	**12.1**
UP LATC	3.2	2.7[†]	1.0	0.5	**7.3**
UP Stockton	6.5	N/A[‡]	0.2	0.2	**6.9**
UP Mira Loma	4.4	N/A[‡]	0.2	0.2	**4.9**
BNSF Richmond	3.3	0.3[†]	0.5	0.6	**4.7**
BNSF Stockton	3.6	N/A[‡]	N/A[‡]	0.02	**3.6**
BNSF Commerce Eastern	0.6	0.4	1.1	1.0	**3.1**
BNSF Sheila	2.2	N/A[‡]	N/A[‡]	0.4	**2.7**
BNSF Watson	1.9	N/A[‡]	< 0.01	0.04	**1.9**

* The UP Roseville Health Risk Assessment (ARB, 2004a) was based on 1999-2000 emission estimate, only locomotive diesel PM emissions were reported in that study.

** The actual emissions were estimated at a range of 22.1 to 25.1 tons per year.

‡ Not applicable.

§ Numbers may not add precisely due to rounding.

† An error of cargo handling equipment emissions was found after the modeling was completed. The applicable change in emissions was believed to be de minimis; consequently, the modeling was not re-performed.

1. Railyard emissions

The BNSF Richmond Railyard emission sources include, but are not limited to, locomotives, on-road container diesel trucks, heavy duty trucks, diesel-fueled equipment, and fuel storage tanks. The facility operates 24 hours per day, 365 days per year. The emissions were calculated on a source-specific and facility-wide basis for the 2005 baseline year. There were 10,752 recorded locomotives arriving/departing or passing through the railyard, and 9,630 locomotives that visited and were served at the facility during the course of the year. The methodology used to calculate the diesel PM and other toxic air contaminant emissions is based on the ARB's *Railyard Emission Inventory Methodology* (ARB, 2006e). The future growth in emissions at the BNSF Richmond facility is not incorporated in the HRA emission inventory, but will be included as part of the mitigation emission reduction efforts. The locomotive emission factors used in the study is presented in Appendix D.

Within the BNSF Richmond Railyard facility, 70% of total diesel PM emissions were estimated to be from locomotive operations, at 3.3 tons per year. The locomotive diesel PM emissions are primarily due to freight movements comprising about 1.5 tons per year. The railyard operations, primarily switching locomotives moving railcars within the facility, contribute 1.2 tons per year, and the locomotive service and inspection activity accounts for about 0.6 tons per year. The remaining 30% of the railyard diesel PM emissions are generated by the other operations from diesel-fueled vehicles and equipment, such as on-road trucks and vehicles, cargo handling equipment, off-road equipment, and railyard stationary facilities. The source-categorized diesel PM emissions are summarized in Table II-2.

Table II-2 BNSF Richmond Railyard and off-site diesel PM emissions.

Diesel PM Emission Sources	Richmond Railyard		Off-site Emissions**	
	Tons per Year*	Percentage	Tons per Year	Percentage
Locomotives	3.3	70 %	-	-
Line Haul Locomotives	1.54	33%		
Switch Locomotives	1.16	25%		
Service/Maintenance	0.55	12%		
Off-road Vehicles and Equipment	0.6	12 %	-	-
On-road Trucks and Vehicles	0.5	11 %	-	-
Cargo Handling Equipment	0.3†	7 %	-	-
Other Stationary Sources	< 0.01	< 1 %	-	-
Off-site Mobile Sources	-	-	11.7	60 %
Off-site Stationary Sources	-	-	8.1	40 %
Total	4.6	100 %	19.8	100 %

* Numbers may not add precisely due to rounding.
** Emissions within the one-mile boundary, and the railyard diesel PM emissions not included.
† An error of cargo handling equipment emissions was found after the modeling was completed. The applicable change in emissions was believed to be de minimis; consequently, the modeling was not re-performed.

Diesel PM is not the only toxic air contaminant emitted in the BNSF Richmond Railyard. A relatively small amount of toxic air contaminants is also emitted from gasoline motor vehicles and engines, and fuel storage tanks in the facility. The total amount of these toxic air contaminants emissions is estimated at about 0.015 tons or 30 pounds per year, which is significantly less than the diesel PM emissions (4.6 tons per year) in the railyard. In addition, using cancer potency weighted factor adjustment (see the details of a similar approach in next section), these non-diesel PM toxic air contaminant emissions are about a factor of 550 less than the cancer potency weighted emissions of diesel PM, i.e., 0.008 vs. 4.6 tons per year. Therefore, only diesel PM emissions are presented in the on-site emission analysis.

2. Surrounding sources

ARB staff evaluated significant off-site mobile and stationary sources of diesel PM emissions within a one-mile distance of the BNSF Richmond Railyard. A one-mile

distance was chosen because the health risk assessment study for the UP Roseville Railyard (ARB, 2004a) indicated that cancer risk associated with on-site railyard diesel PM emissions is substantially reduced beyond a one-mile distance from the railyard.

The off-site non-railyard emissions from on-road mobile sources surrounding the BNSF Richmond Railyard were estimated using Integrated Transportation Network (INT) and the working draft of EMFAC-2007 (V2.23.7) within a one-mile boundary from the railyard. The traffic flows were calculated based on roadway-specific vehicle activity data on diesel trucks and spatially allocated through the traffic network. The estimates do not include the diesel PM emissions generated from other modes such as extended idling, starts, and off-road diesel-fueled equipment outside the railyard. Individual sources such as local truck distribution centers and warehouses were not evaluated due to insufficient activity data; however, the trucking flow related to these local facilities was integrated into overall traffic volume on a county basis estimate. Because the off-site (non-railyard) mobile sources have only focused on the on-road diesel PM emissions, the exclusion of extended idling and off-road mobile sources may result in an underestimation for the off-site diesel PM emissions.

Emissions from off-site stationary sources within a one-mile boundary are identified using the California Emission Inventory Development and Reporting System (CEIDARS) database that contains information reported by the local air districts. Of total off-site non-railyard diesel PM emissions, about 12 tons, or 60%, was generated by mobile sources from local traffic activities, i.e., I-580 and local streets. The stationary source emissions account for the other 40% of off-site non-railyard diesel PM emissions, at about 8 tons per year, contributed primarily from the Chevron Refinery, about one mile from the yard boundary on west. The off-site non-railyard mobile and stationary diesel PM emissions are summarized in Table II-2.

In 2000, ARB's *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles* (ARB, 2000) identified diesel PM, 1,3-butadiene, benzene, carbon tetrachloride, formaldehyde as the top five cancer risk contributors, based on ambient concentrations. These toxic air contaminants account for 95% of the statewide estimated potential cancer risk levels. This study also concluded that diesel PM contributes over 70% percent of the State's estimated potential cancer risk levels, which are significantly higher than other toxic air contaminants.

ARB staff also evaluated other toxic air contaminants from stationary emissions around the BNSF Richmond Railyard. Among the toxic air contaminants other than diesel PM from stationary sources, benzene and formaldehyde were identified to be major contributors and estimated at about 4.5 tons per year. Benzene and formaldehyde were also identified to be major toxic air contaminants generated from the refinery nearby.

The Office of Environmental Health Hazard Assessment (OEHHA) has estimated an inhalation cancer potency factor (CPF) for individual chemicals and some chemical

mixtures such as whole diesel exhaust. Diesel exhaust PM contains many individual cancer causing chemicals. The individual cancer-contributing chemicals from diesel exhaust are not separately evaluated so as to avoid double counting. The compounds (benzene and formaldehyde) listed in Table II-3 are given a weighting factor by comparing each compound's cancer potency factor to the diesel PM cancer potency factor. This factor is multiplied by the estimated actual emissions for a given compound, which gives the potency weighted toxic emission as shown in the Table. As indicated, the cancer potency weighted toxic air contaminant emissions from stationary sources are estimated at about 0.3 tons per year. Based on the emission inventory, the potential cancer risks from these non-diesel toxic air contaminants are considerably lower than the diesel PM emissions, by about a factor of 40. Because of the dominance of diesel PM emissions, other toxic air contaminants from the stationary sources were not included in the analysis.

Cancer potency factors (CPF) are expressed as 95% upper confidence limit of excess cancer cases occurring in an exposed population assuming continuous lifetime exposure to a substance at a dose of one milligram per kilogram of body weight, and are

Table II-3 Cancer potency weighted toxic air contaminant emissions from significant off-site stationary sources surrounding BNSF Richmond Railyard

Toxic Air Contaminant	Cancer Potency Factor	Weighted Factor	Estimated Emissions (tons/year)	Potency Weighted Toxic Emissions (tons/year)
Diesel PM	1.1	1.0	11.7	**11.7**
Benzene	0.1	0.09	3.0	**0.27**
Formaldehyde	0.021	0.019	1.5	**0.03**
Non-Diesel PM Toxic Air Contaminants			4.5	**0.3**

ARB staff also estimated the potential cancer risk levels contributed by the use of gasoline in the region of San Francisco Bay Area Air Basin based on 2005 emission inventory, including 1,3-butadiene, benzene, formaldehyde, and acetaldehyde. Table II-4 presents the emissions of major toxic air contaminants from gasoline-related sources, weighted by individual cancer potency factors. The potency weighted emissions from these carcinogens from all gasoline related sources are estimated at about 481 tons per year. For gasoline-fueled vehicles only, the potency weighted

emissions are estimated at about 253 tons per year, or about 6% of diesel PM emissions regionwide. The potential cancer risks associated with non-diesel PM toxic air contaminants emitted from off-site gasoline vehicular sources are substantially less than the potential cancer risks associated with diesel PM emissions, and are not included in the analysis.

Table II-4 Major toxic air contaminants from gasoline-related sources in the San Francisco Bay Area Air Basin in 2005.

Toxic Air Contaminant	Emissions (tons per year)			
	All Sources	Potency Weighted†	Gasoline Vehicular Sources	Potency Weighted†
Diesel PM	4, 552	4,552	-	-
1,3-Butadiene	414	228	245	135
Benzene	1,997	180	1,153	104
Formaldehyde	3,208	61	605	12
Acetaldehyde	1,355	12	177	2
Total (other than diesel PM)	41,824	481	2,180	253

†: Based on cancer potency weighted factors.

D. What are the potential cancer risks from the BNSF Richmond Railyard?

As discussed previously, ARB developed *Health Risk Assessment Guidance for Railyard and Intermodal Facilities* (ARB, 2006b) to ensure that the methodologies used in railyard health risk assessments meet the requirements for the ARB/Railroad Statewide Agreement. The railyard health risk assessments follow *The Air Toxics Hot Spots Program Risk Assessment Guidelines* (OEHHA, 2003) published by the Office of Environmental and Health Hazard Assessment and is consistent with the methodology used for the UP Roseville Railyard Study (ARB, 2004a).

The U.S. EPA recently approved a new state-of-the-art air dispersion model, AERMOD (**A**merican Meteorological Society/**E**PA **R**egulatory Model Improvement Committee

MODEL), as a regulatory model for health risk assessments. ARB staff used the AERMOD in the railyard health risk assessments. One of the critical inputs required for the air dispersion modeling is meteorological data , such as wind direction and wind speed. These parameters determine where and how the pollutants will be transported and distributed in the air.

Three meteorological stations around the region of the BNSF Richmond Railyard were evaluated for the meteorological inputs of the AERMOD modeling simulations. Based on the AERMOD meteorological data selection criteria, ARB staff determined the data collected at Chevron Refinery station to be more representative than other stations, considering local terrain characteristics, prevailing wind field, and data completeness.

The potential cancer risks from the diesel PM emissions generated at the BNSF Richmond Railyard are estimated by risk isopleths (or contours) presented in Figures II-2. The estimated average potential cancer risk is about 150 chances per million near the railyard property boundaries, assuming a 70-year exposure duration. Beyond the railyard perimeter, the estimated cancer risks decrease rapidly to about 100 chances per million. The risks further decrease to 25 in a million within a half mile from the railyard then to 10 in a million within an another half mile distance. About two miles from the railyard perimeter, the estimated cancer risks are at 5 in a million or lower (isopleth not shown in the figure).

> An **isopleth** is a line drawn on a map through all points of equal value of some measurable quantity; in this case, cancer risk.

The OEHHA Guidelines specify that, for health risk assessments, the location of the point of maximum exposure at the point of maximum impact (PMI) be reported. The PMI is defined as a location or the receptor point with the highest cancer risk level outside of the railyard boundary, with or without residential exposure. The PMI is predicted to be located next to the northwest boundary of railyard fence line based on the highest diesel PM concentrations estimated from the modeling results outside of the facility. It is located downwind from high emission density of areas where about 70 percent of facility-wide diesel PM emissions were generated (see the emission allocation in Appendix F). The cancer risk at the PMI is estimated at to be about 200 chances per million based on a 70-year exposure duration. The land use in the vicinity of the PMI is primarily zoned for industrial use. However, there may be residents living in this zoned area. In the residential zoned area, the potential cancer risk of maximally exposed individual resident (MEIR) or maximum individual cancer risk (MICR) is estimated at about 100 chances in a million, assuming a 70-year lifetime exposure. As indicated by Roseville Railyard Study (ARB, 2004a), the location of the PMI may vary depending upon the settings of the model inputs and parameters, such as meteorological data set or emission allocations in the railyard. Therefore, given the estimated emissions, modeling settings, and the assumptions applied to the risk assessment, there are great uncertainties associated with the estimation of PMI and MICR. These indications should not be interpreted as a literal prediction of disease incidence but more as a tool for comparison. In addition, the estimated point of

maximum impact and maximum individual cancer risk may not be replicated by air monitoring.

ARB staff also conducted a comparison of cancer risks estimated at the PMI versus MICR, and the differences of facility-wide diesel PM emissions between the UP and BNSF railyards. The ratios of cancer risks at the PMI or MICR to the diesel PM emissions do not suggest that one railroad's facilities have statistically higher cancer risks than the other railroad's or vice versa. Rather, the differences are primarily due to emission spatial distributions from individual operations among railyards.

The populated areas near the BNSF Richmond Railyard are located east and northeast of the railyard. The zone of impact between the estimated risks of 10 and 100 in a million levels encompasses approximately 2,500 acres inland area where about 10,000 residents live, based on the 2000 U.S. Census Bureau's data. Table II-5 presents the exposed population and area coverage size for various impacted zones of cancer risks.

Table II-5 Estimated impacted areas and exposed population associated with different potential cancer risk levels for a 70-year exposure.

Estimated Risk (chances per million)	Estimated Impacted Area (acres)*	Estimated Exposed Population
50 - 100	280	1,600
25 - 50	580	1,900
10 - 25	1,600	6,200

* inland area only.

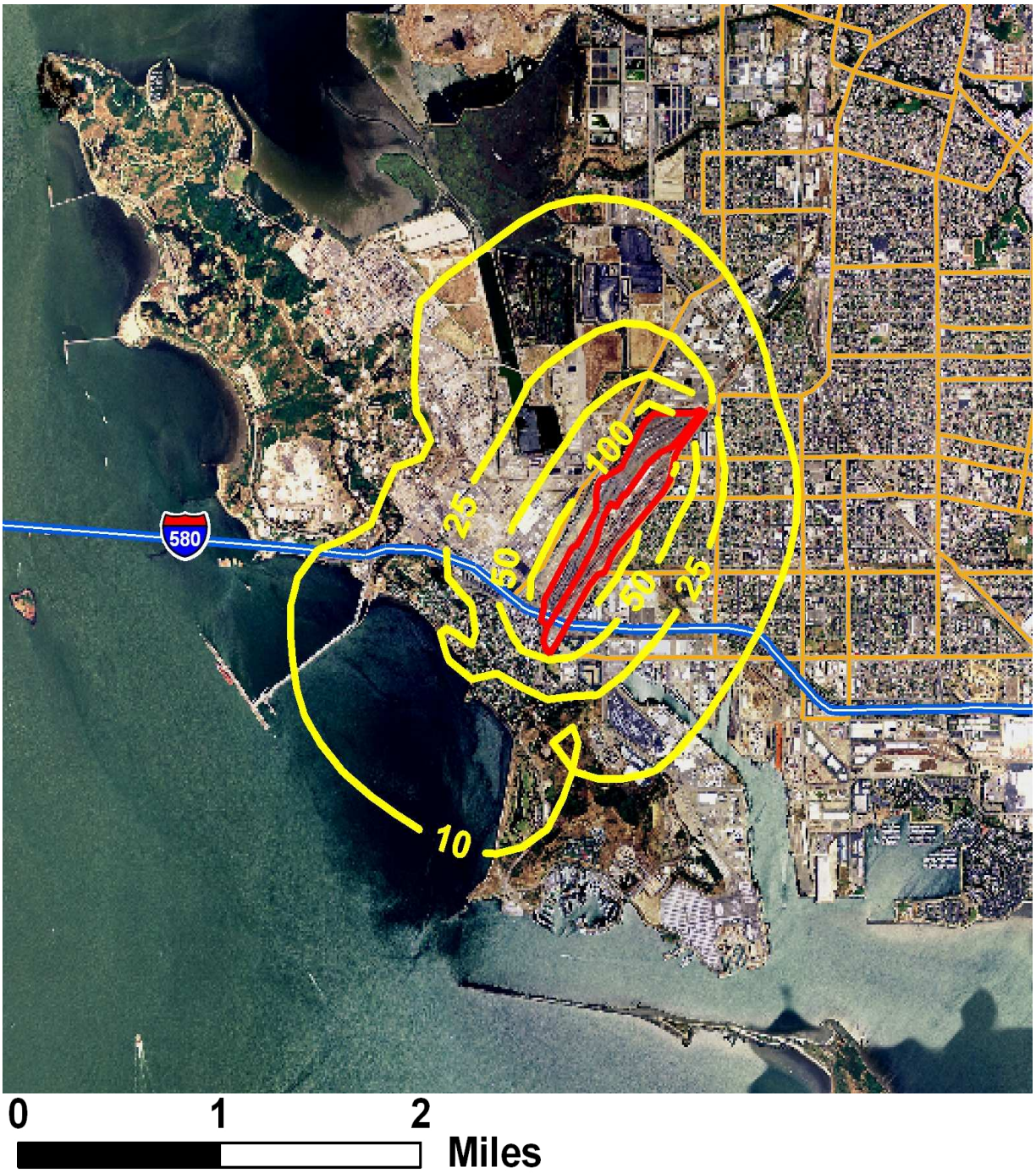


Figure II-2 Estimated potential cancer risks (chances per million) associated with diesel PM emissions at the BNSF Richmond Railyard (based on Tier-1 estimate and 80th percentile breathing rate for 70-year exposure).

The OEHHA (Office of Environmental Health Hazard Assessment) Guidelines recommend a 70-year lifetime exposure duration to evaluate the potential cancer risks for residents. Shorter exposure durations of 30 years and 9 years may also be evaluated for residents and school-aged children, respectively, as a supplement. These three exposure durations – 70 years, 30 years, and 9 years – all assume exposure for 24 hours a day, and 7 days a week. It is important to note that children, for physiological as well as behavioral reasons, have higher rates of exposure than adults on a per unit body weight basis (OEHHA, 2003). To evaluate the potential cancer risks for off-site workers, the Office of Environmental Health Hazard Assessment Guidelines recommend that a 40-year exposure duration be used, assuming workers have a different breathing rate (149 L kg^{-1} day^{-1}) and exposure for an 8-hour workday, five days a week, 245 days a year.

Table II-6 shows the equivalent risk levels of 70- and 30-year exposure durations for exposed residents, and 9- and 40-year exposure durations for children and off-site workers, respectively. As Table II-6 shows, the isopleth line with a potential cancer risk level of 10 chances per million in Figure II-2 would become 4 chances per million for exposed population with a shorter residency of 30 years, 2.5 chances per million for children at the age range of 0-9 (first 9-year childhood), and 2 chances per million for off-site workers.

Table II-6 Equivalent potential cancer risk levels of 70-, 30-, 9-, and 40-year exposure durations associated with on-site railyard diesel PM emissions.

Exposure Duration (years)	**Equivalent Estimated Cancer Risk Levels (chances in a million)**			
70	10	25	50	100
30	4	11	21	43
9*	2.5	6.3	12.5	25
40‡	2	5	10	20

* Exposure duration for school-aged children (age 0-9).
‡ Exposure duration for off-site workers.

It is important to note that the estimated risk levels represent the potential cancer risks in addition to regional background risk from diesel PM emissions. ARB staff estimated the regional background cancer risk due to emissions of all toxic air contaminants at about 660 per million for the San Francisco Bay Area Air Basin in 2000 (ARB, 2006c). Figure II-3 presents a comparison of the estimated average potential cancer risks in various ranges associated with the railyard diesel PM emissions to the regional

background risk level from all air toxic contaminants from the air basin. For example, in the cancer risk range greater than 50 per million, the average risk above the regional background is 74 chances per million. Residents living in that area would have a potential cancer risk of about 735 chances per million.

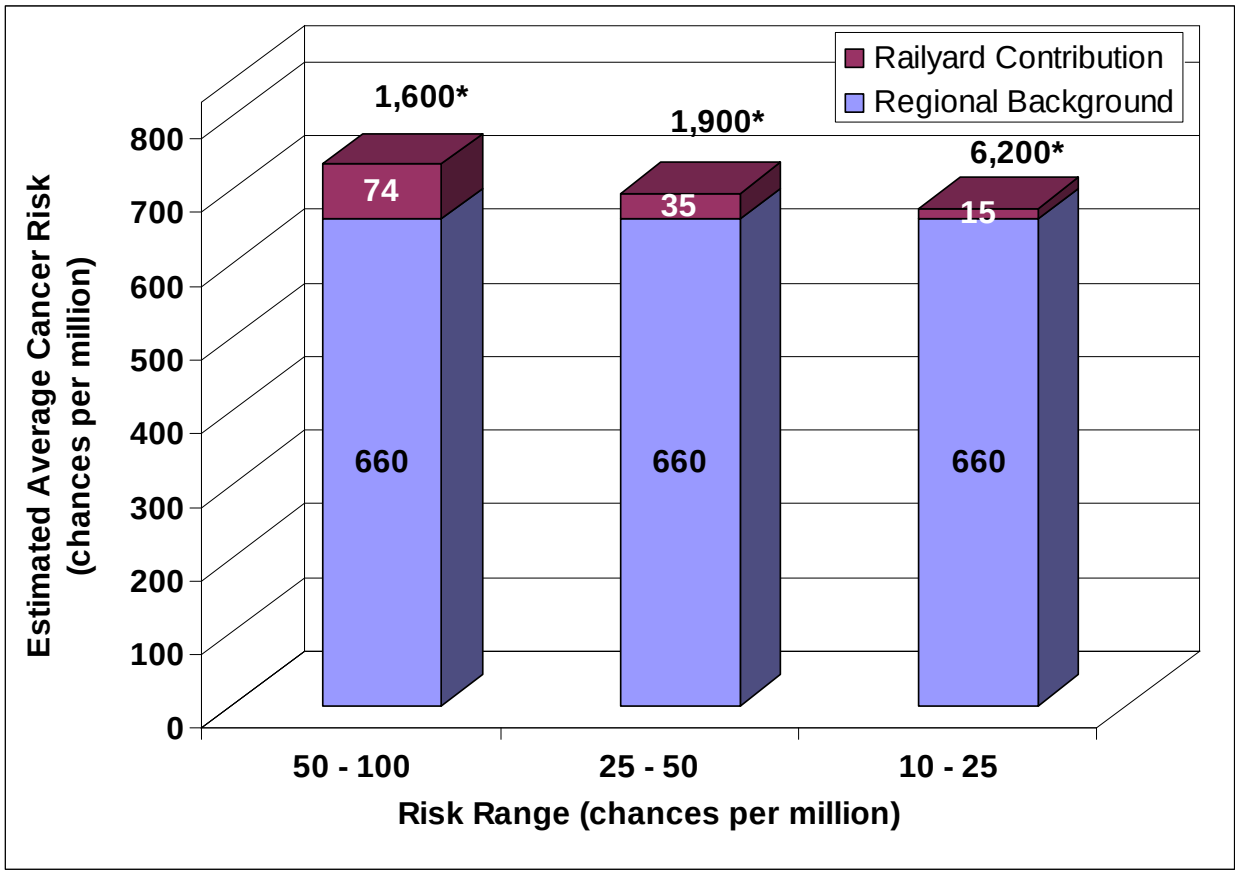


Figure II-3 Comparison of estimated potential cancer risks associated with diesel PM emissions at the BNSF Richmond Railyard to the regional background cancer risk level ("*": Estimated exposed population within each cancer risk range).

E. What are the estimated non-cancer chronic risks near the BNSF Richmond Railyard?

The potential non-cancer chronic health due to the diesel PM emissions at the BNSF Richmond Railyard are estimated as hazard indices from 0.01 to 0.07 around the railyard presented in Figure II-4. The impacted zone between hazard index of 0.01 and 0.05 has an estimated area of 1,600 acres. The level of 0.07 was identified at the

areas near the railyard boundary (not shown in the figure). According to the OEHHA Guidelines (OEHHA, 2003), these levels (less than 1.0) indicate that the potential non-cancer chronic public health risks are less likely to occur.

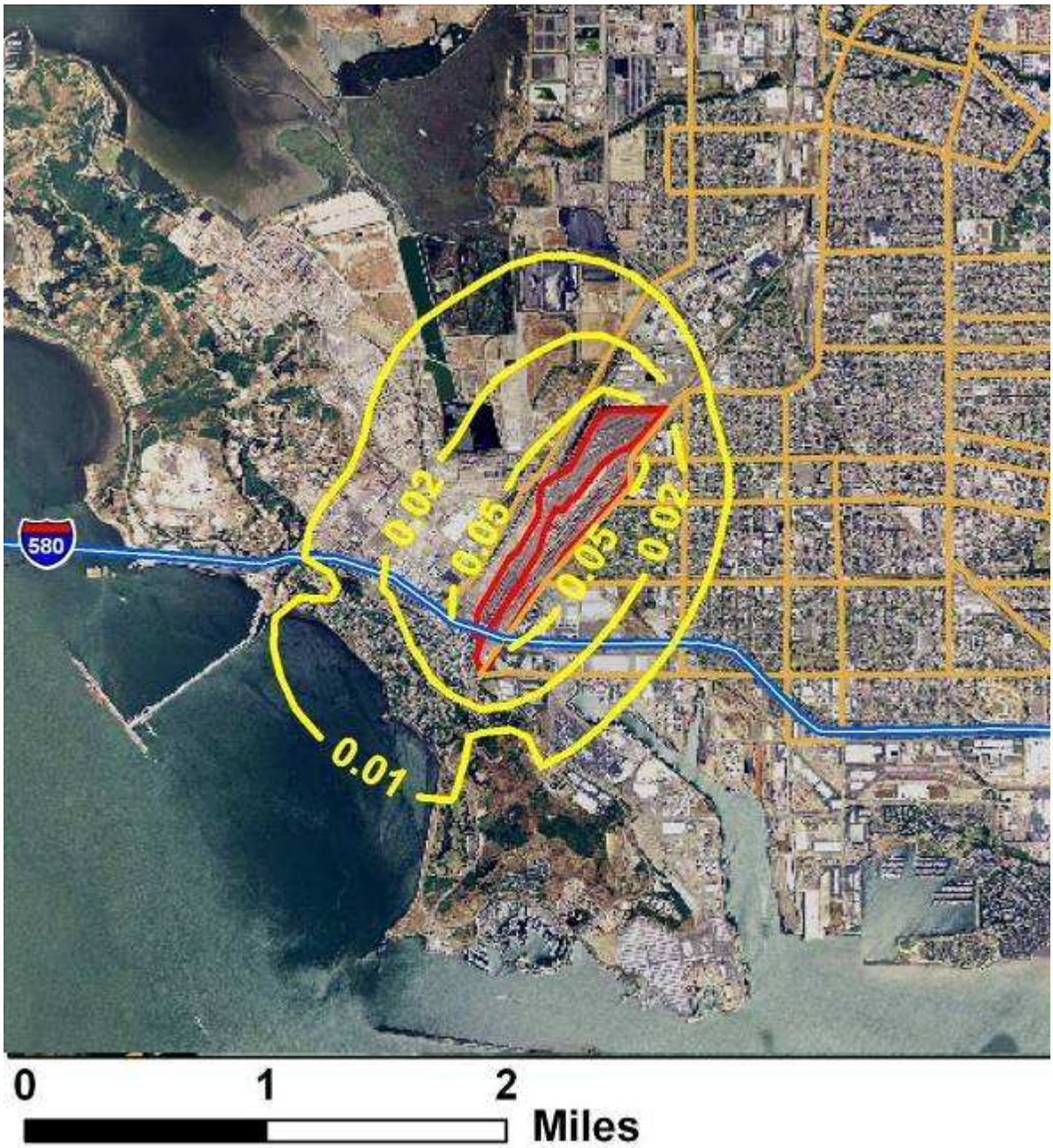


Figure II-4 Estimated non-cancer chronic risks (indicated as Hazard Indices) associated with diesel PM emissions from the BNSF Richmond Railyard.

Due to the uncertainties in the toxicological and epidemiological studies, diesel PM as a whole was not assigned a short-term acute reference exposure level. It is only the specific compounds from diesel exhaust (e.g., acrolein) that independently have potential acute effects (such as irritation of the eyes and respiratory tract) and an assigned acute reference exposure level. Acrolein is a by-product of the combustion or burning process. However, acrolein is a chemically reactive and unstable compound, and easily reacts with a variety of chemical compounds in the atmosphere. Compared to the other chemical compounds from the diesel exhaust, the concentration of acrolein has a much lower chance of reaching a distant off-site receptor. More importantly, given the multitude of activities ongoing at facilities as complex as railyards, there is a much higher level of uncertainty associated with hourly-specific emission data and hourly model-estimated peak concentrations for short-term exposure. Therefore, non-cancer acute risk is not addressed quantitatively in this study. From a risk management perspective, ARB staff believes it is reasonable to focus on diesel PM cancer risk because it is the predominant risk driver and the most effective parameter to evaluate risk reduction actions. Further, actions to reduce diesel PM will also reduce non-cancer health risks.

F. What are the estimated health risks from off-site (non-railyard) emissions?

ARB staff evaluated the health impacts from off-site non-railyard diesel PM emissions near the BNSF Richmond Railyard facility using the U.S. EPA AERMOD dispersion model. The off-site mobile and stationary sources located within a one-mile distance from the railyard were included in the air dispersion model simulations. The emissions consisted of about 11.7 tons per year from on-road diesel mobile sources and 8.1 tons per year from stationary sources. The estimated cancer risks are shown in Figure II-5. The area close to the Chevron Refinery shows higher cancer risks compared to other areas. The refinery was identified to be the most concentrated single diesel PM source (8 tons per year) location outside the railyard. The impacted zone for cancer risk levels greater than 10 in a million was estimated at about 10,200 acres inland area coverage where a residential population of about 58,500 was reported according to the 2000 Census data. Table II-7 presents the exposed population and area coverage for various impacted zones of cancer risks associated with off-site diesel PM emissions. In comparison, the impacted inland area with cancer risk above 10 in a million is about four times larger than the impacted area with similar risk levels from the on-site railyard diesel PM emissions and the associated exposed population is also higher, about by a factor of 5.

.

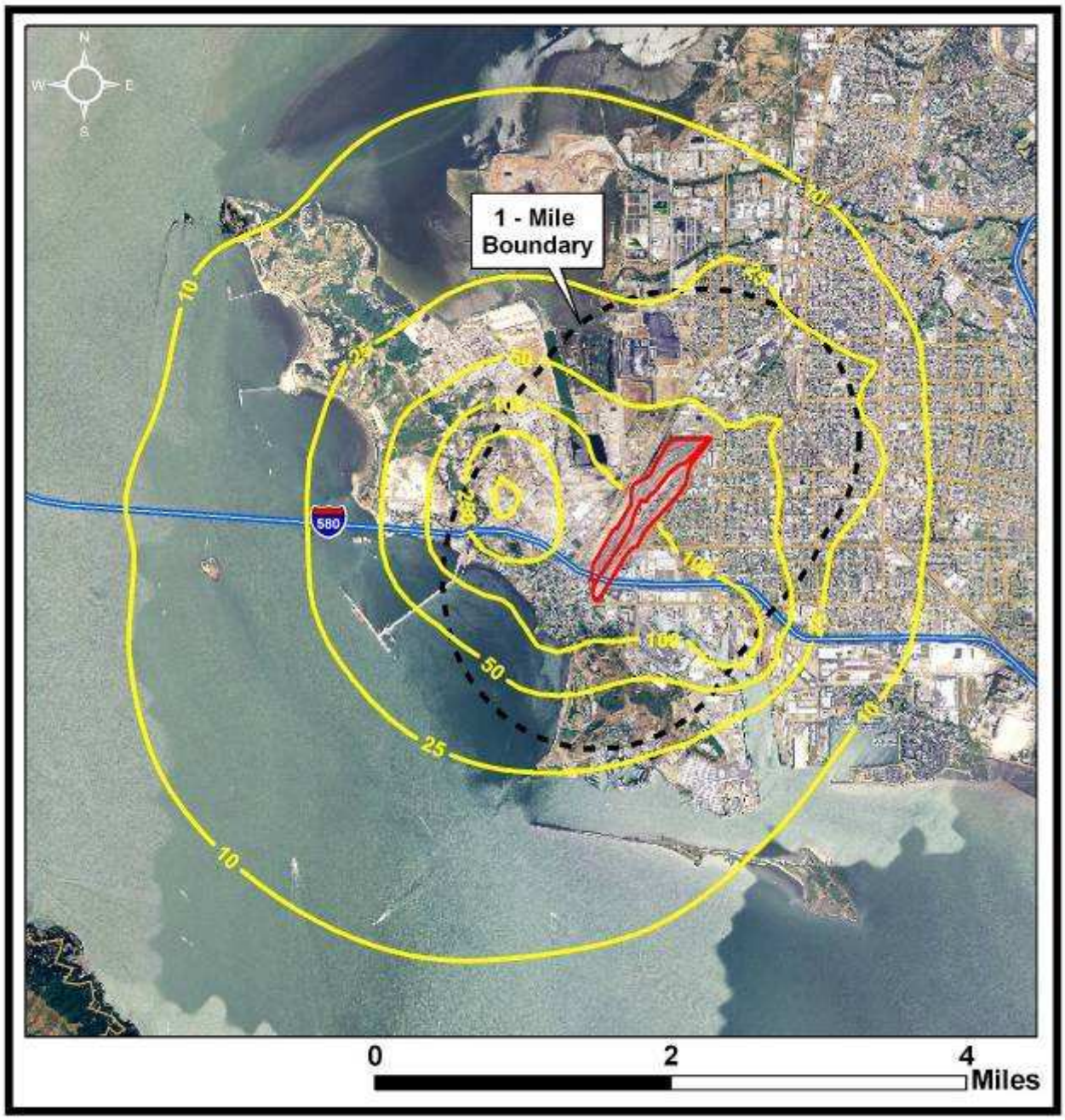


Figure II-5 Estimated cancer chronic risks (chances per million) associated with the off-site diesel PM emissions within the one-mile boundary (dashed line) around the BNSF Richmond Railyard (based on Tier-1 estimate and 80th percentile breathing rate for 70-year exposure).

Table II-7 Area coverage and exposed population of impacted zones for cancer risk levels associated with the off-site diesel PM emissions (based on Tier-1 estimate and 80th percentile breathing rate for 70-year exposure).

Estimated Risk (chances per million)	Estimated Impacted Area (acres)*	Estimated Exposed Population
100 - 250	1,500	3,000
50 - 100	2,000	10,500
25 - 50	2,700	20,000
10 - 25	4,000	25,000

* inland area only.

The estimated non-cancer chronic risks (indicated as hazard indices) from the off-site non-railyard diesel PM emissions range from 0.01 to 0.5. The level of 0.2 to 0.5 are located near the major off-site source diesel PM emissions, presented in Figure II-6. At neighboring residential areas around the railyard, the risk levels range from 0.01 to 0.1 on the east and from 0.05 to 0.2 on the south. According to the OEHHA Guidelines (OEHHA, 2003), these levels indicate that the potential non-cancer chronic health risks are less likely to occur.

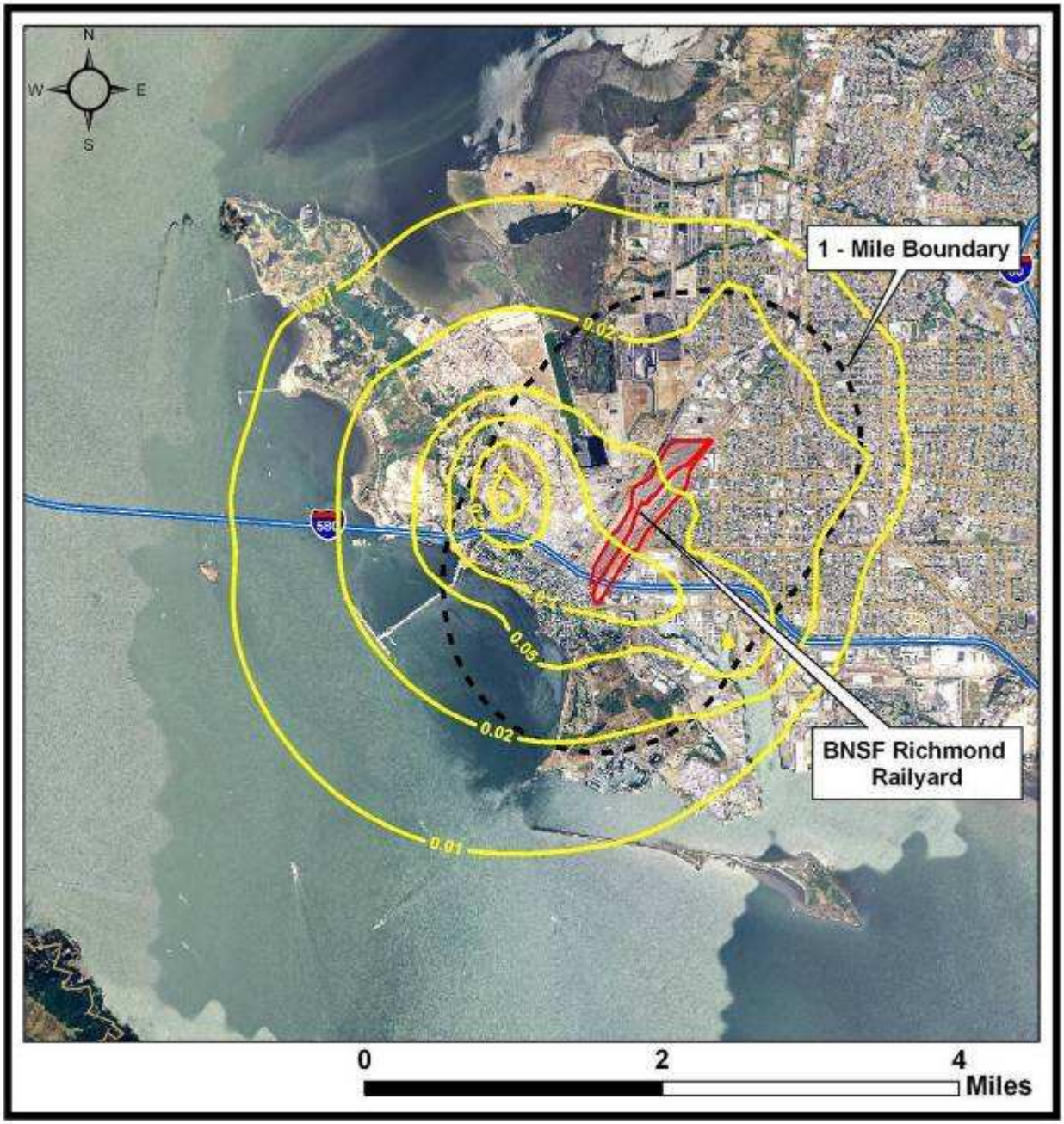


Figure II-6 Estimated non-cancer chronic risks (indicated as Hazard Indices) associated with the off-site non-railyard diesel PM emissions within the one-mile boundary (dashed line) around the BNSF Richmond Railyard.

G. Can study estimates be verified by air monitoring?

Currently, there is no approved specific measurement technique for directly monitoring diesel PM emissions in the ambient air. This does not preclude the use of an ambient monitoring program to measure general air quality trends in a region. Since cancer risk is based on an annual average concentration, a minimum of a year of intensive monitoring data would generally be needed.

H. What activities are underway to reduce diesel particulate matter emissions and public health risks?

The Air Resources Board (ARB) has developed an integrated approach to reduce statewide locomotive and rail railyard emissions through a combination of voluntary agreements, ARB and U.S. EPA regulations, incentive funding programs, and early replacement of California's line haul and railyard locomotive fleets. California's key locomotive and railyard air pollution control measures and strategies are summarized below:

California Locomotive NOx Fleet Average Agreement (1998): Signed in 1998 between ARB and both Union Pacific Railroad (UP) and BNSF Railway (BNSF), it requires the locomotive fleets that operate in the South Coast Air Quality Management District (SCAQMD) to meet, on average, U.S. EPA's Tier 2 locomotive emissions standards by 2010. This measure will provide an estimated 65 percent reduction in locomotive NO_x and up to 50 percent in locomotive particulate matter emissions. A spillover benefit from this Agreement will occur in the rest of the State with an estimated 15% reduction in the San Francisco Bay Area Air Basin by 2010.

Statewide Railroad Agreement (2005): ARB and both UP and BNSF signed a voluntary statewide agreement in 2005. When fully implemented, the Agreement is expected to achieve a 20 percent reduction in locomotive diesel PM emissions in and around railyards through a required number of short-term and long-term measures. As of January 1, 2007, ARB staff estimated the Agreement has reduced diesel PM emissions by more than 15% in and around the railyards statewide.

ARB Diesel Fuel Regulations Extended to Intrastate Locomotives (2007): This regulation, approved in 2004, requires intrastate locomotives to use only California ultra low sulfur (15 parts per million) diesel fuel. The implementation will reduce the intrastate locomotive diesel PM and NO_x emissions by up to 14% and 6% on average, respectively. ARB staff estimates that there are about 100 intrastate locomotives operating within the San Francisco Bay Area Air Basin, and CARB diesel will reduce these locomotive emission by up to 12 tons per year for diesel PM and 120 tons per year for NO_x. The regulation took effect statewide for intrastate locomotives on January 1, 2007.

ARB Cargo Handling Equipment Regulations (2007): This regulation, approved in 2005, requires the control of emissions from more than 4,000 pieces of mobile cargo handling equipment statewide. Implementation of this regulation will reduce diesel PM emissions by approximately 40% in 2010 and 65% in 2015, and NO_x emissions by approximately 25% in 2010 and 50% in 2015. The regulation took effect January 1, 2007; when fully implemented, it is expected, cumulatively, to reduce diesel PM and NO_x emissions from all cargo handling equipment in the State by up to 80 percent by 2020. At a railyard like BNSF Richmond, this regulation could reduce up to 0.2 tons per year diesel PM.

On-Road Heavy Duty Diesel Trucks Regulations: In January of 2001, the U.S. EPA promulgated a Final Rule to reduce emission standards for 2007 and subsequent model year heavy-duty diesel engines (66 FR 5002, January 18, 2001). These emission standards represent a 90% reduction of NO_x emissions, 72% reduction of non-methane hydrocarbon emissions, and 90 percent reduction of PM emissions compared to the 2004 model year emission standards. The ARB adopted similar emission standards and test procedures to reduce emissions from 2007 and subsequent model year heavy-duty diesel engines and vehicles. This stringent emission standards will reduce NO_x and diesel PM emissions statewide from on-road heavy diesel trucks by approximately 50 and 3 tons per day respectively in 2010, by 140 and 6 tons per day respectively in 2015, and 210 and 8 tons per day respectively in 2020.

Transport Refrigeration Unit Air Toxics Control Measure (ATCM): This ATCM is applicable to refrigeration systems powered by integral internal combustion engines designed to control the environment of temperature sensitive products that are transported in trucks, trailers, railcars, and shipping containers. Transport refrigeration units may be capable of both cooling and heating. Estimates show that diesel PM emission factors for transport refrigeration units and transport refrigeration unit Gen-set engines will be reduced by approximately 65% in 2010 and 92% in 2020. California's air quality will also experience benefits from reduced NOx emissions and reduced hydrocarbon emissions. The transport refrigeration unit air toxics control measure is designed to use a phased approach over about 15 years to reduce the PM emissions from in-use transport refrigeration unit and transport refrigeration unit generator set engines that operate in California. The new rule became effective on December 10, 2004

Proposed On-Road In-Use Truck Regulations: The ARB is developing a control measure to reduce diesel PM and oxides of nitrogen, NO_x, emissions from private fleets of on-road heavy-duty diesel-fueled vehicles. This measure includes, but is not limited to, long and short haul truck-tractors, construction related trucks, port hauling trucks, wholesale and retail goods transport trucks, tanker trucks, package and household goods transport trucks, and any other diesel-powered trucks with a gross vehicle weight rating of 14,000 pounds or greater. The proposed goals of the regulations are: (1) by

2014, emissions are to be no higher than a 2004 model year engine with a diesel particulate filter, and (2) by 2020, emissions are to be no higher than a 2007 model year engine.

Proposed In-Use Port and Intermodal Railyard Truck Mitigation Strategies: The ARB is evaluating a port truck fleet modernization program that will substantially reduce diesel PM and NO_x emissions by 2010, with additional reductions by 2020. There are an estimated 12,00 port trucks operating at the 3 major California ports which are a significant source of air pollution, about 7,075 tons per year of NO_x and 564 tons per day of diesel PM in 2005, and operate in close proximity to communities. Strategies will include the retrofit or replacement of older trucks with the use of diesel particulate filters and a NO_x reduction catalysts. ARB staff will propose regulatory strategies for ARB Board consideration by the end of 2007 or early 2008.

ARB Tier 4 Off-Road Diesel-Fueled Emission Standards: On December 9, 2004, the Board adopted a fourth phase of emission standards (Tier 4) that are nearly identical to those finalized by the U.S. EPA on May 11, 2004, in its Clean Air Non-Road Diesel Rule. As such, engine manufacturers are now required to meet aftertreatment-based exhaust standards for PM and NOx starting in 2011 that are over 90 percent lower than current levels, putting off-road engines on a virtual emissions par with on-road heavy-duty diesel engines.

U.S. EPA Locomotive Emission Standards: Under the Federal 1990 Clean Air Act, U.S. EPA has sole authority to adopt and enforce locomotive emission standards. This federal preemption also extends to the remanufacturing of existing locomotives. The ARB has been encouraging the U.S. EPA to expeditiously require the introduction of Tier 4 locomotives built with diesel particulate filters and selective catalytic reduction. U.S. EPA released the notice of proposed regulation rulemaking (NPRM) for locomotives and marine vessels in the Federal Register on April 3, 2007. The NPRM proposed interim reduction in diesel PM emissions for locomotives from 2010-2013, but the final proposed standards would not be applicable to new locomotives until 2017. The final regulations are expected to be approved by early 2008.

ARB Goods Movement Emission Reduction Plan (GMERP): Approved in 2006, the GMERP provides goods movement emissions growth estimates and proposed strategies to reduce emissions from ships, trains, and trucks and to maintain and improve upon air quality. Based largely on the strategies discussed, one of the goals of the GMERP is to reduce locomotive NO_x and diesel PM emissions by up to 90 percent by 2020. The GMERP goals also propose reduce diesel PM and NO_x emissions of locomotives by up to 90% by 2010.

California Railyard Locomotive Replacement Program: One locomotive strategy identified in the GMERP is to replace California's older switcher railyard locomotives (about 800) that operate in and around railyards statewide. There are also Government

incentive programs that may assist in funding the replacement of intrastate locomotives by 2010.

III. SUMMARY OF BNSF RICHMOND RAILYARD ACTIVITY AND EMISSIONS

For the year 2005, the combined diesel PM emissions from the BNSF Richmond Railyard (on-site emissions) and non-railyard significant off-site emission sources within a one-mile distance from the railyard were estimated at about 25 tons per year. Estimated off-site diesel PM emissions from mobile sources (not generally related to the railyard's activities) are about 12 tons per year, or about 48% of the total combined emissions. Off-site stationary sources contribute 8 tons per year of diesel PM emissions or 32% of the total combined on-site and off-site emissions. The BNSF Richmond Railyard diesel PM emissions are estimated at about 4.6 tons per year, accounting for about 20% of the total combined on-site and off-site diesel PM emissions.

A. BNSF Richmond Railyard facility

The BNSF Richmond Railyard is located at 303 South Garrard Boulevard in Richmond, California and is approximately 12 miles north-east of San Francisco. As shown in Figure II-1, the railyard facility is surrounded by commercial, industrial and several residential areas within a two mile distance. The facility also is bordered by Interstate-580 (I-580) to the south, San Pablo Bay to the west/north, and Interstate-80 (I-80) to the east. The San Francisco Bay is located within two miles of the western and southern boundaries of the railyard, and within 3 miles of the northern boundary of the BNSF Richmond Railyard. I-80 is located approximately 3 miles to the east of the BNSF Richmond Railyard. The land use within 20 x 20 kilometers of the facility includes open water (42%), low intensity residential area (20%), grassland (12%), shrub and forest land (15%), industrial facility (5.5%), and other types of uses (5.4%).

B. BNSF Richmond Railyard operations

Activities at the BNSF Richmond railyard include locomotive maintenance, locomotive line haul arrivals and departures, locomotive switching (i.e., movement of railcars within the yard), cargo handling operations, track maintenance, portable engines, on-road fleet vehicles, on-road container trucks, transportation refrigeration units, and stationary source activities. The approximate locations of these activities at the facility are shown in Figures III-1 and III-2.

The BNSF Richmond Railyard is generally divided into two operational areas: (1) the locomotive and freight repair areas, located predominantly in the south and east portions of the facility, and (2) the intermodal area, located in the north and west portions of the facility. The detailed description of the railyard operation activities is presented in the *BNSF Richmond Toxic Air contaminant Emission Inventory* (ENVIRON, 2006a).

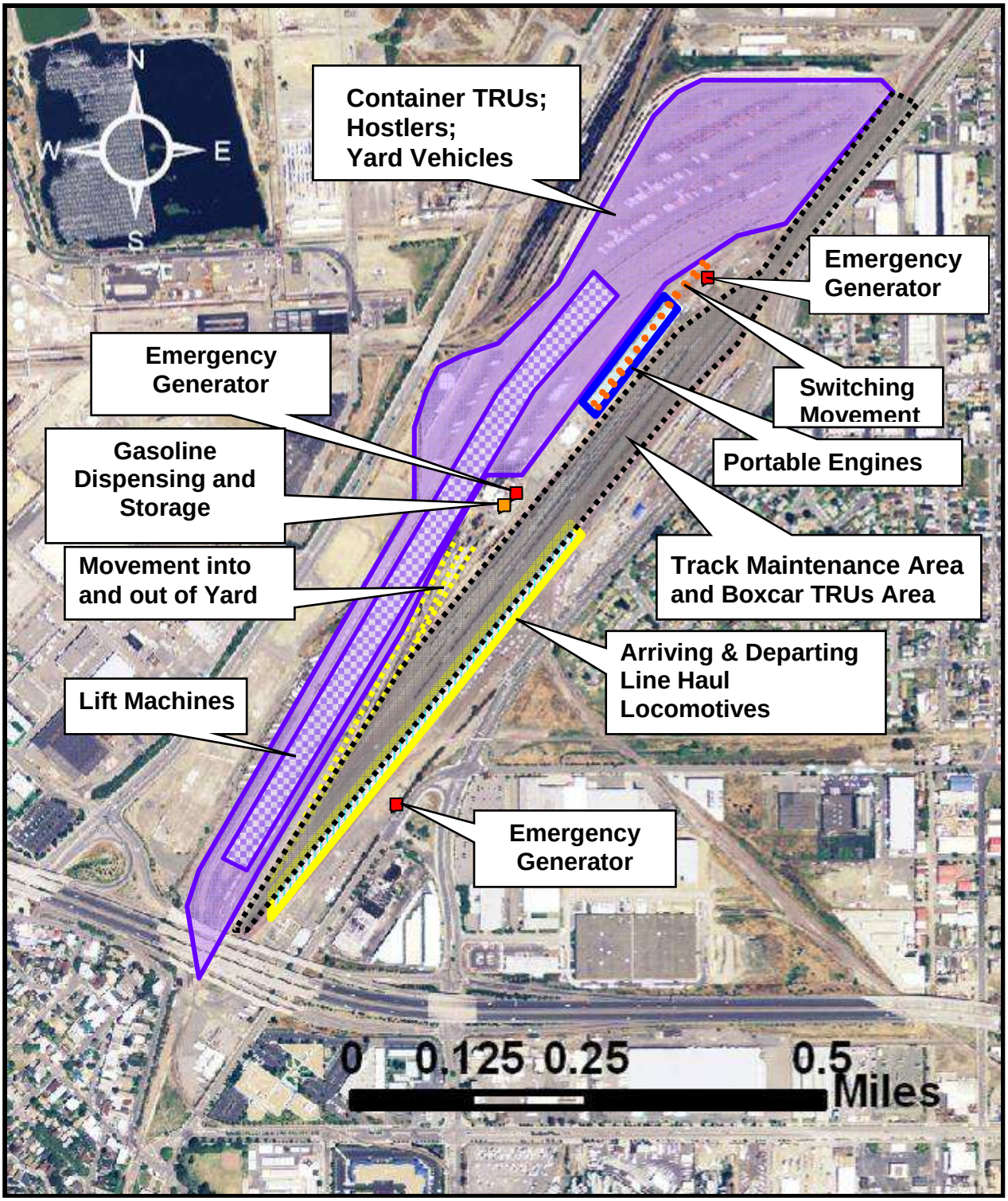


Figure III-1 Locomotive operation activities and other stationary emission sources at the BNSF Richmond Railyard.

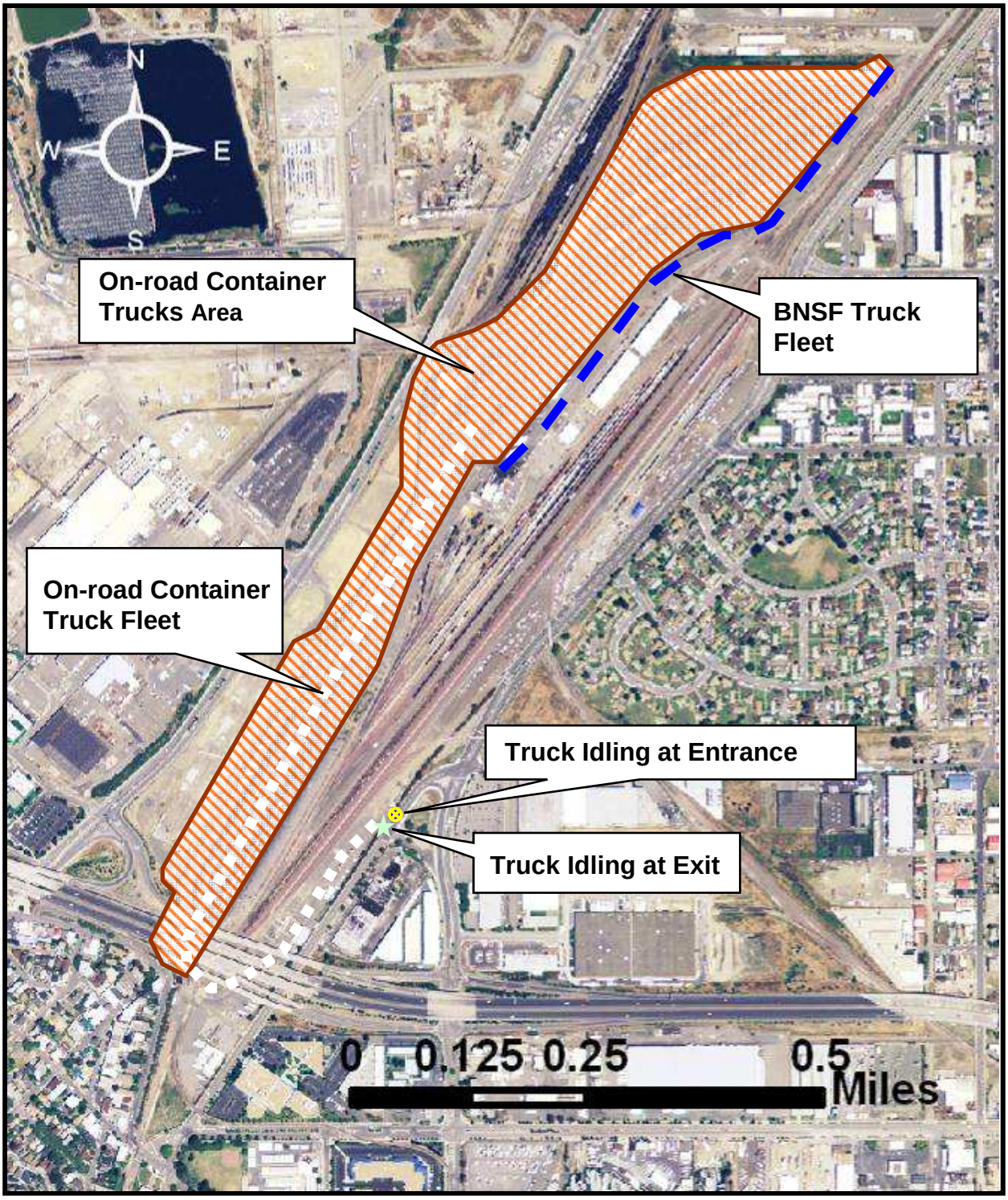


Figure III-2 Operation areas of on-road trucks and fleet at the BNSF Richmond Railyard.

C. BNSF Richmond Railyard emission inventory summary

The BNSF Richmond Railyard activity data for the railyard emissions inventory was provided by the BNSF. The methodology used to calculate the diesel PM and other toxic air contaminant emission factors is based on ARB's *Railyard Emission Inventory Methodology* (ARB, 2006e) and emission factor model of working draft of EMFAC-2007 (V2.23.7) and OFFROAD-2006. Detailed calculation methodologies and emission factors are included in the emission inventory report (ENVIRON, 2006a).

The total diesel PM emission inventory within the railyard is summarized in Table III-1 by source categories. As indicated in Table III-1, locomotives are the largest diesel PM emission source at the BNSF Richmond Railyard, about 3.26 tons per year, or about 71% of total railyard diesel PM emissions in 2005.

Table III-1 Summary of diesel PM emissions at the BNSF Richmond Railyard.

On-site Source Types	Tons per Yea**r	Percentage
Locomotive	3.26	70 %
Off-Road Equipment	0.56	12 %
On-Road Truck and Vehicles*	0.51	11 %
Cargo Handling Equipment	0.32†	7 %
Other and Stationary Sources	< 0.01	< 0.1%
Total	4.63	100 %

* Emissions from on-site truck/vehicle activities only, different from off-site truck emission estimates.

** Numbers may not add precisely due to rounding.

† An error of cargo handling equipment emissions was found after the modeling was completed. The applicable change in emissions was believed to be de minimis; consequently, the modeling was not re-performed.

1. Locomotive emissions

Locomotive operations at the BNSF Richmond Railyard are divided into three emissions categories: (1) basic locomotive services (i.e., refueling, maintenance, sanding, etc.), (2) switching (i.e., moving railcars within the yard), and (3) arriving-departing line haul locomotives. The main locomotive operations were further divided into activity subcategories to describe the emission modes and spatial allocation, such as locomotive movements, idle, and locomotives in-consist. The locomotive emission activity categories used in the air dispersion model are listed as follows:

Basic Operations

- Movement into yard
- Idling while refueling
- Locomotives in-consist
- Movement out of yard

Switching Engine Idling and Movement

Arriving/Departing Line Haul Locomotives

The locomotive operations data includes the number of engines serviced, and the typical time in notch setting for those engines receiving services. Temporal emission profiles were estimated for each activity based on hourly locomotive counts. The profiles developed account for hourly, daily and seasonal temporal variation and are reflected in air dispersion modeling to capture operation variation. Table III-2 presents the summary of diesel PM emissions from locomotive operation activities. As shown in Table III-2, about half of the locomotive diesel PM emissions result from line haul locomotives, about one-third from switch locomotive operations, and 17% of diesel PM emissions is contributed by locomotive service and maintenance.

According to BNSF, the BNSF interstate locomotives were fueled out of state before they entered the California borders. BNSF estimated a fuel mixture of about 50% CARB-EPA on-road to 50% non-road diesel fuel, based on the refueling data (see the *BNSF Richmond Railyard Toxic Air Contaminant Emission Inventory*, ENVIRON, 2006a). This approach overestimated non-road (i.e., non CARB-EPA diesel fuel) fuel usage, since it disregarded the consumption of out-of-state fuel before arriving California. This was, therefore, a conservative assumption. A more realistic operating scenario would be a fuel mixture of about 75% CARB-EPA on-road to 25% non-road diesel fuel, which would account for substantial volumes of non-road diesel fuel being consumed before arriving in California. By assuming a mixture of 50% CARB-EPA on-road to 50% non-road diesel fuel, BNSF estimated a sulfur content of about 1,050

ppmw. The locomotive diesel PM emission factors used in this study is presented in Appendix D.

Table III-2 Diesel PM emissions by locomotive operation activity.

Operation Activity	**Tons per Year**	**Percentage**
Arrival/Departure Line Haul Locomotives	1.54	47 %
Switch Locomotives Conducting Yard Operations	1.16	36 %
Locomotive Service/Maintenance	0.55	17 %
Total	3.26	100 %

The ARB has developed an integrated approach to reduce statewide locomotive emissions through a combination of voluntary agreements, ARB and U.S. EPA regulations, incentive funding programs, and early replacement of California's line haul and yard locomotive fleets. The detailed approach is discussed in Chapter II. In the future, the BNSF Richmond Railyard will benefit from these mitigation measures as diesel PM emissions from locomotives are gradually reduced as the locomotive fleets turnover.

2. Cargo handling equipment

Cargo handling equipment is used to move intermodal freight and containers at the BNSF Richmond Railyard. Two types of equipment were included in cargo handling equipment, railyard vehicles and hostlers. The diesel PM emissions due to cargo handling equipment activities were estimated using emission factors of OFFROAD-2006. The total diesel PM emissions from cargo handling equipment was estimated as 0.32 tons in 2005, equivalent to about 6% of total diesel PM emissions at the railyard.

In December 2005, ARB adopted a new regulation for cargo handling equipment to reduce diesel PM and NO_x emissions beginning in 2007. This regulation will provide up to 80% diesel PM control or better from the best available control technology by 2020. Therefore, starting in 2007, the BNSF Richmond Railyard will benefit from these mitigation measures as diesel PM emissions from cargo handling equipment are gradually reduced as the equipment fleets turnover.

3. On-road diesel trucks and fleet vehicles

On-road trucks included tractor-trailers trucks that receive or deliver containers to the intermodal area at the BNSF Richmond Railyard. In 2005, the truck gate counts showed an estimated 56,000 trips, assuming a one-hour stay time on site for all entering trucks. The on-road fleet vehicles owned by BNSF were used as employee vehicles, and other passenger vehicles and small trucks were used for both on-site and off-site travel. The emissions calculated due to this source category is based on the emission factors from the working draft of EMFAC-2007 (V2.23.7).

On-road diesel trucks and vehicles contributed about 11% of the total railyard diesel PM emissions, at about 0.51 tons per year in 2005. As shown in Table III-3, about 99% of the on-road diesel emissions are from on-road container trucks, and less than 0.01 tons are from on-road fleet vehicles.

In January of 2001, the U.S. EPA promulgated a Final Rule for emission standards for 2007 and subsequent model year heavy-duty diesel engines (66 FR 5002, January 18, 2001). These emission standards represent a 90 percent reduction of oxides of nitrogen emissions, 72 percent reduction of non-methane hydrocarbon emissions, and 90 percent reduction of particulate matter emissions compared to the 2004 model year emission standards. Starting in 2007, the BNSF Richmond Railyard will benefit from these measures as diesel PM emissions from heavy-duty diesel fueled trucks are gradually reduced as the truck fleets turnover.

Table III-3 Diesel PM emissions by on-road truck operations.

On-Road Truck Operations	Tons per Year	Percentage
On-Road Container Trucks	0.51	99 %
On-Road Fleet Vehicles	< 0.01	1 %
Total	0.51	100 %

4. Off-road equipment

There are three main types of off-road equipment operated at the site: transport refrigeration units, track maintenance equipment, and portable engines. Emissions

were estimated based on specific emissions factors from the draft ARB's OFFROAD-2006, annual hours of usage, and load factors.

Diesel PM emissions from off-road equipment operated at the railyard were estimated to be about 0.56 tons per year, or about 12% of total railyard diesel PM emissions. Table III-4 summarizes the amount and percentage of diesel PM emissions for the off-road and stationary sources. Among the off-road diesel PM emissions, transport refrigeration units and off-road diesel equipment account for 75% and 20%, respectively. The off-road track maintenance and stationary emissions from other sources contribute the rest 6% of the emissions.

Table III-4 Diesel PM emissions of off-road engines and equipment.

Off-Road Equipment	**Tons per Year**	**Percentage**
Transport Refrigeration Units	0.43	75%
Off-Road Diesel Equipment	0.11	20 %
Off-Road Track Maintenance	0.02	4 %
Stationary Sources	< 0.01	< 1 %
Total	0.56	100%

In November 2004, ARB adopted a new regulation: *Airborne Toxic Control Measure (ATCM) for In-Use Diesel-Fueled Transport Refrigeration Units (TRUs), TRU Generator Sets and Facilities where TRUs Operate*. This regulation applies to all TRUs in California, including those coming into California from out-of-state. It requires in-use TRU and TRU generator set engines to meet specific diesel PM emissions that vary by horsepower range and engine model year, starting December 31, 2008 for engine model years 2001 or older. ARB staff estimates that diesel PM emissions for TRUs and TRU generator set engines will be reduced by approximately 65% by 2010 and 92% by 2020. Starting in 2009, the BNSF Richmond Railyard will benefit from these mitigation measures as diesel PM emissions from TRUs are gradually reduced as their fleets turnover.

5. Stationary sources

The diesel PM emissions from stationary sources at the BNSF Richmond Railyard include three emergency generators, as shown in Figure III-1. The emissions were estimated based on equipment manufacturer PM certification levels and estimated hours of usage from the Bay Area Air Quality Management District (BAAQMD) permit levels for these sources. The amount of diesel PM emissions for year 2005 was estimated at about 10 pounds per year or 0.1% of total diesel PM emissions at the railyard.

6. Other Toxic Air Contaminant Emissions

The total organic gas (TOG) emissions generated from various sources were estimated at about 0.4 tons per year in the BNSF Richmond Railyard, presented in Table III-5. Among the total organic gases, relatively small amount of toxic air contaminant emissions were estimated at about 0.015 tons or 30 pounds per year, including benzene, formaldehyde, 1,3-butadiene and acetaldehyde, the major toxic air contaminants from gasoline-related sources. In comparison with the diesel PM emissions generated at the facility, these toxic air contaminants are estimated at about 0.3% of total estimated diesel PM emissions in the railyard. The potential cancer risks contributed by these toxic air contaminants are found to be considerably lower than the diesel PM emissions, about a factor of 550 less, based on cancer potency weighted factor adjustment discussed in Chapter II. Because of the dominance of diesel PM emissions, these gaseous toxic air contaminants are not included in the health impact evaluation in this study.

Table III-5 Non-diesel total organic gas emissions at the BNSF Richmond Railyard.

Activity Source	Total Organic Gases (Tons per Year)	Percentage
On-Road Fleet Vehicle	0.33	83 %
Portable Engines	0.07	16 %
Track Maintenance Equipment	< 0.01	< 0.1 %
Other Stationary Sources	< 0.01	1 %
Total	0.40	100 %

D. Off-site non-railyard emission inventory

The off-site non-railyard emissions were estimated from the stationary and mobile sources within a one-mile off-site zone surrounding the BNSF Richmond Railyard perimeter as shown in Figure III-3. Table III-6 provides a summary of off-site stationary diesel PM emissions by the different facilities or owners identified by ARB Staff. The total stationary diesel PM emissions was estimated at about 8 tons per year in 2005. A large percentage, 99%, of the total local stationary diesel PM emissions is generated by the refinery facility nearby. (see Figure II-1). Chevron's staff estimated that diesel PM emission at the refinery facility were recently lowered to about 1.4 tons from 8 tons per year in 2005, by replacing some diesel-fueled pumps in March 2006[3].

Recently, California State Lands Commission reported about 53 tons per year PM emissions generated by Chevron Richmond Long Wharf Marine Terminal operations, ship and barge activity for the period of year 2000 through 2002 (CSLC, 2006). The document was prepared by Chambers Group, Inc. Per the conversation between the Chambers Group, Inc. and Chevron Product Company, the PM emissions reported in the document were not speciated.

Chevron estimated the distance from end of wharf (where ships dock and most PM emissions occur) to railyard as about 1.7 to 2.2 miles (from the yard boundary vs. middle of the yard). Therefore, the Terminal emissions will be beyond the proposed one-mile off-site boundary. In order to account for shipping emissions outside the Terminal, a different dispersion model tool may be needed, such as CalPuff (an integrated Gaussian puff modeling system), to accommodate a much large modeling domain because the ship emissions are calculated from the Farallon Islands, about 27 miles off the coast and west from San Francisco, to the Chevron Long Wharf Marine Terminal. ARB staff suggests that the emissions at Chevron Long Wharf Marine Terminal be recognized qualitatively as a significant off-site diesel PM source outside of the scope of the HRA study.

[3] Staff communication between the ARB and Chevron Products Company, August, 2007.

Figure III-3 Off-site one-mile distance boundary (dashed line) from the BNSF Richmond Railyard (encompassed by solid lines).

Table III-6 Summary of off-site stationary diesel PM emissions at one-mile off-site boundary from the railyard boundary.

Off-Site Stationary Diesel PM Sources	Tons per Year	Percentage
CHEVRON Refinery	8.0	99 %
CHEVRON Research and Technology	0.1	1 %
City of Richmond Water Pollution Control Facility	< 0.1	< 0.1 %
City of Richmond	< 0.1	< 0.1 %
Total	8.1	100 %

ARB staff also evaluated other toxic air contaminants emissions around the BNSF Richmond Railyard. Among the toxic air contaminants other than diesel PM from stationary sources, benzene and formaldehyde were identified to be dominant health risk contributors and estimated at about 4.5 tons per year, as presented in Table III-7. Based on California Emission Inventory Development and Reporting System (CEIDAS) database, benzene and formaldehyde were reported from the estimated emissions associated with the refinery facility in the area.

Table III-7 Significant toxic air contaminant emissions identified from off-site stationary sources within one-mile off-site boundary

Toxic Air Contaminant	Tons per Year
Benzene	3.0
Formaldehyde	1.5
Total	4.5

The off-site mobile diesel PM emissions were estimated from on-road vehicle sources based on the Integrated Transportation Network (INT) and working draft of EMFAC-2007 (V2.23.7) model within a one-mile boundary around the railyard, and calculated by different classifications of truck gross vehicle weight shown in Table III-8. In 2005, the total diesel PM emissions were estimated at about 12 tons per year with 98% from heavy-heavy duty and medium heavy duty trucks. The two classifications account for 10 and 1.6 tons per year, respectively. The distribution of off-site roadway traffic volumes is summarized in Table III-9.

Table III-8 Summary of off-site mobile diesel PM emissions within one-mile off-site boundary by vehicle classifications.

Vehicle Types of Off-Site Mobile Diesel PM Sources	**Gross Vehicle Weight (pounds)**	**Tons per Year**	**Percentage**
Light Heavy Duty Diesel Trucks	8,501-14,000	< 0.2	2 %
Medium Heavy Duty Diesel Trucks	14,001-33,000	1.6	14 %
Heavy Heavy Duty Trucks	> 33,000	10.0	84 %
Total		11.7	100 %

Table III-9 Off-site mobile diesel PM emissions by traffic flows within one-mile off-site boundary.

Major Traffic Flows	**Tons per Year**	**Percentage**
I-580	6.5	56%
Local Streets	5.2	44%
Total	11.7	100%

The traffic volumes were evaluated using roadway specific vehicle activity data on diesel trucks and spatially allocated through the traffic network. The estimates do not include off-road diesel-fuel equipment or vehicles, e.g., heavy-construction equipment,

and extended truck idling from various operation patterns, such as truck queuing at the railyard entrance gate or on local streets. Because of insufficient activity data, the traffic flow generally related to the facilities of local truck distribution centers and warehouses was reflected in the emission inventory on a county basis. The methodology for mobile diesel PM emission estimation is summarized in Appendix A.

E. Current applicable diesel fuel regulations and their benefits to the railyards

1. California Air Resources Board (CARB) diesel fuel specifications

The initial California diesel fuel specifications were approved by the Board in 1988 and limited sulfur and aromatic contents. The requirements for "CARB diesel," which became applicable in October 1993, consisted of two basic elements:

- A limit of 500 parts per million by weight (ppmw) on sulfur content to reduce emissions of both sulfur dioxide and directly emitted PM.

- A limit on aromatic hydrocarbon content of 10 volume percent for large refiners and 20 percent for small refiners to reduce emissions of both PM and NO_x.

At a July 2003 hearing, the Board approved changes to the California diesel fuel regulations that, among other things, lowered the maximum allowable sulfur levels in California diesel fuel to 15 ppmw beginning in June 2006. Thus, ARB's specifications for sulfur and aromatic hydrocarbons are shown in Table III-10.

Table III-10 California diesel fuel standards

Implementation Date	Maximum Sulfur Level (ppmw)	Aromatics Level (% by volume)	Cetane Index
1993	500	10	N/A
2006	15	10	N/A

The regulation limiting aromatic hydrocarbons also includes a provision that enables producers and importers to comply with the regulation by qualifying a set of alternative specifications of their own choosing. The alternative formulation must be shown, through emissions testing, to provide emission benefits equivalent to that obtained with a 10 percent aromatic standard (or in the case of small refiners, the 20 percent standard). Most refiners have taken advantage of the regulation's flexibility to produce alternative diesel formulations that provide the required emission reduction.

2. U.S. EPA on-road diesel fuel specifications

The United States Environmental Protection Agency (U.S. EPA) has also established separate diesel fuel specifications for on-road diesel fuel and off-road (non-road) diesel fuel. The initial U.S. EPA diesel fuel standards were applicable in October 1993. The U.S. EPA regulations prohibited the sale or supply of diesel fuel for use in on-road motor vehicles, unless the diesel fuel had a sulfur content no greater than 500 ppmw. In addition, the regulation required on-road motor-vehicle diesel fuel to have a cetane index of at least 40 or have an aromatic hydrocarbon content of no greater than 35 percent by volume (vol. %). All on-road motor-vehicle diesel fuel sold or supplied in the United States, except in Alaska, must comply with these requirements. Diesel fuel, not intended for on-road motor-vehicle use, must contain dye solvent red 164.

On January 18, 2001, the U.S. EPA published a final rule which specified that, beginning June 1, 2006, refiners must begin producing highway diesel fuel that meets a maximum sulfur standard of 15 ppmw for all and later model year diesel-fueled on-road vehicles The current U.S. EPA on-road diesel fuel standard is shown in Table III-11.

Table III-11 U.S. EPA diesel fuel standards

Applicability	Implementation Date	Maximum Sulfur Level (ppmw)	Aromatics Maximum (% by volume)	Cetane Index‡ (Minimum)
On-Road	2006	15	35	40
Non-road *	1993	5,000	35	40
Non-road *	2007	500	35	40
Non-road, *excluding loco/marine* *	2010	15	35	40
Non-road, *loco/marine**	2012	15	35	40

* Non-road diesel fuels must comply with ASTM No. 2 diesel fuel specifications for aromatics and cetane index.

‡ A measure of the combustion quality of diesel fuel via the compression ignition process.

3. U.S. EPA non-road diesel fuel specifications

Until recently, fuel supplied to outside of California was allowed a sulfur content of up to 5,000 ppmw (parts per million by weight). However, in 2004, the U.S. EPA published a strengthened rule for the control of emissions from non-road diesel engines and fuel. The U.S. EPA rulemaking requires that sulfur levels for non-road diesel fuel be reduced from current uncontrolled levels of 5,000 ppmw ultimately to 15 ppmw, though an interim cap of 500 ppmw is contained in the rule. Beginning June 1, 2007, refiners are required to produce non-road, locomotive, and marine diesel fuel that meets a maximum sulfur level of 500 ppmw. This does not include diesel fuel for stationary sources. In 2010, non-road diesel fuel will be required to meet the 15 ppmw standard except for locomotives and marine vessels. In 2012, non-road diesel fuel used in locomotives and marine applications must meet the 15 ppmw standard. The non-road diesel fuel standards are shown above in Table III-11.

4. What are the current properties of in-use diesel fuel?

Table III-12 shows average in use level of sulfur content and four other properties for motor vehicle diesel fuel sold in California after the California and Federal diesel fuel regulation became effective in 1993. The corresponding national averages are shown for the same properties for on-road diesel fuel only since the U.S. EPA sulfur standard does not apply to off-road or non-vehicular diesel fuel. Non-road diesel fuel sulfur levels have been recorded as about 3,000 ppmw in-use and similar levels as U.S. EPA on-road diesel fuel for aromatics at about 35 percent by volume in-use.

Table III-12 Average 1999 properties of reformulated diesel fuel.

Property	California	U.S.(1)
Sulfur, ppmw	10(2)	10 (2)
Aromatics, vol.%	19	35
Cetane No.	50	45
PNA(3), wt.%	3	NA
Nitrogen, ppmw	150	110

(1) U.S. EPA, December 2000.
(2) Based on margin to comply with 15 ppmw sulfur standards in June 2006.
(3) Polynuclear aromatics.

5. Diesel fuels used by California-based locomotives

The ARB Board approved a regulation in November 2004 which extended the CARB diesel fuel requirements to intrastate locomotives (those operating 90 percent or more of the time in California) effective on January 1, 2007. UP and BNSF agreed in the 2005 railroad Agreement to dispense only CARB diesel or U.S. EPA on-road diesel fuels to interstate locomotives that fueled in California beginning on January 1, 2007.

Line haul locomotives have a range of about 800 to 1,200 miles between refueling. BNSF locomotives typically refuel at Belen, New Mexico before traveling to Barstow, California and UP locomotives typically refuel at Salt Lake City, Utah before traveling to Roseville in northern California or Colton in southern California. These major out-of-state railroad facilities have the option to use Federal non-road diesel fuels for the refueling of line haul locomotives. When these out-of-state line haul locomotives arrive in California they typically have about 10 percent remaining volume of diesel fuel relative to their tank capacity.

UP and BNSF surveyed each of the California refueling centers, and major interstate fueling centers to California, to estimate the average diesel fuel properties for locomotives for the railyard health risk assessments. Diesel fuel sulfur levels were estimated to be an average of 1,100 ppmw based on the mixture of CARB, U.S. EPA on-road, and non-road diesel fuel consumed by locomotives in California in 2005. ARB staff believes this is a conservative estimate for the types of diesel fuels and sulfur levels consumed by locomotives in California.

The U.S. EPA on-road and CARB on-road and off-road diesel ultra low sulfur specifications (15 ppmw) went into effect on June 1, 2006. The CARB diesel fuel requirements for intrastate locomotives went into effect on January 1, 2007. The U.S. EPA non-road diesel fuel sulfur limit will drop from 5,000 ppmw to 500 ppmw on June 1, 2007. In 2012, the non-road diesel limits for fuel used in locomotives and marines will drop from 500 ppmw to 15 ppmw.

The NO_x emission benefits associated with the use of CARB diesel compared to U.S. EPA on-road and non-road diesel fuels are due to the CARB aromatic hydrocarbon limit of 10 percent by volume or an emission equivalent alternative formulation limit. ARB staff estimates that use of CARB diesel provides a 6 percent reduction in NO_x and a 14 percent reduction in particulate emissions compared with the use of U.S. EPA on-road and non-road diesel fuels. In addition, CARB diesel fuel will provide over a 95 percent reduction in fuel sulfur levels in 2007 compared to U.S. EPA non-road diesel fuel. This reduction in diesel fuel sulfur levels will provide SO_x emission reductions, and additional PM emission reductions by reducing indirect (secondary formation) PM emissions formed from SO_x.

In addition, the ARB, UP and BNSF Railroads entered into an agreement in 2005 which requires at least 80 percent of the interstate locomotives must be fueled with either CARB diesel or U.S. EPA on-road ultra low sulfur diesel fuel by January 1, 2007. Both the CARB diesel fuel regulation for intrastate locomotives and the 2005 Railroad Agreement for interstate locomotives require the use of ultra low sulfur diesel fuel in 2007, five years earlier than the U.S. EPA non-road diesel fuel regulations for locomotives in 2012.

6. What are the current properties of in-use diesel fuel?

Both the U.S. EPA and CARB diesel fuels had sulfur levels lowered from 500 ppmw to 15 ppmw on June 1, 2006. Under the prior sulfur specification of 500 ppmw, CARB diesel fuel in-use sulfur levels averaged around 140 ppmw versus U.S. EPA on-road sulfur levels of about 350 ppmw. With the 2006 implementation of the 15 ppmw sulfur levels, in-use levels for both CARB diesel and U.S. EPA on-road now average about 10 ppmw.

Sulfur oxides and particulate sulfate are emitted in direct proportion to the sulfur content of diesel fuel. Reducing the sulfur content of diesel fuel from the California's statewide average of 140 ppmw to less than 10 ppmw would reduce sulfur oxide emissions by about 90 percent or by about 6.4 tons per day from 2000 levels. Direct diesel particulate matter emissions would be reduced by about 4 percent, or about 0.6 tons per year in 2010 for engines not equipped with advanced particulate emissions control technologies. U.S. EPA on-road lower sulfur diesel fuel would provide similar levels of sulfur oxide and direct diesel particulate matter emission reductions.

The emissions reductions would be obtained with low sulfur diesel used in mobile on-road and off-road engines, portable engines, and those stationary engines required by district regulations to use CARB diesel. In addition, NO_x emissions would be reduced by 7 percent or about 80 tons per year for those engines not currently using CARB diesel, assumed to be about 10 percent of the stationary engine inventory and including off-road mobile sources such as interstate locomotives.

The lower sulfur diesel makes much more significant emissions reductions possible by enabling the effective use of advanced emission control technologies on new and retrofitted diesel engines. With these new technologies, emissions of diesel particulate matter and NO_x can be reduced by up to 90 percent. Significant reductions of non-methane hydrocarbons and carbon monoxide can also be achieved with these control devices.

IV. AIR DISPERSION MODELING OF BNSF RICHMOND RAILYARD

Air dispersion modeling is conducted to estimate the downwind dispersion of diesel PM emissions resulting from the on-site and off-site sources at the BNSF Richmond railyard. A description of the air quality modeling parameters is provided in this chapter, including air dispersion model selection, estimated emissions, meteorological data selection, model receptor network, and building wake effects. .

A. Air dispersion model selection

Air dispersion models or other air quality models are often used to simulate atmospheric processes on different scale applications where the spatial scale ranges from the tens of meters to the tens of kilometers, or to hundreds of kilometers over large scale domains. Selection of air dispersion models usually depends on a number of factors, such as characteristics of emission sources, the type of terrain at the emission source locations, and the scale of source-receptor relationships. For the BNSF Richmond Railyard, the U.S. EPA's AERMOD (**A**merican Meteorological Society/**E**PA **R**egulatory **MOD**el) is used for air dispersion modeling work. The AERMOD is a model preferred by the *US EPA Guideline for Air Quality Methods (*40 CFR Part 51, Appendix W*)* (US EPA , 2005) for micro-scale applications. The AERMOD model was developed as replacement for its predecessor, the U.S. EPA Industrial Sources Complex (ISC) air dispersion model, to improve the accuracy of model estimations. This replacement was made in November 2005, and AERMOD has become a U.S. EPA regulatory dispersion model after a one-year transition period of promulgation,

The AERMOD model is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain. In the stable boundary layer, it assumes the distribution of pollutant concentrations to be normal (or bell-shaped, or Gaussian) in both the vertical and the horizontal directions. In the mixing layer (or the convective boundary layer) near ground surface, the horizontal distribution of a plume mass is also assumed to be normal, but the vertical mass distribution is described with a bi-normal probability density function. In addition, the AERMOD model treats "plume lofting," whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the mixing layer. For sources in both the convective boundary layer and the stable boundary layer, the AERMOD model treats the enhancement of lateral dispersion resulting from plume meander.

> ***Mixing Layer****: A type of atmospheric boundary layer characterized by vigorous turbulence tending to stir and uniformly mix.*

B. Source characterization and parameters

The emission sources from the locomotives and other diesel PM sources at the BNSF Richmond Railyard are characterized as one of the following source types, required by the ARB Guidelines (ARB, 2006e):

- Point source (a source with emissions emanating from a known point, with buoyancy due to either thermal or mechanical momentum). A point source is characterized by a height, diameter, temperature, and exit velocity.

- Volume source (a source with emissions that have no buoyancy and are emanated from a diffuse area). A volume source is characterized by an initial lateral and vertical dimension (initial dispersion) and a release height.

- Area source (a source with emissions that have no buoyancy and are emanated from a diffuse plane or box). An initial vertical dimension and release height may also be specified for an area source.

When a mobile source is stationary, such as when it is idling or undergoing load testing, the emissions are simulated as a series of point sources. Model parameters for point sources include emission source height, diameter, exhaust temperature, exhaust exit velocity, and emission rate. When a mobile source is traveling, the emissions are simulated as a series of volume sources to mimic the effects of initial dispersion due to plume downwash. Key model parameters for volume sources include emission rate (or strength), source release height, and initial lateral and vertical dimensions of volumes.

The emission rates for individual locomotives are a function of locomotive makes, notch setting, activity time, duration, and operating location. Emission source parameters for locomotive model classifications at the yard, including emission source height, diameter, exhaust temperature, and exhaust velocity. While the UP used data from the Roseville Railyard Study (ARB, 2004) based on the most prevalent locomotive model of switchers and line hauls to parameterize locomotive emission settings, the BNSF assumed more specific temperatures and stack heights from their switchers and line haul locomotives fleets. In total, the assumptions on the locomotive emission parameters are slightly different between UP and BNSF; however, both are within reasonable ranges according to their activities, and the slight differences in stack height have an insignificant impact on predicted air concentrations, within 2 percent, based on a sensitivity analysis conducted by ARB staff.

According to the BNSF, some locomotives at the Richmond Railyard had been equipped with AESS (automatic engine start-stop) or SmartStart device (by ZTR Control System) in 2005[4]. However, the BNSF used a more conservative approach that did not

[4] Staff communication between the ARB, BNSF, and ENVIRON, September, 2007.

incorporate the benefits of using the devices in the locomotive emissions estimation. ARB staff believes that the BNSF's approach is more protective in terms of health impacts.

For the stationary locomotives, they were not uniformly distributed throughout the yard, the locations of individual locomotive emission sources used for the model inputs were determined based on the detailed locomotive distribution and activity information provided by BNSF. The emissions from all stationary sources (storage tanks, sand tower, waste water treatment plant, etc.) and portable sources (welders, steam cleaners, air compressors, etc.) are simulated as a series of point sources.

C. Meteorological data

The AERMOD model requires meteorological parameters to characterize air dispersion dynamics in the atmosphere. Wind speed determines how rapidly the pollutant emissions will be diluted in air. It also influences emission plume rise, thus affecting downwind concentrations of pollutants. Under low wind conditions, the plume's initial buoyancy and inertia will cause the emissions to go higher into the air than during high wind conditions. Wind direction determines where pollutants will be transported. Atmospheric stability determines the rate of mixing in the atmosphere and is typically characterized by the atmospheric vertical temperature profile. The difference of ambient temperature and the emission source exhaust exit temperature determines the initial buoyancy. In general, the greater the temperature difference, the higher the plume rise. The model also incorporates upper air sounding data, cloud ceiling height, and cloud coverage, which will determine the mixing height in the atmosphere.

The meteorological data used in the model are selected on the basis of representativeness. Representativeness is determined primarily on whether the wind speed/direction distributions and atmospheric stability estimates generated through the use of a particular meteorological station (or set of stations) are expected to mimic those actually occurring at a location where such data are not available. Typically, the key factors for determining representativeness are proximity of the meteorological station and the presence or absence of nearby terrain features that might alter airflow patterns.

> ***AERMET****: A meteorological preprocessing program for AERMOD..*

Meteorological data of a five-year period, 2001 to 2005, was collected from the Chevron Refinery on-site station (1.5 miles from the BNSF Richmond Railyard), the most representative meteorological station from three sites. However, the Chevron Refinery site does not have a record of pressure measurements. The data for cloud cover and pressure are collected from National Weather Service's (NWS's) Oakland Metropolitan Airport station from the same period. Upper air data from Oakland Airport was used in AERMET (US EPA, 2004) processing for model inputs.

Surface parameters supplied to the model were specified for the area surrounding the surface meteorological monitoring site as recommended by AERMOD and ARB Guidelines (ARB, 2006b). According to the sensitivity analyses conducted by BNSF, the impacts on the diesel PM air concentration predictions by using the long-term (i.e., five-year) vs. short-term (i.e., one-year) are found to be insignificant. This is consistent with the findings from a sensitivity analysis from one of UP railyards conducted by ARB staff (see Appendix G). Therefore, whether five-year or one-year meteorological data are used, the modeling results show similar estimated exposures and potential cancer risks surrounding the railyard facility.

Figure IV-1 presents the wind rose and Figure IV-2 provides the wind class frequency distributions for the meteorological conditions at BNSF Richmond Railyard facility. The other nearest met station, UC Berkeley Richmond field station, approximately 2.5 miles from the BNSF Richmond Railyard, was eliminated from consideration due to non-consecutive yearly data and different terrain features. Due to the features of a ridge line running northwest from Point Potrero to Point San Pablo, it is more likely that wind patterns observed at the Chevron Refinery station, where predominant wind flows are parallel to the features, i.e., southerly as shown in Figure IV-1, are more representative of the BNSF Richmond Railyard than the wind patterns at the UC Berkeley Richmond station, where predominant winds blow perpendicular to these terrain features. The observed yearly average wind speed over a five-year (2001-2005) period at the Chevron Refinery station is 3.8 meters per second.

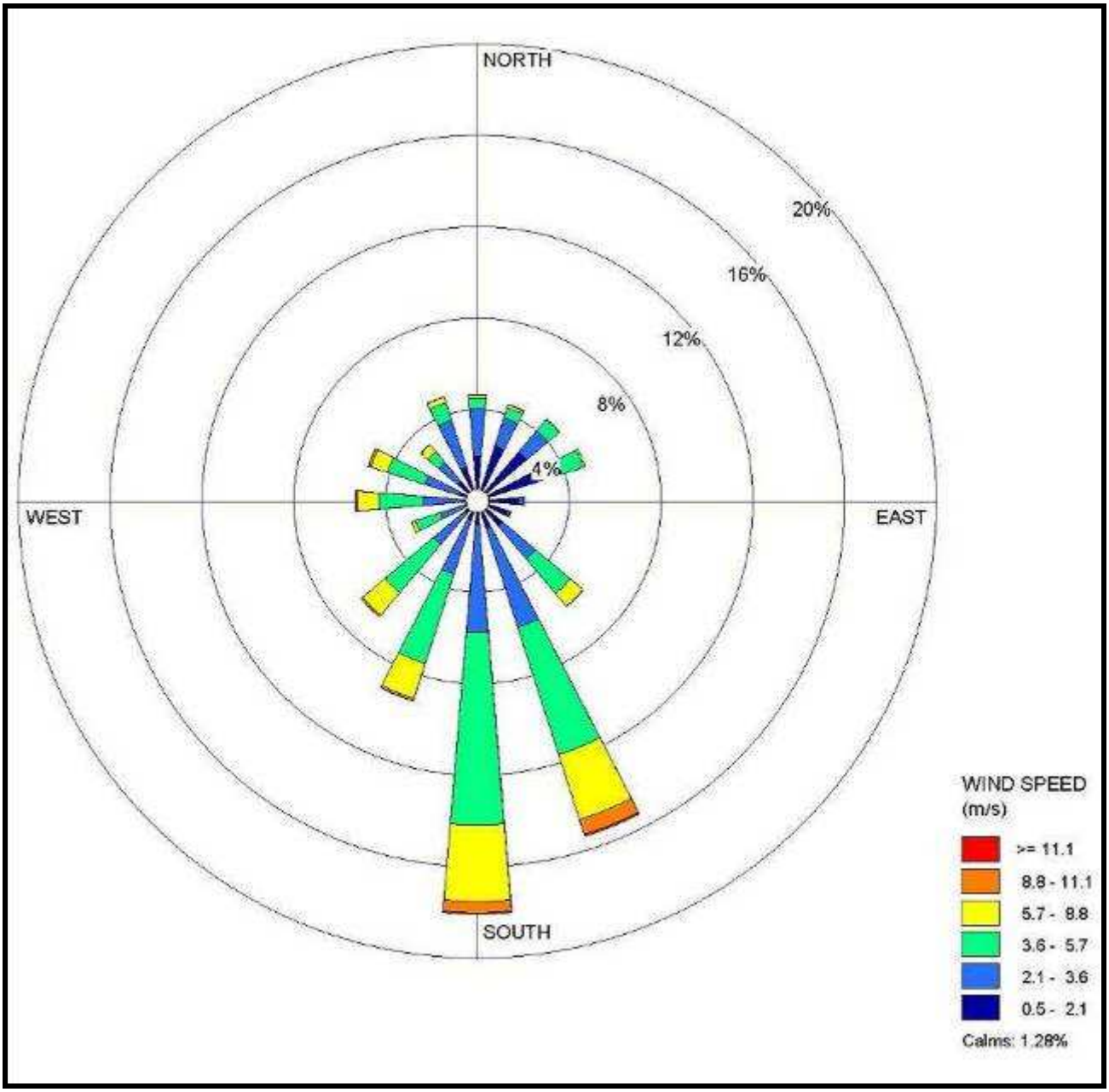


Figure IV-1 Wind Rose Plot of Chevron Refinery Meteorological Station at Richmond for the year 2001–2005.

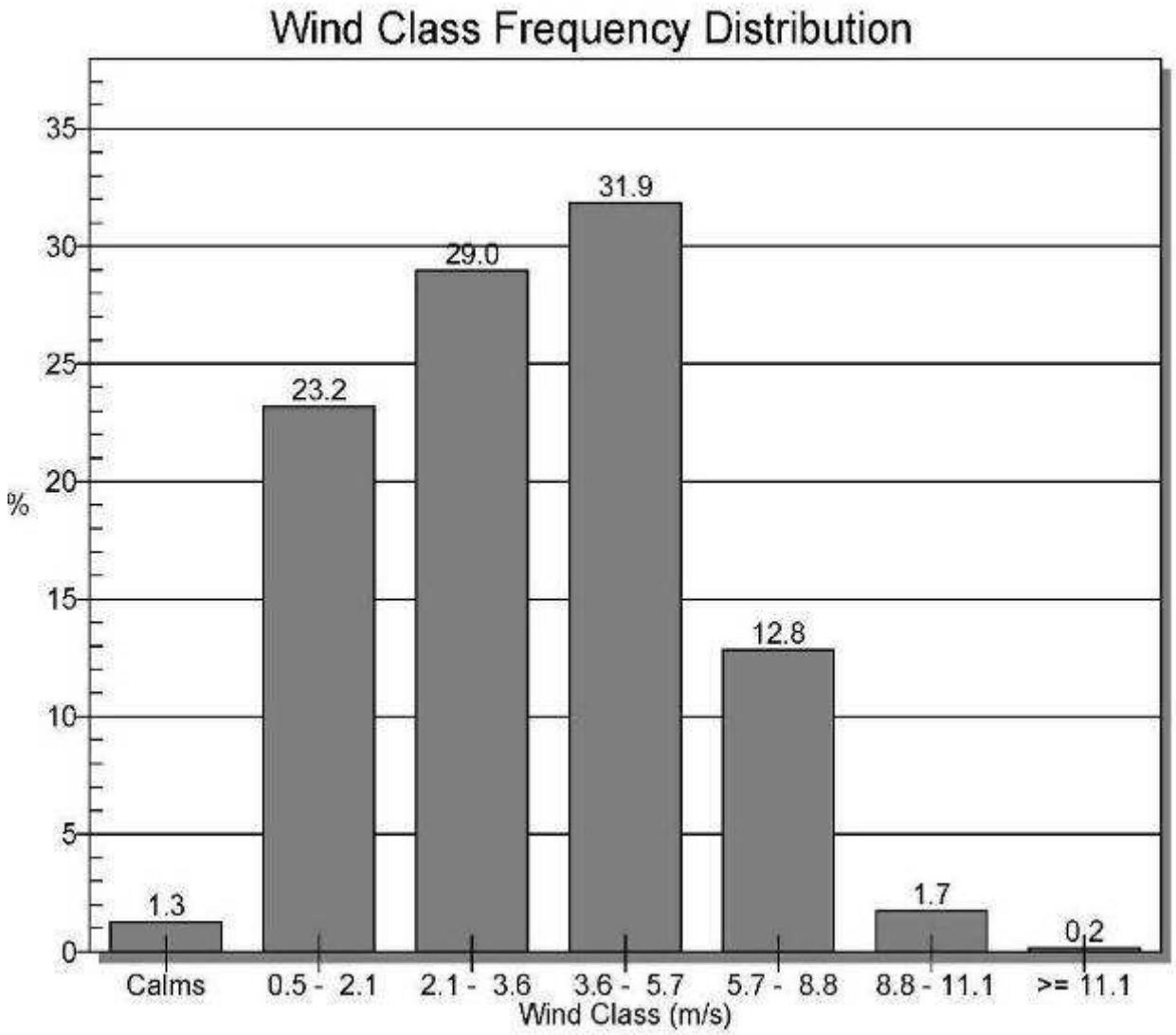


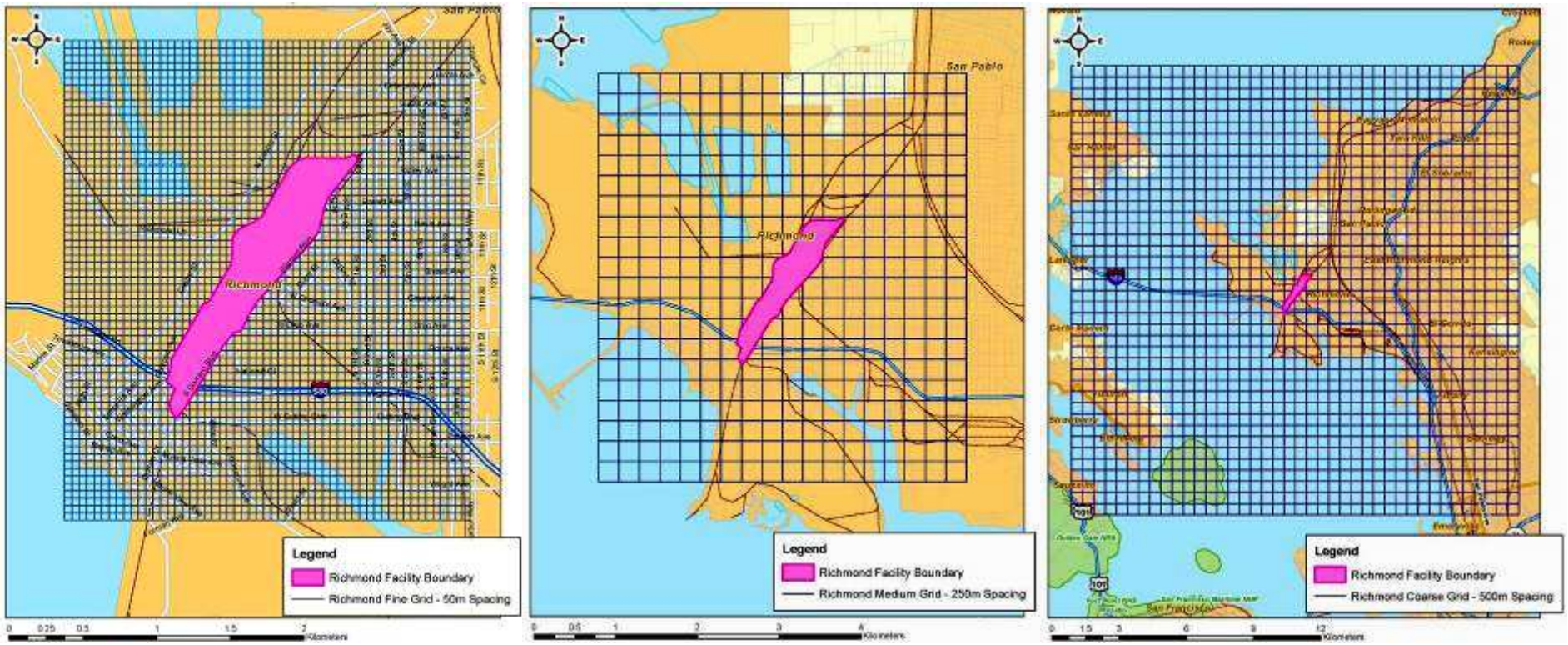
Figure IV-2 Wind class frequency distribution of Chevron Refinery meteorological station at Richmond for the year 2001–2005.

The detailed procedures for meteorological data preparation and the QA/QC are documented in the modeling report (ENVIRON, 2006b)

D. Model receptors

Model receptors are the defined discrete locations where concentrations are estimated by the dispersion model. A Universal Transverse Mercator (UTM) coordinate grid receptor network is used in the study where an array of points are identified by their coordinates. This network is capable of identifying the emission sources within the railyard with respect to the receptors in the nearby areas.

According to the *ARB Railyard Health Risk Assessment Guidance for Railyard and Intermodal Facilities* (ARB, 2006b), the modeling domain is defined as a 20×20 km region, which covers the railyard in the center of domain and extends to the surrounding areas. To better capture the different concentration gradients surrounding the railyard area, three sets of receptor grids were used for the BNSF Richmond Railyard air dispersion modeling assessment. The ARB's Guidance require coarse and fine modeling receptor grids, including a fine receptor grid with spacing of 50 meters out to a distance of approximately 750 meters from the facility boundary, and a coarse receptor grid with spacing of 500 meters out to ten kilometers from the facility boundary. A medium receptor grid was applied to model simulations in addition to coarse and fine receptor grids, with spacing of 250 meters out to a distance of approximately 1,500 meters from the facility boundary. The locations of the fine, medium and coarse receptor grid networks are presented in Figures IV-3a, IV-3b, and IV-3c, respectively. However, the receptors located over the open water areas will be eliminated from modeling simulations because there is no population reported in this area. The final selected receptors are presented in Figure IV-4.



(a) **(b)** **(c)**

Figure IV-3 The Receptor Grid Networks of Air Dispersion Modeling at the BNSF Richmond Railyard Facility.
a: Fine Grid; b: Medium Grid; c: Coarse Grid. (Source: *Air Dispersion Modeling Assessment of Air Toxic Emissions from BNSF Richmond Railyard*, ENVIRON, 2006b)

Figure IV-4 Model receptors and locations for air dispersion modeling at the BNSF Richmond Railyard.

E. Building wake effects

One of characterizations in the air dispersion model is mixing process of air pollutants due to the air flow cause by surrounding environment. The spacing and placement of emission sources relative to surrounding building or structures can have such an effect on the pollutant plume in the air. If pollutant emissions are released at or below the Good Engineering Practice (GEP) height as defined by U.S. EPA Guidance (US EPA, 1985), the plume dispersion may be affected by surrounding facility buildings and structures. The aerodynamic wakes and eddies produced by the buildings or structures may cause pollutant emissions to be mixed more rapidly to the ground, causing elevated ground level concentrations. The AERMOD model has the option to simulate the effects of building downwash. To do so, "direction-specific" building dimensions for each emission point need to be input. The direction-specific building dimensions represent the building width perpendicular to the wind direction along with the building height, and are estimated by a model built-in module, the Building Profile Input Program – Plume Rise Model Enhancements, to account for potential building-induced aerodynamic downwash effects.

Although BNSF Richmond Railyard included building wake effects in their modeling analyses, BNSF conducted a sensitivity analysis and found that the building wake effect has an insignificant impact on the diesel PM air concentrations of the railyard. This sensitivity analysis also indicated that, at receptor distances close to the sources (i.e., within 100 meters), building downwash may have a large impact on the modeled concentrations. However, at distances further away from the sources (i.e., 400 to 700 meters), receptor concentrations from model predictions with and without building downwash were similar (ENVIRON, 2006b).

F. Model implementation inputs

One of the basic inputs to AERMOD is the runstream setup file which contains the selected modeling options, as well as source location and parameter data, receptor locations, meteorological data file specifications, and output options. Another type of basic type of input data needed to run the model is the meteorological data. AERMOD requires two types of meteorological data files. One consists of surface scalar parameters, and the other file consists of vertical profiles of meteorological data. For applications involving elevated terrain effects, the receptor and terrain data will need to be processed by the terrain preprocessing program before input to the AERMOD model.

Source inputs require source identification and source type. Each source type requires specific parameters to define the source. For example, the required details for a point source are emission rate, release height, emission source diameter, exhaust exit temperature, and exhaust exit velocity. The requirements and the format of input files to the AERMOD are documented in the user's guide of AERMOD (US EPA, 2004a).

V. HEALTH RISK ASSESSMENT OF BNSF RICHMOND RAILYARD

This chapter describes the ARB's guidelines on health risk assessment and characterization of potential cancer and non-cancer risks associated with exposure to toxic air contaminants, especially diesel PM emissions from the sources within and surrounding the BNSF Richmond Railyard, followed by a discussion of uncertainties with respect to the components of health risk assessment.

A. ARB railyard health risk assessment guidelines

The railyard HRA follows *The Air Toxics Hot Spots Program Risk Assessment Guidelines* published by OEHHA, and is consistent with the methodologies used for the UP Roseville Railyard Study (ARB, 2004a). The OEHHA Guidelines outline a tiered approach to risk assessment, providing risk assessors with flexibility and allowing for consideration of site-specific differences:

- Tier-1: a standard point-estimate approach that uses a combination of the average and high-end point-estimates.

- Tier-2: utilizes site-specific information for risk assessment when site-specific information is available and is more representative than the Tier 1 point-estimates.

- Tier-3: a stochastic or random approach for exposure assessment when the data distributions are available.

- Tier-4: similar to the Tier 3 approach, but all site-specific data distributions are used.

> ***Percentile**: Any one of the points dividing a distribution of values into parts each of which contain 1/100 of the values. For example, the 65th percentile breathing rate is a value such that the breathing rates from 65 percent of population are less or equal to it.*

The Health Risk Assessment is based on the railyard specific emission inventory and air dispersion modeling predictions. The OEHHA guidelines recommend that all health hazard risk assessments adopt a Tier-1 evaluation for the Hot Spots Program, even if other approaches are also presented. Two point-estimates of breathing rates in Tier-1 methodology are used for this HRA, one representing an average and the other representing a high-end value based on the probability distribution of breathing rate. The average and high-end of point-estimates are defined as 65th percentile and 95th percentile from the distributions identified in the OEHHA guidelines. In 2004, ARB recommended the interim use of the 80th percentile value (the midpoint value of the 65th and 95th percentile breathing rates referred as an estimate of central tendency) as

the minimum value for risk management decisions at residential receptors for the breathing intake (ARB, 2004b). The 80th percentile corresponds to a breathing rate of 302 Liters/Kilogram-day (302 L/Kg-day) from the probability distribution function. As indicated by the OEHHA Guidelines, the Tier-1 evaluation is useful in comparing risks among a number of facilities and similar sources.

The ARB has also developed *Health Risk Assessment Guidance for Railyard and Intermodal Facilities* (ARB, 2006b) to help ensure that the air dispersion modeling and HRA performed for each railyard meet the OEHHA guidelines. The risk assessment adopted in this study assumes that the receptors (or an individual) will be exposed to the same toxic levels for 24 hours per day for 70 years. If a receptor is exposed for a shorter period of time to a given ambient concentration of diesel PM, the cancer risk will proportionately become less.

B. Exposure assessment

Exposure assessment is a comprehensive process that integrates and evaluates many variables. Three process components have been identified to have significant influences on the results of a health risk assessment – emissions, meteorological conditions, and exposure duration of nearby residents. The emissions have a linear effect on the risk levels, given meteorological conditions and a defined exposure duration. Meteorological conditions have a critical impact on resultant ambient concentration of a pollutant, with higher concentrations found along the predominant wind direction and under calm wind conditions. An individual's proximity to the emission plume, exposure duration, and the individual's breathing rate also play key roles in determining the potential risk. The longer the exposure time for an individual is, the greater the estimated potential risk for the individual will be. A 24-hour per day, 70-year lifetime exposure, duration has been assumed for the quantification of health risk for residents in this study. In addition, 40- and 9-year exposure assessments were conducted for off-site workers and school-aged children, respectively. Children have a greater risk than adults, i.e., an early life exposure, because they have greater exposure on a per unit body weight basis and also due to other factors.

Diesel PM is not the only TAC emitted from the BNSF Richmond Railyard. A relatively small amount of gasoline TACs are also generated at the railyard from gasoline-fueled engines and storage tanks. The gasoline emissions were found to be dominated by 1,3-butadiene, benzene, formaldehyde, and acetaldehyde. The total amount was estimated at 30 pounds per year and considerably lower than diesel PM emissions (4.6 tons per year) within the BNSF Richmond Railyard based on the year 2005 emission inventory. As described in Chapter III, the cancer potency weighed emissions of these TACs are about a factor 550 less than the diesel PM emissions at the railyard. ARB staff also evaluated the health impacts of the diesel PM emissions and other TACs from off-site stationary and mobile sources around the BNSF Richmond Railyard.

The relationship between a given level of exposure to diesel PM and the cancer risk is estimated by using the diesel PM cancer potency factor (CPF). A description of how the diesel cancer potency factor was derived can be found in the document of *Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant* (ARB, 1998) and a shorter description can be found in the Air Toxics Hot Spot Program Risk Assessment Guidelines, Part II, Technical Support Document for Describing Available Cancer Potency Factors (OEHHA, 2002). The use of the diesel unit risk factor for assessing cancer risk is described in the OEHHA guidelines. The potential cancer risk is estimated by multiplying the inhalation dose by the CPF of diesel PM, i.e., 1.1 $(mg/kg\text{-}day)^{-1}$.

C. Risk characterization

Risk characterization is defined as the process of obtaining a quantitative estimate of risk. The process integrates the results of air dispersion modeling and relevant toxicity data (e.g., diesel PM CPF) to estimate potential cancer or non-cancer health impacts associated with contaminant exposure.

Exposures to pollutants usually occur through different intake pathways, such as air breathing, dermal contact, ingestion of contaminated produce, and ingestion of fish that have taken up contaminants from water bodies. These exposures can all contribute to an individual's health risk. However, diesel PM risk is evaluated by the inhalation pathway only because the risk contributions by other pathways of exposure are known to be insignificant compared to the inhalation intake and difficult to quantify. It should be noted that the background or ambient diesel PM concentrations are not incorporated into the risk quantification in this study. Additional details on the risk characterization are provided in the Toxic Hot Spot Program Risk Assessment Guidelines (OEHHA, 2000).

To characterize the risk from the diesel PM emissions, three Cartesian receptor networks are used for the coverage of BNSF Richmond Railyard and its surrounding areas, including (1) a fine receptor grid network with spacing of 50 meters out to a distance of approximately 750 meters from the facility boundary, (2) a medium receptor grid with spacing of 250 meters out to a distance of approximately 1,500 meters from the facility boundary, and (3) a coarse receptor grid with spacing of 500 meters out to ten kilometers from the facility boundary. These receptor grid networks are graphically presented in Figure IV-3a, IV-3b, and IV-3c. The risk levels are presented as two-dimensional isopleths (or contours). These isopleths are used to display the risk plume ranges and gradient (or risk changes with distance) in all wind directions.

In the following sections, the cancer risk levels and non-cancer chronic risk levels resulting from on-site and off-site diesel PM emissions will be presented, followed by a discussion of non-cancer acute risk assessment.

D. Risk characterization associated with on-site emissions

1. Cancer risk

The operation activities at BNSF Richmond Railyard indicates diesel PM emissions are contributed by several sources, including locomotives, heavy heavy duty and light heavy duty on-road diesel trucks, heavy diesel-powered equipment, portable equipment and other stationary sources.

Figure V-1 shows the isopleths of estimated potential cancer risk from on-site railyard diesel PM emissions based on the 80th percentile breathing rate approach and a 70-year exposure duration. The average estimated potential cancer risk is about 150 chances per million around the railyard property boundaries. Beyond the railyard perimeter, the estimated cancer risks decrease rapidly to about 100 chances per million. The risks further decrease to 25 in a million within a half mile from the railyard then to 10 in a million within another half-mile distance. About two miles from the railyard perimeter, the estimated cancer risks are at 5 in a million or lower (not shown in the figure). A large population surrounding the facility is located at the eastern area of railyard facility with risk levels less than the level of 5 in a million, or about 1 mile from the eastern boundary of the yard. The closest residential area is located south of the railyard, where the estimated cancer risks range from about 25 to 100 chances per million.

The OEHHA Guidelines specify that, for health risk assessments, the location of the point of maximum exposure at the point of maximum impact (PMI) be reported. The PMI is defined as a location or the receptor point with the highest cancer risk level outside of the railyard boundary, with or without residential exposure. The PMI is predicted to be located next to the northwest boundary of railyard fence line based on the highest diesel PM concentrations estimated from the modeling results outside of the facility. It is located downwind from high emission density of areas where about 70 percent of facility-wide diesel PM emissions were generated (see the emission allocation in Appendix F). The cancer risk at the PMI is estimated at to be about 200 chances per million based on a 70-year exposure duration. The land use in the vicinity of the PMI is primarily zoned for industrial use. However, there may be residents living in this zoned area. In the residential zoned area, the potential cancer risk of maximally exposed individual resident (MEIR) or maximum individual cancer risk (MICR) is estimated at about 100 chances in a million, assuming a 70-year lifetime exposure. As indicated by Roseville Railyard Study (ARB, 2004a), the location of the PMI may vary depending upon the settings of the model inputs and parameters, such as

meteorological data set or emission allocations in the railyard. Therefore, given the estimated emissions, modeling settings, and the assumptions applied to the risk assessment, there are great uncertainties associated with the estimation of PMI and MICR. These indications should not be interpreted as a literal prediction of disease incidence but more as a tool for comparison. In addition, the estimated point of maximum impact and maximum individual cancer risk may not be replicated by air monitoring.

ARB staff also conducted a comparison of cancer risks estimated at the PMI versus MICR, and the differences of facility-wide diesel PM emissions between the UP and BNSF railyards. The ratios of cancer risks at the PMI or MICR to the diesel PM emissions do not suggest that one railroad's facilities have statistically higher cancer risks than the other railroad's or vice versa. Rather, the differences are primarily due to emission spatial distributions from individual operations among railyards.

Table V-1 shows the estimated area coverage and exposed population for different cancer risk ranges estimated from modeling results. The zone of impact with a risk of between 10 and 100 chances per million encompasses approximately 2,500 acres inland area, which expands about one-mile distance from the railyard. The estimated exposed population within the risk range is about 10,000 residents based on 2000 Census data.

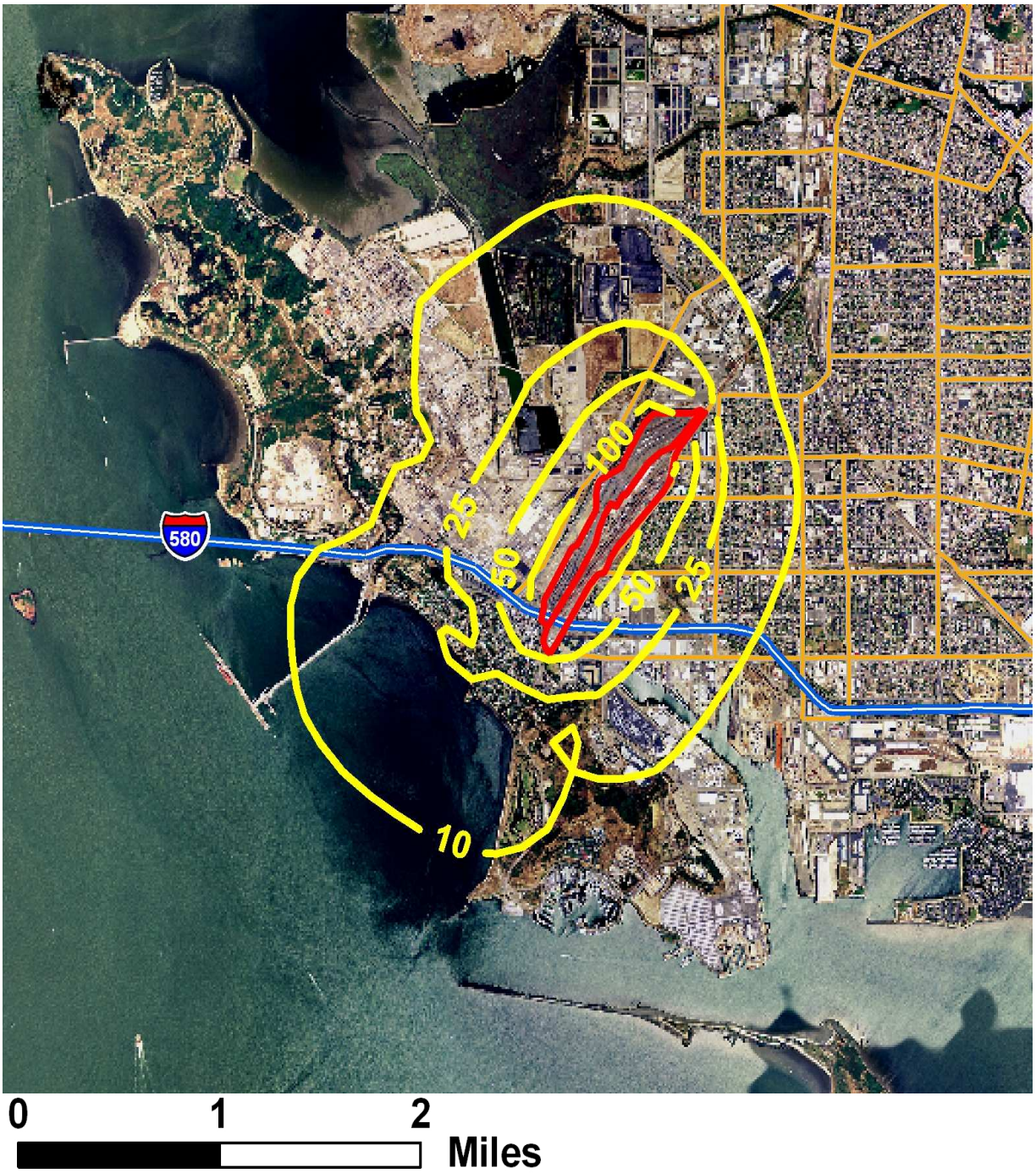


Figure V-1 Estimated potential cancer risk (in a million) associated with on-site diesel PM emissions at the BNSF Richmond Railyard facility (based on Tier-1 estimate and 80th percentile breathing rate for 70-year exposure duration).

Table V-1 Estimated acreage and exposed population of different cancer risk zones associated with on-site railyard diesel PM emissions (based on Tier-1 estimate and 80th percentile breathing rate for 70-year exposure duration).

Estimated Risk (in a million)	Impacted Area (Acres)	Distance from Railyard (Miles)	Exposed Population
10 – 25	1,600	0.4	6,200
25 – 50	580	0.2	1,900
50 – 100	280	0.1	1,600

The OEHHA Guidelines recommend a 70-year lifetime exposure duration to evaluate the potential cancer risks for residents. Shorter exposure duration of 30 years and 9 years may be also provided for shorter residency and children as supplement information. These exposure durations are all based on the exposures of 24 hours a day, and 7 days a week. It is important to note that children, for physiological as well as behavioral reasons, have higher rates of exposure than adults on a per unit body weight basis. To evaluate the potential cancer risks for off-site workers, the OEHHA Guidelines recommend that a 40-year exposure duration to be used, assuming workers have a different breathing rate of 149 Liters/Kilogram-day for an 8-hour workday, with adjustments of five days a week and 245 days a year. Table V-2 shows the equivalent risk levels of 70-, 30-year exposure durations for exposed residents, and 40-, 9-year exposure durations for workers and school-aged children, respectively. Using Table V-2, the isopleth line with a risk level of 10 in a million in Figures V-1 would become 4 in a million for exposed population with a shorter residency of 30 years, 2.5 in a million for children at the age range of 0-9 (the first 9-year childhood), and 2 in a million for off-site workers.

Table V-2 Equivalent potential cancer risk levels of 70-, 30-, 9-, and 40-year exposure durations associated with on-site railyard diesel PM emissions (based on Tier-1 methodology and 70-year exposure).

Exposure Duration (years)	Equivalent Estimated Cancer Risk Levels (chances in a million)			
70	10	25	50	100
30	4	11	21	43
9*	2.5	6.3	12.5	25
40‡	2	5	10	20

* Exposure duration for school-aged children during the first 9-year childhood.
‡ Exposure duration for off-site workers.

ARB staff also estimated other toxic air contaminants generated at the railyard. In the BNSF Richmond Railyard, the total toxic air contaminant emissions other than diesel PM is estimated at about 0.015 tons or 30 pounds per year, including benzene, formaldehyde, 1,3-butadiene and acetaldehyde. Using cancer potency weighted factors adjustment discussed in Chapter II, these non-diesel PM toxic air contaminants have considerably less potential cancer risks, about a factor of 550 less, as compared to the diesel PM, a predominant emission at the BNSF Richmond Railyard. Hence, only diesel PM emissions are presented in the on-site emission analysis.

2. Non-cancer chronic risk

The quantitative relationship between the amount of exposure to a substance and the incidence or occurrence of an adverse health impact is referred to a dose-response assessment. According to the OEHHA Guidelines, dose-response information for non-carcinogens is presented in the form of reference exposure levels. OEHHA has developed chronic reference exposure levels for assessing non-cancer health impacts from long-term exposure.

A chronic reference exposure level is a concentration level, expressed in units of micrograms per cubic meter ($\mu g/m^3$) for inhalation exposure, at or below which no adverse health effects are anticipated following long-term exposure. Long-term exposure for these purposes has been defined as 12% of a lifetime, or about eight years for humans. The methodology for developing chronic reference exposure levels is fundamentally the same as that used by U.S. EPA in developing the inhalation

Reference Concentrations (RfCs) and oral Reference Doses (RfDs). Chronic reference exposure levels are frequently calculated by dividing the no observed adverse effect level (NOAEL) or lowest observed adverse effect levels (LOAEL) in human or animal studies by uncertainty factors. A substantial number of epidemiologic studies have found a strong association between exposure to ambient particulate matter and adverse health effects. For diesel PM, OEHHA has determined a chronic reference exposure level of 5 $\mu g/m^3$, with the respiratory system, as a target of the reference exposure level.

It should be emphasized that exceeding the chronic reference exposure level does not necessarily indicate that an adverse health impact will occur. However, levels of exposure above the reference exposure level have an increasing but undefined probability of resulting in an adverse health impact, particularly in sensitive individuals (e.g., depending on the toxicant, the very young, the elderly, pregnant women, and those with acute or chronic illnesses).

The significance of exceeding the reference exposure level is dependent on the seriousness of the health endpoint, the strength and interpretation of the health studies, the magnitude of combined safety factors, and other considerations. In addition, there is a possibility that a reference exposure level may not be protective of certain small, unusually sensitive human subpopulations. Such subpopulations can be difficult to identify because of their small numbers, lack of knowledge about toxic mechanisms, and other factors. It may be useful to consult OEHHA staff when a reference exposure level is exceeded.

As described previously, reference exposure level for diesel PM is essentially the U.S. EPA reference concentration (RfC) first developed in the early 1990s based on histological changes in the lungs of rats. Since the identification of diesel PM as a toxic air contaminant, California has evaluated the latest literature on particulate matter health effects to set the ambient air quality standard. Diesel PM is a component of particulate matter in the air. Health effects from particulate matter in humans include illness and death from cardiovascular and respiratory disease, and exacerbation of asthma and other respiratory illnesses. Additionally, a body of literature has been published, largely after the identification of diesel PM as a toxic air contaminant and adoption of the REL, which shows that diesel PM can enhance allergic responses in humans and animals. Thus, it should be noted that the reference exposure level does not reflect adverse impacts of particulate matter on cardiovascular and respiratory disease and deaths, exacerbation of asthma, and enhancement of allergic response.

The hazard index is then calculated by taking the annual average diesel PM concentration, and dividing by the chronic reference exposure level of 5 $\mu g/m^3$. A hazard index value of 1 or greater indicates an exceedance of the chronic reference exposure level, and some adverse health impacts would be expected.

***Hazard Index**: The ratio of the potential exposure to the substance and the level at which no adverse effects are expected.*

As part of this study, ARB staff conducted an analysis of the potential non-cancer health impacts associated with exposures to the model-predicted ambient levels of directly emitted diesel PM from on-site sources within the modeling domain. The hazard index values were calculated, and then plotted as a series of isopleths in Figure V-2. As shown in the figure, the hazard index values are relatively small in the vicinity areas around the railyard facility, ranging from 0.01 to 0.05. A higher hazard index value of 0.1 was estimated near the facility on the west side of the fence line.

The Table V-3 presents estimated area coverage of non-cancer risk for three different ranges of hazard index, 0.01 to 0.02, 0.02 to 0.05, and 0.05 to 0.1. Although the coverage extends over populated areas on the west and south of the railyard, the average chronic risk levels are much lower than 1.0. The estimated results indicate that the potential non-cancer chronic health risks are less likely to occur according to the OEHHA Guidelines (OEHHA, 2003).

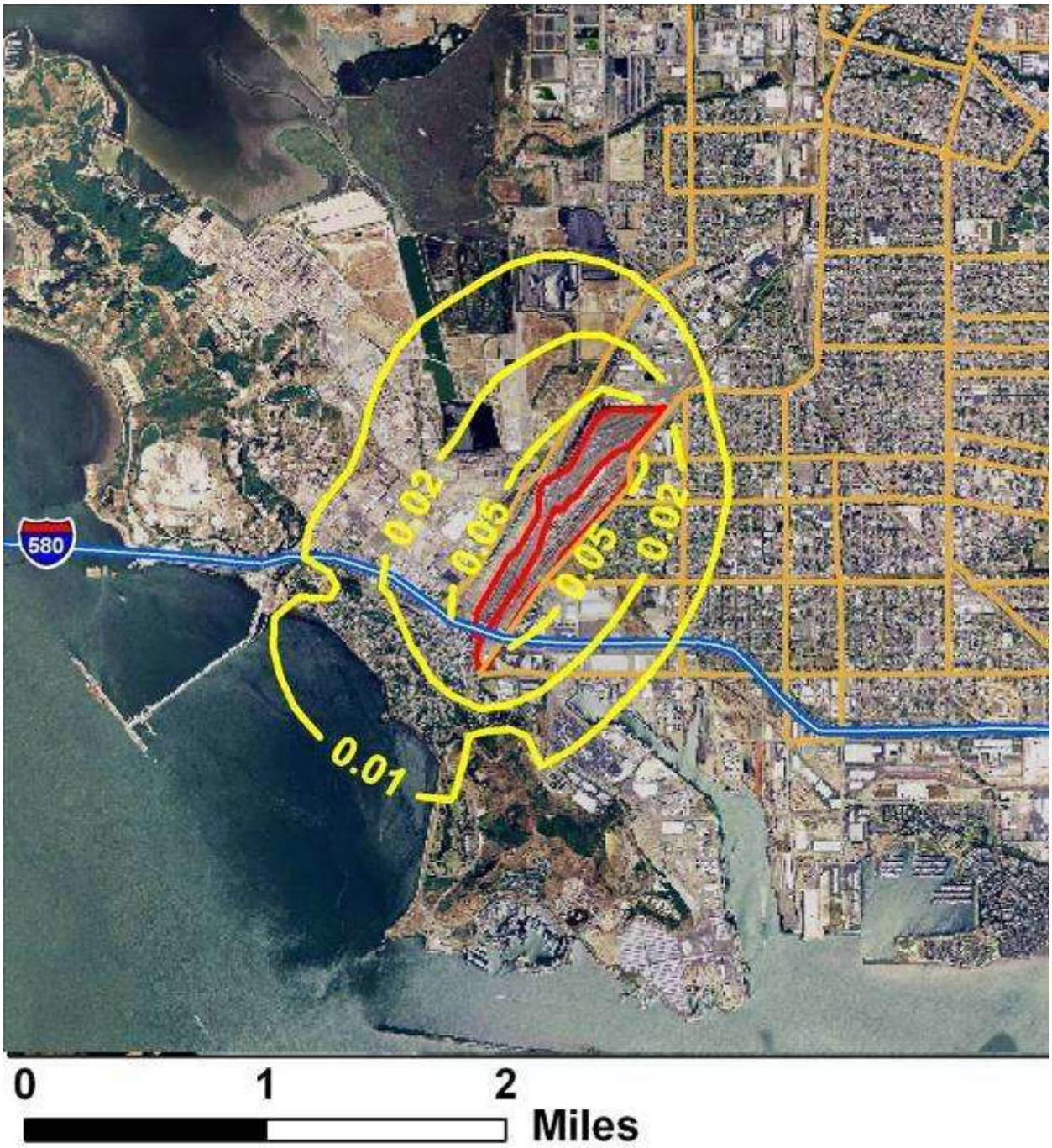


Figure V-2 Estimated non-cancer chronic risks (indicated as a Hazard Index) associated with the on-site diesel PM emissions at BNSF Richmond Railyard.

Table V-3 The impacted area of non-cancer chronic risks by estimated hazard indices associated with on-site railyard diesel PM emissions at the BNSF Richmond Railyard.

Estimated Hazard Index of Non-cancer Chronic Risk	Impacted Area (Acres)	Exposed Population
0.01 – 0.02	1,107	3,500
0.02 – 0.05	525	2,300
0.05 – 0.1	34	< 300

3. Non-cancer acute risk

According to the OEHHA Guidelines, an acute reference exposure level is an exposure that is not likely to cause adverse health effects in a human population, including sensitive subgroups, exposed to a given concentration for the specified exposure duration (generally one hour) on an intermittent basis. Non-cancer acute risk characterization involves calculating the maximum potential health impacts based on short-term acute exposure and reference exposure levels. Non-cancer acute impacts for the diesel PM are estimated by calculating a hazard index.

Due to the uncertainties in the toxicological and epidemiological studies, diesel PM as a whole was not assigned a short-term acute reference exposure level. It is only specific compounds of diesel exhaust (e.g., acrolein) that independently have potential acute effects (such as irritation of the eyes and respiratory tract), and an assigned acute reference exposure level. Acrolein is a by-product of combustion of fossil fuel. In addition, acrolein has been largely used as a chemical intermediate in the manufacture of adhesives. It also has been found in other different sources, such as fires, water treatment ponds, and tobacco smoke. However, acrolein is a chemically reactive and unstable compound, and easily reacts with a variety of chemical compounds in the atmosphere. Compared to the other chemical compounds in the diesel exhaust, the concentration of acrolein has a much lower chance of reaching a distant off-site receptor. Given the multitude of activities ongoing at facilities as complex as railyards, there is a much higher level of uncertainty associated with hourly-specific emission data and hourly model-estimated peak concentrations for short-term exposure, which are essential to assess the acute risk. Therefore, non-cancer acute risk is not addressed

quantitatively in this study. From a risk management perspective, ARB staff believes it is reasonable to focus on diesel PM cancer risk because it is the predominant risk driver and the most effective parameter to evaluate risk reduction actions. Further, actions to reduce diesel PM will also reduce non-cancer risks.

E. Risk characterization associated with off-site (non-railyard) emissions

1. Cancer risk

The isopleths for the potential cancer risks of 70-year exposure from off-site diesel PM emissions are illustrated in Figure V-3. The overall cancer risk isopleths are centered at Chevron Refinery, where the higher risks were estimated, and gradually spread out over in-land and open water areas. The 99 percent or 8 tons of stationary diesel PM emissions around the one-mile zone from the BNSF Railyard was identified as the sources generated by the Chevron Refinery, within one mile from the railyard perimeter on west.

The diesel PM emissions from mobile sources were generally generated from I-580 on south and local traffic on east of the railyard. As shown in Figure V-3, the mobile diesel PM emissions from I-580 on south have relatively higher impacts on the estimated caner risks around the railyard area, compared with the emissions from the local traffic on east of the railyard. The impacted zone for cancer risk levels greater than 10 chances per million was estimated at about 10,200 acres inland area coverage where a residential population of about 58,500 was reported according to the 2000 Census data. The impacted zones and exposed population are summarized in Table V-4. In comparison, the impacted inland area with cancer risk above 10 in a million is about four times larger than the impacted area with similar risk levels from the on-site railyard diesel PM emissions and the associated exposed population is also higher, about by a factor of 5.

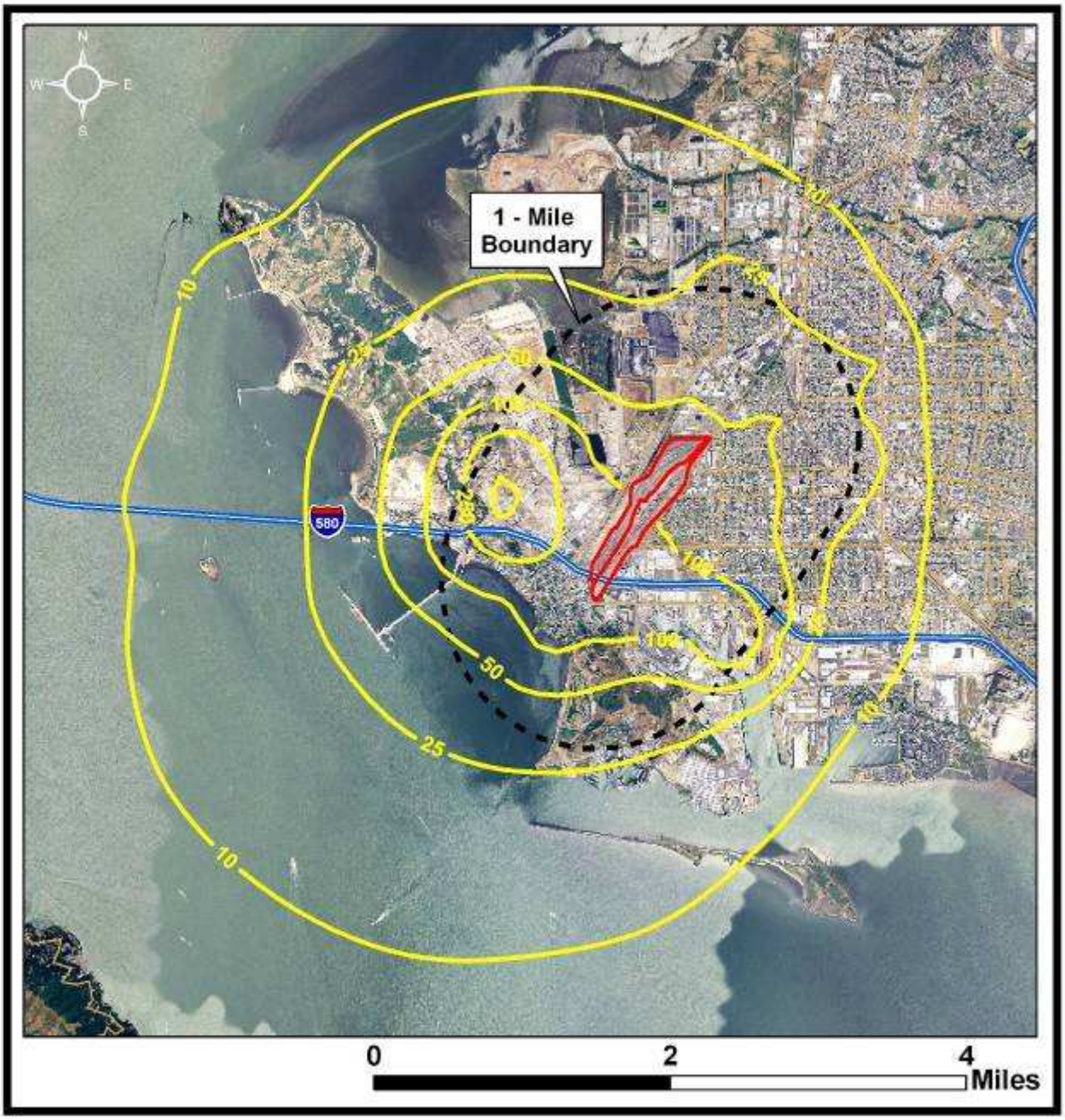


Figure V-3 Estimated potential cancer risks (as chances per million) from off-site stationary and mobile diesel PM emissions within the one-mile boundary (dashed line) around the BNSF Richmond Railyard (based on Tier-1 estimate and 80th percentile breathing rate for a 70-year exposure duration).

Table V-4 The estimated acreages of impacted zones and the associated exposed population, based on Tier-1 estimate and 80th percentile breathing rate for 70-year exposure duration.

Estimated Risk (in a million)	Impacted Area* (Acres)	Exposed Population
10 – 25	4,000	25,000
25 – 50	2,700	20,000
50 – 100	2,000	10,500
100 – 250	1,500	3,000

* inland area only

ARB staff evaluated other toxic air contaminants emissions around the BNSF Richmond Railyard. Among the toxic air contaminants other than diesel PM from stationary sources, benzene and formaldehyde were identified to be dominant cancer risk contributors and estimated at about 4.5 tons per year. Based on California Emission Inventory Development and Reporting System (CEIDAS) database, benzene and formaldehyde were reported from the estimated emissions associated with facilities nearby. According to the cancer potency factors estimated by the OEHHA Guidelines, benzene and formaldehyde are given a weighting factor by comparing each compound's cancer potency factor to the diesel PM cancer potency factor. This factor is multiplied by the estimated actual emissions for that compound, which gives the cancer potency weighted toxic emission as presented in Table V-5. As shown in the Table, the potency weighted toxic air contaminant emissions from stationary sources are estimated at about 0.3 tons per year. Based on the estimated emissions, the potential cancer risks from these non-diesel toxic air contaminants are considerably lower, about a factor of 40 less compared to the diesel PM emissions.

Table V-5 Cancer potency weighted toxic air contaminant emissions from significant off-site non-railyard stationary sources surrounding BNSF Richmond Railyard.

Toxic Air Contaminant	Cancer Potency Factor	Weighted Factor	Estimated Emissions (tons/year)	Potency Weighted Toxic Emissions (tons/year)
Diesel PM	1.1	1.0	11.7	**11.7**
Benzene	0.1	0.09	3.0	**0.27**
Formaldehyde	0.021	0.019	1.5	**0.03**
Non-Diesel PM Toxic Air Contaminants			4.6	**0.3**

ARB staff also estimated the potential cancer risk levels contributed by the use of gasoline in the San Francisco Bay Area Air Basin based on 2005 emission inventory. Table V-6 presents the emissions of major toxic air contaminants weighted by individual cancer potency factor. The cancer potency weighted emissions of these carcinogens from all gasoline related sources in the Air Basin are estimated at about 481 tons per year for the major risk contributors, 1,3-butadiene, benzene, formaldehyde and acetaldehyde. For gasoline-fueled vehicles only, the cancer potency weighted emissions are estimated at about 253 tons per year, or about 6% of diesel PM emissions basinwide. The potential cancer risks associated with non-diesel PM toxic air contaminants emitted from off-site gasoline vehicular sources are substantially less than the potential cancer risks associated with diesel PM emissions. Because of the risk dominance from diesel PM emissions, these air toxic contaminants are not included in the analysis of this study.

Table V-6 Major toxic air contaminants from gasoline-related sources in San Francisco Bay Area Air Basin, based on 2005 emission inventory.

Toxic Air Contaminant	Emissions (tons per year)			
	All Sources	Potency Weighted†	Gasoline Vehicular Sources	Potency Weighted†
Diesel PM	4, 552	4,552	-	-
1,3-Butadiene	414	228	245	135
Benzene	1,997	180	1,153	104
Formaldehyde	3,208	61	605	12
Acetaldehyde	1,355	12	177	2
Total (other than diesel PM)	41,824	481	2,180	253

†: Based on cancer potency weighted factors.

2. Non-cancer chronic risk

The estimated non-cancer chronic risks (indicated as hazard index) from the off-site diesel PM emissions range from 0.01 to 0.5. The level of 0.2 to 0.5 are located near the major off-site source diesel PM emissions, presented in Figure V-4. At neighboring residential areas around the railyard, the risk levels range from 0.01 to 0.1 on the east and from 0.05 to 0.2 on the south. The estimated results may suggest that the potential non-cancer chronic health risks be less likely to occur.

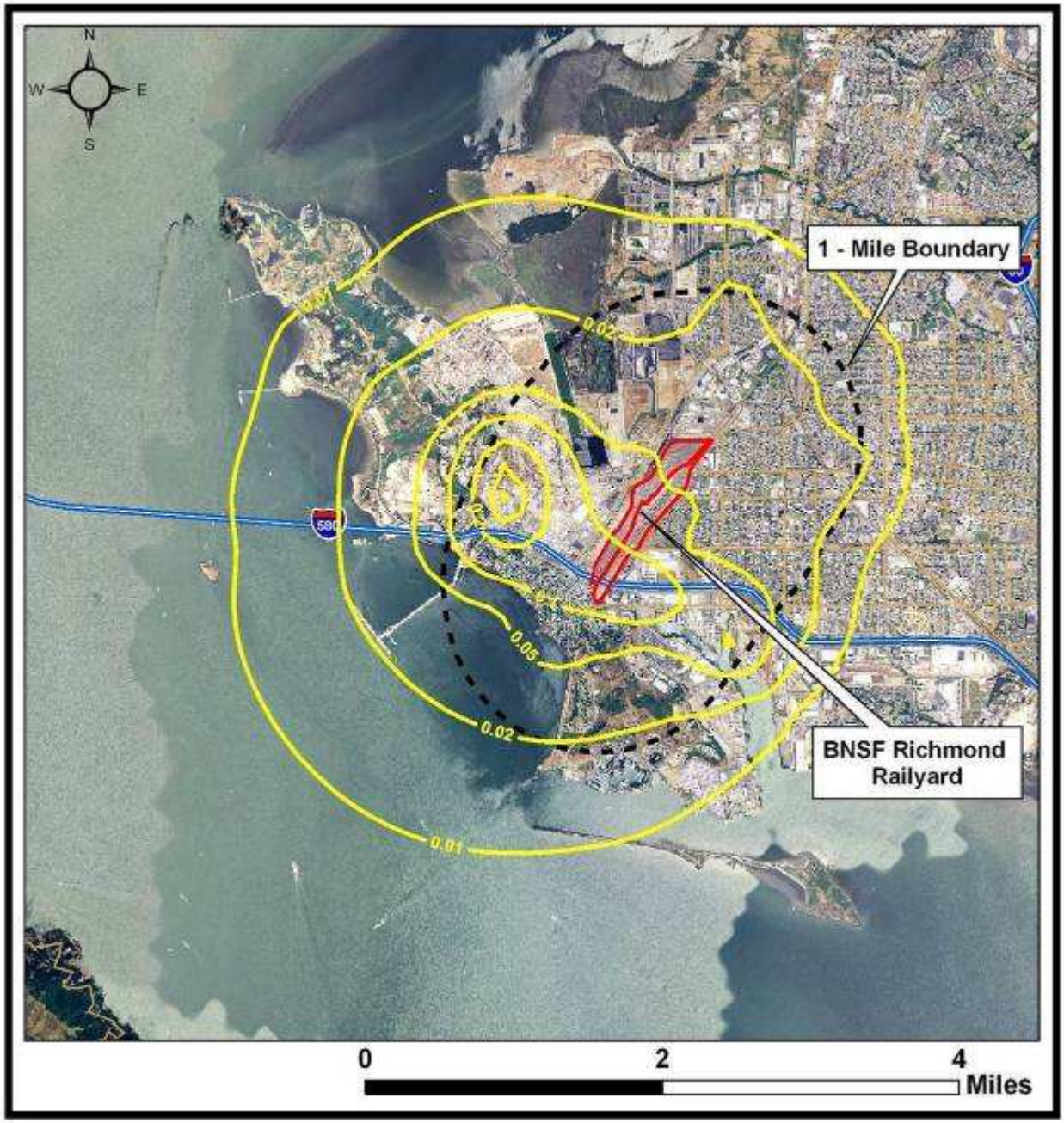


Figure V-4 Estimated non-cancer risks (indicated as hazard indices) associated with the off-site non-railyard diesel PM emissions within a one-mile off-site boundary (dashed line) around the BNSF Richmond Railyard**.**

F. Risks to sensitive receptors surrounding the BNSF Richmond Railyard

Individuals may be more sensitive to toxic exposures than the general population. These sensitive subpopulations include school-aged children, elderly, and patients. There are thirty one sensitive receptors identified in a one-mile boundary area around the BNSF Richmond Railyard. These receptors include elementary schools, preschools, child care centers, hospitals, and health facilities. Table V-7 summarizes the numbers of sensitive receptors identified in different levels of estimated cancer risks based on 70-year exposure duration. The potential non-cancer chronic health risks at these sensitive receptors are found to be less than the hazard index of 1.0, and are less likely to occur.

Table V-7 Numbers of sensitive receptors identified in different levels of estimated cancer risks (based on a 70-year exposure duration) associated with on-site railyard diesel PM emissions.

Estimated Cancer Risk (chances in a million)	Number of Sensitive Receptors
50 – 100	1
25 – 50	1
10 – 25	7
< 10	22

G. Uncertainty and limitations

Risk assessment is a complex procedure which requires the integration of many variables and assumptions. The estimated diesel PM concentrations and risk levels produced by a risk assessment are based on several assumptions, many of which are designed to be health protective so that potential risks to individual are not underestimated.

As described previously, the health risk assessment consists of three components: (1) emission inventory, (2) air dispersion modeling, and (3) risk assessment. Each component has a certain degree of uncertainty associated with its estimation and prediction due to the assumptions made. Therefore, there are uncertainties and limitations with the results.

The following subsections describe the specific sources of uncertainties in each component. In combination, these various factors may result in potential uncertainties in the location and magnitude of predicted concentrations, as well as the potential health effects actually associated with a particular level of exposure.

1. Emission inventory

The emission rate often is considered to be proportional to the type and magnitude of the activity at a source, e.g., the operation. Ideally, emissions from a source can be calculated on the basis of measured concentrations of the pollutant in the sources and emission strengths, e.g., a continuous emission monitor. This approach can be very costly and time consuming and is not often used for the emission estimation. Instead, emissions are usually estimated by the operation activities or fuel consumption and associated emission factors based on source tests.

The uncertainties of emission estimates may be attributed to many factors such as a lack of information for variability of locomotive engine type, throttle setting, level of maintenance, operation time, and emission factor estimates. Quantifying individual uncertainties is a complex process and may in itself introduce unpredictable uncertainties[5].

For locomotive sources at the BNSF Richmond Railyard, the activity rates include primarily the number of engines in operation and the time spent in different power settings. The methodology used for the locomotive emissions is based on these facility-specific activity data. The number of engines operating in the facility is generally well-tallied by BNSF's electronic monitoring of locomotives entering and leaving the railyard. However, the monitoring under certain circumstances may produce duplicate readings that can result in overestimates of locomotive activity. In addition to recorded activity data, surveys and communications with facility personnel, and correlations from

---

[5] The railyard HRAs have been performed using a methodology according to the ARB's and OEHHA Guidelines, and consistent with previous health risk analyses conducted by ARB. Similar to any model with estimations, the primary barriers of an HRA to determine objective probabilities are lack of adequate scientific understanding and more precise levels of data. Subjective probabilities are also not always available.

Tier-1 methodology is a conservative point approach but suitable for the current HRA's scope, given the condition and lack of probability data. Tier-1 approach used in the HRAs is consistent with previous health risk analyses performed by ARB, "The Roseville Railyard Study (ARB, 2004)" and "Diesel PM Exposure Assessment Study for the Ports of Los Angeles and Long Beach (ARB, 2006b)". By recognizing associated uncertainties or variability, the HRAs have qualitatively discussed the limitation and caveats of possible underestimation and overestimation in emission inventory and modeling predictions because of assumptions and simplifications. The discussion provides an additional reference for HRA results even though quantitative uncertainty bounds are unavailable. Most importantly, it is not practical to characterize and quantify the uncertainty of estimated health risks without the support of robust scientific data and actual probability distribution functions of model variables. An attempt to incorporate subjective judgments on uncertainty analyses can lead to misinterpretation of HRA findings.

other existing data, (e.g., from the Roseville Railyard Study (ARB, 2004a)), all were used to verify the emission estimations in the emission inventory.

Uncertainties also exist in estimates of the engine time in mode. Idling is typically the most significant operational mode, but locomotive event recorder data could not distinguish when an engine is on or off during periods when the locomotive is in the idle notch. As a result, a professional judgment is applied to distinguish between these two modes. While the current operations may not be precisely known, control measures already being implemented are expected to result in reduced activity levels and lower emissions than are estimated here for future years.

As discussed previously, emission factors are often used for emission estimates according to different operating cycles. The Roseville Railyard Study (ARB, 2004a) developed representative diesel PM emission factors for locomotives in different duty cycles. To reduce the possible variability of locomotive population and the uncertainty from assumptions, the emission factors were updated in the study to cover a wide range of locomotive fleet in the State (see Appendix D). The fuel usage in the locomotives in 2005 was calculated from the BNSF's annual fuel consumption database. These critical updates for locomotive emission inventory have established the most representative locomotive emission factors for the study.

For non-locomotive emissions, uncertainty associated with vehicles and equipment at the railyard facility also exists because the duty cycles (i.e., engine load demanded) are less well characterized. Default estimates of the duty cycle parameters may not accurately reflect the typical duty demanded from these vehicles and equipment at any particular site. In addition, national and state regulations have targeted these sources for emission reductions. Implementation of these rules and fleet turnover to newer engines meeting more strict standards should significantly reduce emissions at these rail sites in future years. However, the effects of these regulations have not been incorporated in the emission estimates, so estimated emissions are greater than those expected for future years at the same activity level.

2. Air dispersion modeling

An air dispersion model is derived from atmospheric diffusion theory with assumptions or, alternatively, by solution of the atmospheric-diffusion equation assuming simplified forms of effective diffusivity. Within the limits of the simplifications involved in its derivation, the model-associated uncertainties are vulnerably propagated into its downstream applications.

Model uncertainty may stem from data gaps that are filled by the use of assumptions. Uncertainty is often considered as a measure of the incompleteness of one's knowledge or information about a variate whose true value could be established if a perfect measurement is available. The structure of mathematical models employed to

represent scenarios and phenomena of interest is often a key source of model uncertainty, due to the fact that models are often only a simplified representation of a real-world system, such as the limitation of model formulation, the parameterization of complex processes, and the approximation of numerical calculations. These uncertainties are inherent and exclusively caused by the model's inability to represent a complex aerodynamic process. An air dispersion model usually uses simplified atmospheric conditions to simulate pollutant transport in the air, and these conditions become inputs to the models (e.g., the use of non site-specific meteorological data, uniform wind speed over the simulating domain, use of surface parameters for the meteorological station as opposed to the railyard, substitution of missing meteorological data, and simplified emission source representation). There are also other physical dynamics in the transport process, such as the small-scale turbulent flow in the air, which are not characterized by the air dispersion models. As a result of the simplified representation of real-world physics, deviations in pollutant concentrations predicted by the models may occur due to the introduced uncertainty sources.

The other type of uncertainty is referred as reducible uncertainty, a result of uncertainties associated with input parameters of the known conditions, which include source characteristics and meteorological inputs. However, the uncertainties in air dispersion models have been improved over the years because of better representations in the model structure. In 2006, the U.S. EPA modeling guidance was updated to replace the Industrial Source Complex model with AERMOD as a recommended regulatory air dispersion model for determining single source and source complex. Many updated formulations have been incorporated into the model structure from its predecessor, ISCST3, for better predictions from the air dispersion process. Nevertheless, quantifying overall uncertainty of model predictions is infeasible due to the associated uncertainties described above, and is beyond the scope of this study.

3. Risk assessment

The toxicity of toxic air contaminants is often established by available epidemiological studies, or use of data from animal studies where data from humans are not available. The diesel PM cancer potency factor is based on long term studies of railyard workers exposed to diesel exhaust in concentration approximately ten times typical ambient exposures The differences within human populations usually cannot be easily quantified and incorporated into risk assessments. Factors including metabolism, target site sensitivity, diet, immunological responses, and genetics may influence the response to toxicants. In addition, the human population is much more diverse both genetically and culturally (e.g., lifestyle, diet) than inbred experimental animals. The variability among humans is expected to be much greater than in laboratory animals. Adjustment for tumors at multiple sites induced by some carcinogens could result in a higher potency. Other uncertainties arise (1) in the assumptions underlying the dose-response model used, and (2) in extrapolating from large experimental doses, where, for example, other toxic effects may compromise the assessment of carcinogenic potential

due to much smaller environmental doses. Also, only single tumor sites induced by a substance are usually considered. When epidemiological data are used to generate a carcinogenic potency, less uncertainty is involved in the extrapolation from workplace exposures to environmental exposures. However, children, a subpopulation whose hematological, nervous, endocrine, and immune systems are still developing and who may be more sensitive to the effects of carcinogens on their developing systems, are not included in the worker population and risk estimates based on occupational epidemiological data are more uncertain for children than adults.

Human exposures to diesel PM are often based on limited availability of data and are mostly derived based on estimates of emissions and duration of exposure. Different epidemiological studies also suggest somewhat different levels of risk. When the Scientific Review Panel (SRP) identified diesel PM as a toxic air contaminant (ARB, 1998), the panel members endorsed a range of inhalation cancer potency factors (1.3×10^{-4} to 2.4×10^{-3} $(\mu g/m^3)^{-1}$) and a risk factor of 3×10^{-4} $(\mu g/m^3)^{-1}$, as a reasonable estimate of the unit risk. From the unit risk factor an inhalation cancer potency factor of 1.1 $(mg/kg\text{-}day)^{-1}$ can be calculated, which is used in the study. There are many epidemiological studies that support the finding that diesel exhaust exposure elevates relative risk for lung cancer. However, the quantification of each uncertainty applied in the estimate of cancer potency is very difficult and can be itself uncertain.

This study adopts the standard Tier 1 approach recommended by the OEHHA for exposure and risk assessment. A Tier 1 approach is an end-point estimate methodology without the consideration of site-specific data distributions. It also assumes that an individual is exposed to an annual average concentration of a pollutant continuously for individual is exposed to a specific time period. The OEHHA recommends the lifetime 70-year exposure duration with a 24-hour per day exposure be used for determining residential cancer risks. This will ensure a person residing in the vicinity of a facility for a lifetime will be included in the evaluation of risk posed by the facility. Lifetime 70-year exposure is a conservative estimate, but it is a historical benchmark for comparing facility impacts on receptors and for evaluating the effectiveness of air pollution control measures. Although it is not likely that most people will reside at a single residence for 70 years, it is common that people will spend their entire lives in a major urban area. While residing in urban areas, it is very possible to be exposed to the emissions of another facility at the next residence. In order to help ensure that people do not accumulate an excess unacceptable cancer risk from cumulative exposure to stationary facilities at multiple residences, the 70-year exposure duration is used for risk management decisions. However, if a facility is notifying the public regarding health risk, it is a useful indication for a person who has resided in his or her current residence less than 70 years to know that the calculated estimate of his or her cancer risk is less than that calculated for a 70-year risk (OEHHA, 2003). Risk assessment is best viewed as a comparative tool rather than a literal prediction of diesel incidence in a community.

Since the Tier-1 methodology is used in the study for the health risk assessment, the results have been limited to deterministic estimates based on conservative inputs. For example, an 80 percentile breathing rate approach is used to represent a 70-year lifetime inhalation that tends toward the high end for the general population. Moreover, the results based on the Tier-1 estimates do not provide an indication of the magnitude of uncertainty surrounding the quantities estimated, nor an insight into the key sources of underlying uncertainty.

REFERENCES

ARB, 1998. Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant, Staff Report, April, 1998

ARB, 2000. Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles, Staff Report, October, 2000.

ARB, 2002. Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates, Staff Report, May. 2002.

ARB, 2004a. Roseville Railyard Study, October, 2004.

ARB, 2004b. ARB Recommended Interim Risk Management Policy for Inhalation-Based Residential Cancer Risk, March, 2004. (http://www.arb.ca.gov/toxics/harp/rmpolicyfaq.htm)

ARB, 2005. ARB/Railroad Statewide Agreement Particulate Emissions Reduction Program at the California Rail Yards. Sacramento, CA. June, 2005.

ARB, 2006a. Emission Reduction Plan for Ports and Goods Movement in California, March, 2006.

ARB, 2006b. Health Risk Assessment Guidance for Railyard and Intermodal Facilities. July, 2006.

ARB, 2006c. The California Almanac of Emissions and Air Quality, 2006 Edition.

ARB, 2006d. Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, Finial Report. April, 2006.

ARB, 2006e. Railyard Emissions Inventory Methodology. July, 2006.

CSLC, 2006. Draft Environmental Impact Report for the Chevron Richmond Long Wharf Marine Terminal Lease Consideration, California State Lands Commission, February, 2006.

ENVIRON, 2006a. BNSF Richmond Railyard Toxic Air Contaminant Emission Inventory. Emeryville, CA. November, 2006.

ENVIRON, 2006b. Air Dispersion Modeling Assessment of Air Toxic Emissions from BNSF Richmond Railyard, Report No. 06-12910J5B. Emeryville, CA. November, 2006.

Krewski, D., Burnett, R.T., Goldberg, M.S., Hoover, K., Siemiatycki, J., Jarret, M., Abrahamowicz, M., White, W.H., Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality, Special Report, Health Effects Institute, Cambridge, MA, 2000.

Lloyd, A.C., Cackett, T.A., Critical Review, Diesel Engines: Environmental Impact and Control, *J. Air & Waste Manage. Assoc*., 2001, 51, 809-847.

OEHHA, 2000. Air Toxics Hot Spot Program Risk Assessment Guidelines: Part IV-Technical Support Document for Exposure Analysis and Stochastic Analysis. Office of Environmental Health Hazard Assessment. September, 2000.

OEHHA, 2002. Air Toxics Hot Spot Program Risk Assessment Guidelines: Part II-Technical Support Document for Describing Available Cancer Potency Factors. Office of Environmental Health Hazard Assessment. December, 2002.

OEHHA, 2003. Air Toxics Hot Spots Program Risk Assessment Guidelines: The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments. Office of Environmental Health Hazard Assessment. August, 2003.

Pope, C.A, III; Thun, M.J.; Namboodiri, M.M.; Dockery, D.W.; Evans, J.S.; Speizer, F.E.; Heath, J.C.W. Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of U.S. Adults, *Am. J. Respir. Crit. Care. Med.*, 1995, 151, 669-674.

Pope, C.A, III; Burnett, R.T., Thun, M.J.; Calle, E.E. Krewski, D., Ito, K., Thurston, G.D. Lung Cancer, Cardiopulmonary Mortality, and Long-Term Exposure to Fine Particulate Air Pollution, *J. Am. Med. Assoc*., 2002, 287, 1132-1141.

Pope, C.A.; III; Burnett, R.T.; Thurston, G.D.; Thun, M.J.; Calle, E.E.; Krewski, D.; Godleski, J.J. Cardiovascular Mortality and Long-Term Exposure to Particulate Air Pollution: Epidemiological Evidence of General Pathophysiological Pathways of Disease; *Circulation,* 2004, *109,* 71-77.

SCAQMD, 2000. Multiple Air Toxics Exposure Study in the South Coast Air Basin (MATES-II), Final Report, March, 2000.

U.S. EPA, 1985. Guideline for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations) – Revised. EPA-450/4-80-023R, Office of Air Quality Planning and Standards, U.S. EPA, Research Triangle Park, NC. June, 1985.

U.S. EPA, 2004a. User's Guide for the AMS/EPA Regulatory Model – AERMOD. Report No. EPA-454/B-03-001. Office of Air Quality Planning and Standards.

Emissions Monitoring and Analysis Division, Research Triangle Park, NC. September, 2004.

U.S. EPA, 2004b. User's Guide for the AERMOD Meteorological Preprocessor. Report No. EPA-454/B-03-002. Office of Air Quality Planning and Standards. Emissions Monitoring and Analysis Division, Research Triangle Park, NC. September, 2004.

U.S. EPA, 2005. Federal Register, Part III, 40 CFR part 51, Vol. 70, No. 216, November 9, 2005.

This page left intentionally blank

APPENDIX A

METHODOLOGY OF OFF-SITE MOBILE SOURCE EMISSIONS

INTRODUCTION

This assessment includes on-road mobile emissions from all heavy duty diesel truck running exhaust as it is the primary source of diesel particulate emissions within the on-road vehicle fleet. Traditionally, on-road mobile emission inventories are generated at the county scale using California's emission factor model EMFAC and then allocated to large grid cells using the Direct Travel Impact Model (DTIM). To enhance the spatial resolution we have estimated emissions based on roadway specific vehicle activity data and allocated them to individual roadway links. All roadway links within a 1-mile buffer of BNSF Richmond Railyards were included in this assessment.

As more and more work has been done to understand transportation modeling and forecasting, access to local scale vehicle activity data has increased. For example, the various Metropolitan Planning Organizations (MPOs) are mandated by the Federal government to maintain a regional transportation plan and regional transportation improvement plan. These reports assess the impact the travel growth and assess various transportation improvement plans. Planning is based on travel activity results from Transportation Demand Models (TDMs) that forecast traffic volumes and other characteristics of the transportation system. Currently, more than a dozen MPOs as well as the California Department of Transportation (Caltrans) maintain transportation demand models. Through a system of mathematical equations TDMs estimate vehicle population and activity estimates such as speed and vehicle miles traveled (VMT) based on data about population, employment, surveys, income, roadway and transit networks and transportation costs. The activity is then assigned a spatial and temporal distribution by allocating them to roadway links and time periods. A roadway link is defined as a discrete section of roadway with unique estimates for the fleet specific population and average speed and is classified as a freeway, ramp, major arterial, minor arterial, collector, or centroid connector. Link based emission inventory development utilizes these enhanced spatial data and fleet and pollutant specific emission factors to estimate emissions at the neighborhood scale.

METHODOLOGY

Estimating emissions from on-road mobile sources outside the rail yards was broken into four main processes and described below. The first step involves gathering vehicle activity data specific to each link on the roadway network. Each link contains 24 hours worth of activity data including vehicle miles traveled, vehicle type, and speed. The activity is then apportioned to the various heavy duty diesel truck types (Table A-1) where speed-specific VMT is then matched to an emission factor from EMFAC to estimate total emissions from each vehicle type for each hour of the day. The working draft (version V2.23.7) of EMFAC2007 was used for this assessment because at the time this project was underway EMFAC2007 was not completed. The working draft of EMFAC, however, contains nearly all the revisions in EMFAC2007 that would affect these calculations.

Table A-1: Heavy duty truck categories

Class	Description	Weight (GVW)	Abbreviation	Technology Group
T4	Light-Heavy Duty Diesel Trucks	8,501-10,000	LHDDT1	DIESEL
T5	Light-Heavy Duty Diesel Trucks	10,001-14,000	LHDDT2	DIESEL
T6	Medium-Heavy Duty Diesel Trucks	14,001-33,000	MHDDT	DIESEL
T7	Heavy-Heavy Duty Diesel Trucks	33,001+	HHDDT	DIESEL

Step 1: Obtain Link-Specific Activity Data[6]

The link specific activity data for heavy duty trucks necessary to estimate emissions are speed and vehicle miles traveled (VMT), where VMT is a product of vehicle volume (population) and link length. Link activity for Ventura, Los Angeles, Orange, and more than 90% of Riverside and San Bernardino counties are provided by the Southern California Association of Governments (SCAG)[i] Heavy Duty Truck Transportation Demand Model. Heavy duty truck activity is modeled using truck specific data, commodity flows and goods movement data. SCAG, however, is the only MPO with a heavy duty truck model. The remaining counties under the rail yard study are covered by the Integrated Transportation Network (ITN) developed by Alpine Geophysics[ii]. The Integrated Transportation Network was developed by stitching together MPO transportation networks and the Caltrans statewide transportation network. Link specific truck activity from the ITN is estimated as a fraction of the total traffic on the links and is based on the fraction of trucks within each county as it is estimated in EMFAC.

The product of truck volume and link length is referred to as vehicle miles traveled (VMT) and has units of miles. Transportation demand models provide total VMT for each link without further classification into the various heavy duty truck weight and fuel type classifications. Therefore, in order to assess the emissions only from heavy duty diesel trucks the total heavy duty truck VMT is multiplied by the fraction of trucks that are diesel. Once the total diesel VMT is calculated the heavy duty truck diesel VMT is

---

[i] "SCAG Transportation Modeling", http://www.scag.ca.gov/modeling/ [accessed January 2007].

ii Wilkinson, James (Alpine Geophysics); et al. "Development of the California Integrated Transportation Network (ITN)," Alpine Geophysics – Atmospheric and Hydrologic Sciences, La Honda, CA (2004). http://www.arb.ca.gov/airways/CCOS/docs/III3_0402_Jun06_fr.pdf

multiplied by the fraction of trucks that make up the four weight classifications. The fuel and weight fractions are specific to each county and are derived from total VMT for each weight and fuel class in EMFAC for each county. The data is then compiled into an activity matrix (Table A-2) composed of a link identification code, hour of the day, speed, light heavy duty diesel 1 truck (LHDDT1) VMT, light heavy duty diesel 2 truck (LHDDT2) VMT, medium heavy duty diesel truck (MHDDT) VMT, and heavy heavy duty diesel truck (HHDDT) VMT. Due to difficulty in determining weight fractions on all roadways, the county average was used. However, because railyards are commonly located in industrial areas one would expect higher diesel truck fractions near the railyards. Thus, the diesel PM emissions near the railyards are also expected to be relatively higher than other areas.

Table A-2 Activity matrix example

LINK I. D.	Hour	Speed (mph)	LHDDT1 VMT (miles)	LHDDT2 VMT (miles)	MHDDT VMT (miles)	HHDDT VMT (miles)
49761	12	45	0.37	0.48	3.17	5.51
49761	3	45	0.14	0.18	1.16	2.00
49761	3	35	0.16	0.21	1.37	2.38
50234	4	55	0.19	0.26	1.68	2.92

Step 2: Derive Gram per Mile Emission Factors

The second step of the emission inventory process involves developing emission factors for all source categories for a specified time period, emission type, and pollutant. Running exhaust emission factors based on vehicle type, fuel type and speed were developed from the Emfac mode of EMFAC. These are composite emission factors based on the model year distribution for each county and provided in units of grams of emissions per mile traveled. Emission factors are based on test cycles that reflect typical driving patterns, and non-extended idling is included.

Finally, a matrix of emission factors by speed and vehicle type was assembled for each county for light heavy-duty diesel trucks 1 and 2 (LHDDT1 and LHDDT2), medium heavy-duty diesel trucks (MHDDT) and heavy heavy-duty diesel trucks (HHDDT). The following is an example of such a matrix (Table A-3):

Table A-3 Emission factor matrix example.

	Diesel PM Emission Factors (g/mile)			
Speed (mph)	**LHD1 DSL**	**LHD2 DSL**	**MHD DSL**	**HHD DSL**
12	0.101	0.145	0.631	2.371
20	0.072	0.105	0.455	1.277
45	0.037	0.054	0.235	0.728
60	0.033	0.047	0.206	1.095

Step 3: Calculate Emissions

Diesel PM emission factors are provided as grams per mile specific to each speed and heavy duty truck type (see table above). To estimate emissions the activity for each diesel heavy duty truck type was matched to the corresponding emission factor (EF). For example, a 0.25 mile long link at 3 am in the morning has 8 heavy heavy-duty diesel trucks (HHDDTs) traveling at 45 miles per hour. This equates to a VMT of 2.00 miles (8 trucks*0.25 miles). EMFAC has provided a gram per mile emission factor for HHDDT traveling at 45 mph in Los Angeles County as 0.728 grams DPM/mile. In order to estimate total emissions from HHDDTs on that link during that hour of the day the following calculation is made:

$$TotalEmissions(grams) = EF \cdot (Volume \cdot LinkLength) = EF \cdot VMT$$

$$TotalEmissions(grams) = EF \cdot VMT = 0.728 \frac{grams}{mile} \cdot 2.00 miles = 1.45 grams$$

The steps outlined above and in Steps 1 and 2 can be represented with this single equation that provides an emissions total for each link for each hour of the day.

$$Emissions = VMT_{link} \cdot \sum_{i,j} Fraction_{i,j} \cdot EF_{i,j}$$

where

- Emissions – the total emissions in grams for each link
- i = represents the individual diesel heavy duty truck types (LHDDT1, LHDDT2 – light heavy duty diesel trucks 1 and 2; MHDDT – medium heavy duty diesel truck; and HHDDT – heavy heavy duty diesel truck)
- j – represent the hours of the day (hours 1-24)
- VMT_{Link} - total VMT for that link for all heavy duty trucks (gasoline and diesel)

- Fraction = the fraction of the VMT that is attributable to each diesel heavy duty truck type The fraction is estimated based on VMT estimates in EMFAC: Example: $VMT_{MHDDT}/VMT_{\text{all heavy duty trucks (gasoline \& diesel)}}$
- EF = the heavy duty diesel truck emission factors. The emission factor is vehicle type and speed specific and is thus matched according to the link specific activity parameters.

From this expression diesel particulate matter emissions are provided for each link and for each hour of the day. Finally, emissions are summed for all links for all hours of the day to provide a total daily emission inventory.

Step 4: QA/QC – Quality Assurance/Quality Control

To assure that the total emissions were calculated correctly the total emissions (grams) were divided by the total diesel VMT to estimate a composite diesel gram per mile emission factor. This back-calculated emission factor was checked against emission factors in EMFAC. In addition, where possible, heavy duty truck gate counts provided for the rail yards were checked against traffic volumes on the links residing by the gates.

LIMITATIONS AND CAVEATS

We have made several important assumptions in developing this inventory. While these assumptions are appropriate at the county level they may be less appropriate for the particular areas modeled in this assessment. For example, the county specific default model year distribution within EMFAC, and vehicle type VMT fractions were assumed to be applicable for all links within the domain modeled. In the vicinity of significant heavy heavy-duty truck trip generators it is reasonable to expect that surrounding links will also have higher heavy heavy-duty truck fractions. In these cases using EMFAC county vehicle mix fractions may underestimate the total diesel particulate emissions from on-road heavy duty trucks. In this inventory EMFAC county defaults were employed as there is insufficient data available to assess the vehicle mix fractions surrounding the railyards.

Travel demand model results are checked by comparing actual traffic counts on links where the majority of vehicle travel takes place. Therefore, there will be greater uncertainty associated with activity from minor arterials, collectors, and centroid connectors than from higher volume freeways. Data based strictly on actual traffic counts for each street would provide better activity estimates, but unfortunately very little data is available for such an analysis. While links representing freeways are accurately allocated spatially, the allocation of neighborhood streets and other minor roads are not as well represented.

The emissions inventory developed for this study only included diesel particulate matter emissions from running exhaust as it is the primary diesel source from on-road mobile sources. Emissions from other modes such as off-road equipment, extended idling, starts, and off-road equipment outside the rail yards were excluded. Vehicle activity from distribution centers, rail yards and ports, however, are included as they are captured on the roadway network by the travel demand models.

APPENDIX B

METHODOLOGY OF OFF-SITE STATIONARY SOURCE EMISSIONS

Emissions from off-site stationary source facilities were identified using the California Emission Inventory Development and Reporting System (CEIDARS) database, which contains information reported by the local air districts for stationary sources within their jurisdiction.

Geographic information system (GIS) mapping tools were used to create a one-mile buffer zone outside the property boundary footprint reported for each railyard. The CEIDARS facilities whose latitude/longitude coordinates fell within the one-mile buffer zone were selected.

The reported criteria pollutants in CEIDARS include carbon monoxide, nitrogen oxides, sulfur oxides, total organic gases, and particulate matter (PM). The reported toxic pollutants include the substances and facilities covered by the Air Toxics "Hot Spots" (AB 2588) program. Diesel exhaust particulate matter (diesel PM) was estimated from stationary internal combustion (IC) engines burning diesel fuel, operating at stationary sources reported in CEIDARS. Diesel PM emissions were derived from the reported criteria pollutant PM that is ten microns or less in diameter (criteria pollutant PM10) emitted from these engines. In a few cases, diesel exhaust PM was reported explicitly under the "Hot Spots" reporting provisions as a toxic pollutant, but generally the criteria pollutant PM10 reported at diesel IC engines was more comprehensive than the toxics inventory, and was therefore the primary source of data regarding diesel PM emissions.

The CEIDARS emissions represent annual average emission totals from routine operations at stationary sources. For the current analysis, the annual emissions were converted to grams per second, as required for modeling inputs for cancer and chronic non-cancer risk evaluation, by assuming uniform temporal operation during the year. (The available, reported emission data for acute, maximum hourly operations were insufficient to support estimation of acute, maximum hour exposures).

The CEIDARS 2004 database year was used to provide the most recent data available for stationary sources. Data for emissions, location coordinates, and stack/release characteristics were taken from data reported by the local air districts in the 2004 CEIDARS database wherever available. However, because microscale modeling requires extensive information at the detailed device and stack level that has not been routinely reported, historically, by many air districts, much of the stack/release information is not in CEIDARS. Gaps in the reported data were addressed in the following ways. Where latitude/longitude coordinates were not reported for the stack/release locations, prior year databases were first searched for valid coordinates, which provided some additional data. If no other data were available, then the coordinates reported for the overall facility were applied to the stack locations. Where parameters were not complete for the stack/release characteristics (i.e., height, diameter, gas temperature and velocity), prior year databases were first searched for valid data. If no reported parameters were available, then U.S. EPA stack defaults from

the Emissions Modeling System for Hazardous Air Pollutants (EMS-HAP) program were assigned. The U.S. EPA stack defaults are assigned based on the Source Classification Code (SCC) or Standard Industrial Classification (SIC) code of the operation. If an applicable U.S. EPA default was not available, then a final generic default was applied. To ensure that the microscale modeling results would be health-protective, the generic release parameters assumed relatively low height and buoyancy. Two generic defaults were used. First, if the emitting process was identifiable as a vent or other fugitive-type release, the default parameters assigned were a height of five feet, diameter of two feet, temperature of 100 degrees Fahrenheit, and velocity of 25 feet per second. For all remaining unspecified and unassigned releases, the final generic default parameters assigned were a height of twenty feet, diameter of two feet, temperature of 100 degrees Fahrenheit, and velocity of 25 feet per second. All English units used in the CEIDARS database were converted to metric units for use in the microscale modeling input files.

APPENDIX C

SUMMARY OF AIR DISPERSION MODELING RESULTS FROM OFF-SITE DIESEL PM EMISSIONS

Impacts from off-site pollution sources near the BNSF Richmond rail yard facility were modeled using the U.S. EPA-approved AERMOD dispersion model. Specifically, off-site mobile and stationary diesel PM (DPM) emission sources located out to a distance of one mile from the perimeter of the BNSF Richmond rail yard were included. Other emission sources that were located immediately beyond the one mile zone from the facility, such as a high-volume freeway, have the potential to impact receptors in the modeling grid, but were not considered.

To facilitate modeling of these off-site emission sources, the information summarized in Table C-1 was provided by external sources.

Table C-1. Data provided by others for off-site emission source modeling.

Type of Data	Description	Data Source
Emission Estimates	Off-site DPM emissions for 2005 Mobile Sources: 11.7 TPY. DPM Stationary Sources: 8.1 TPY DPM	ARB
Receptor Grid	41x41 Cartesian grid covering 400 km^2 with uniform spacing of 500 meters. Grid origin: (544700, 4188800) in UTM Zone 10.	Environ
Meteorological Data	AERMET-Processed data for 2001-2005 *Surface*: Chevron Refinery (on-site) *Upper Air*: Oakland Metro. Airport	Environ
Surface Data	Albedo: 0.13 to 0.19 Bowen Ratio: 0.33 to 3.92 Surface Roughness: 0.20 to 0.94	Environ

The spatial and temporal emissions provided for these sources were converted into the appropriate AERMOD ready files. The off-site emissions were modeled using the same coarse receptor grid and meteorological data used by the consultants for their rail yard model runs, as indicated in the table above.

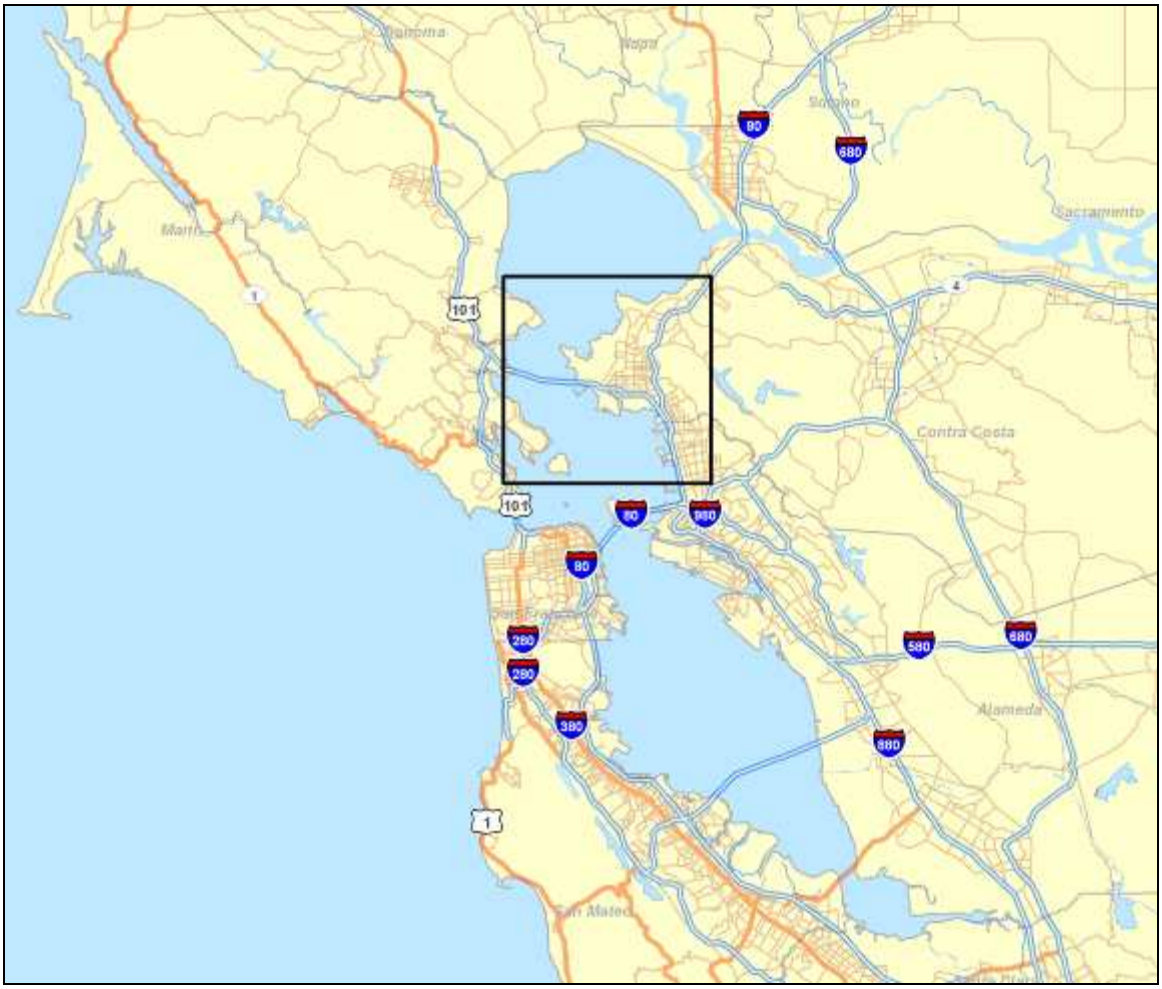


Figure C-1 Region surrounding the BNSF Richmond rail facility with the modeling domain indicated by the black outline.

Figure C-1 illustrates the region surrounding the BNSF Richmond modeling domain. The domain has dimensions 20 km x 20 km and contains a grid of 1681 receptors with a 500 meter uniform grid spacing.

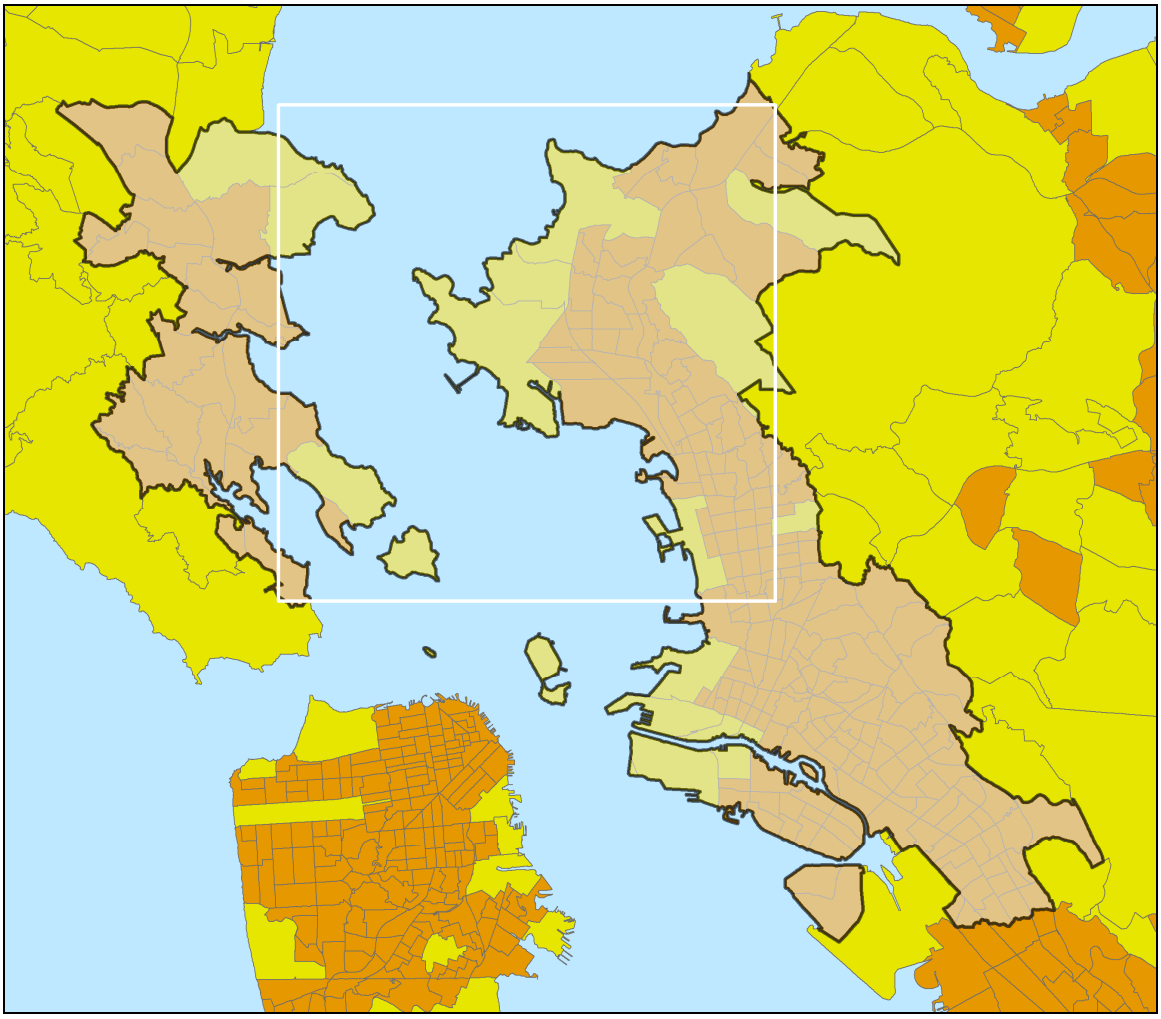


Figure C-2 BNSF Richmond Urban Population: Orange denotes areas with at least 750 people/km^2. The highlighted region is the contiguous urban area used for modeling purposes.

AERMOD requires an estimate of the urban population for urban source modeling. The urban population parameter was determined by estimating the area of continuous urban features as defined by the model guidelines (AERMOD Implementation Guide September 27, 2005). According to the guidelines, areas with a population of at least 750 people per square kilometer are considered urban. The continuous urban area selected can be seen in Figure C-2. The population in this selected area is 987,035.

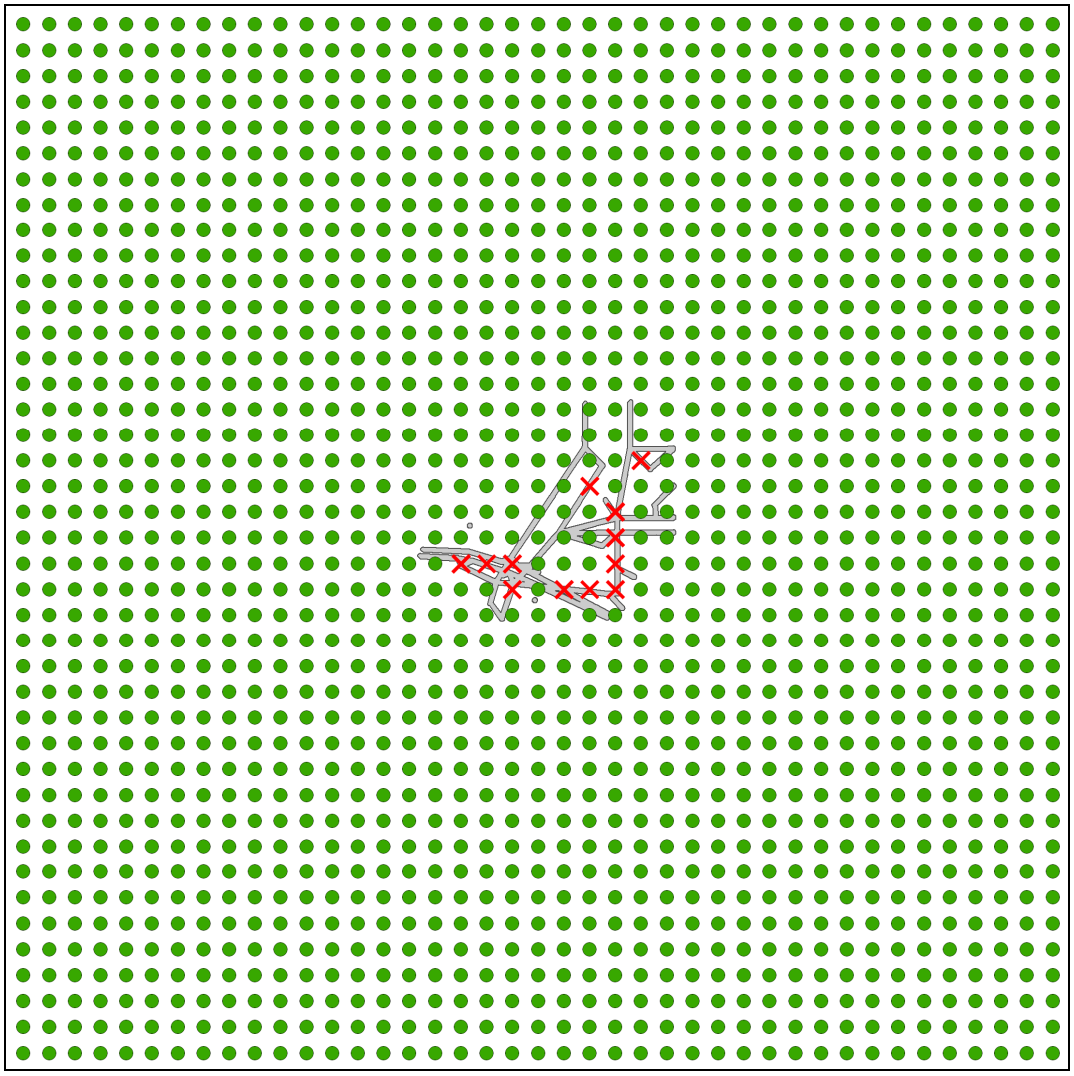


Figure C-3 The receptor network of off-site emission modeling

The off-site stationary and on-road emission sources used in the BNSF Richmond model runs are plotted along with the receptor network in Figure 3. These sources do not represent all stationary and roadway sources within the domain, but rather a subset made up of those roadways and facilities within one mile of the perimeter of the rail yard facility. Diesel PM off-site emissions used in the off-site modeling runs consisted of 11.7 tons per year from roadways and 8.1 tons per year from stationary facilities, representing emissions for 2005. Roadway emissions were simulated as AERMOD area sources with an aspect ratio of no greater than 100 to 1, with a width of 7.3 meters and a release height of 4.15 meters.

As indicated above, Figure 3 illustrates a 20 km x 20 km gridded receptor field with uniform 500 meter spacing of receptors that are plotted as "●". Because a uniform grid

sometimes places receptors on a roadway, those within 35 meters of a roadway were omitted. The basis for this is that these receptors are likely to fall on the roadway surface, versus a dwelling or workplace, and have high model-estimated concentrations, which could skew average concentration isopleths. Locations where receptors were removed are displayed as an "**x**" in Figure C-3. After removal, 1669 of the original 1681 receptors remained.

The same meteorological data used by Environ was used for the off-site modeling runs. The data were compiled by Environ from the nearby Chevron Refinery on-site station (37.95°N, 122.38°W). Upper air data for the same t ime period was obtained from the Oakland Metropolitan Airport upper air station (37.717°N, 122.217°W). The model runs used five years of meteorological data from 2001 through 2005.

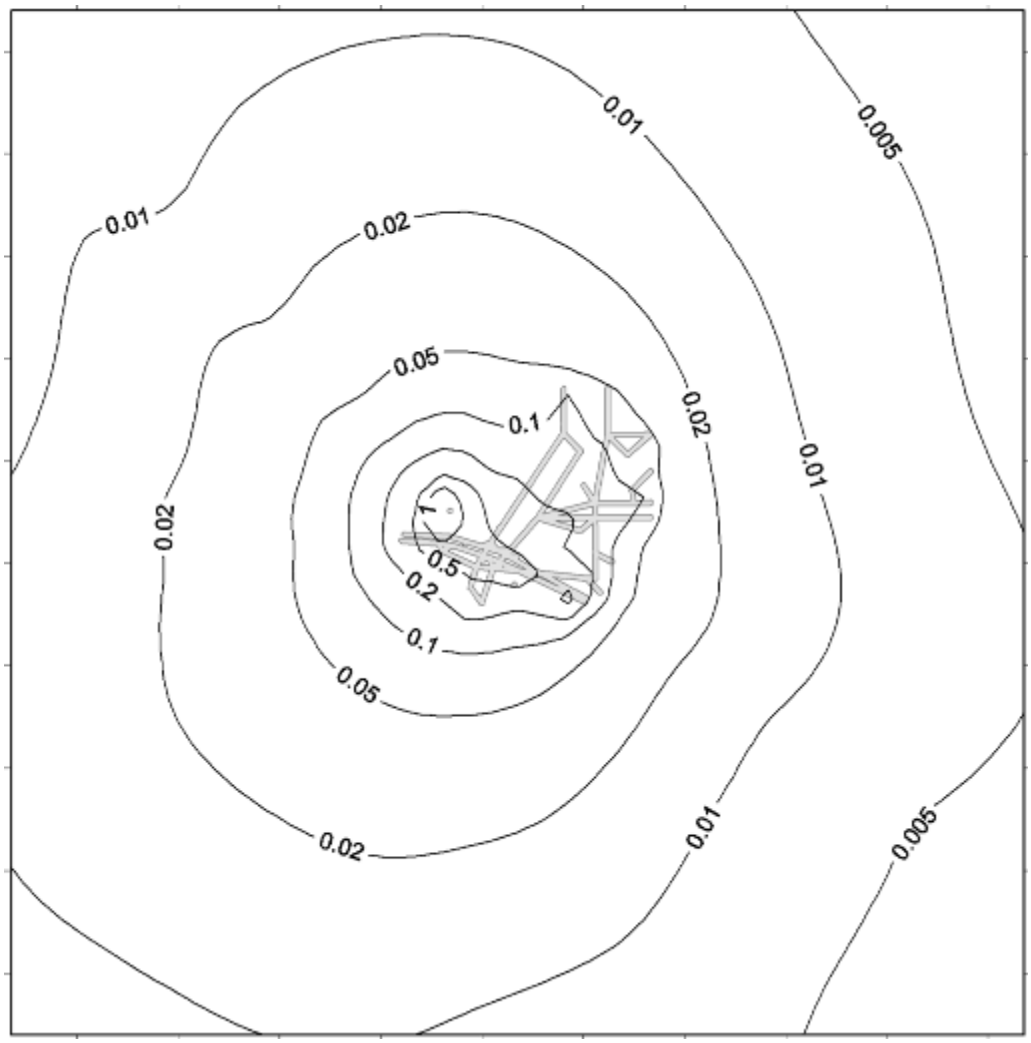


Figure C-4 Annual average diesel PM concentrations (μg/m^3) from off-site emission sources.

Figure C-4 shows annual average diesel PM concentrations from the off-site emissions. Highest values occur near the oil refinery and major freeways; the five highest concentrations at a receptor and their locations are provided in Table C-2.

Table C-2 The locations of estimated maximum annual diesel PM concentrations ($\mu g/m^3$) from off-site mobile and stationary source emissions

UTM-x (meters)	UTM-y (meters)	Mobile	Stationary	Total (Off-site)
553,200	4198,800	0.191	1.762	1.953
553,200	4198,800	0.090	1.407	1.497
553,700	4198,800	0.189	0.701	0.890
554,700	4197,800	0.789	0.053	0.842
553,700	4199,300	0.100	0.665	0.765

APPENDIX D

LOCOMOTIVE DIESEL PM EMISSION FACTORS

Locomotive Diesel PM Emission Factors (g/hr)												
Model Group	Tier	Throttle Setting										Source[1]
		Idle	DB	N1	N2	N3	N4	N5	N6	N7	N8	
Switcher	N	31.0	56.0	23.0	76.0	131.8	146.1	181.5	283.2	324.4	420.7	ARB and ENVIRON
GP-3x	N	38.0	72.0	31.0	110.0	177.7	194.8	241.2	383.4	435.3	570.9	ARB and ENVIRON
GP-4x	N	47.9	80.0	35.7	134.3	216.2	237.5	303.5	507.4	600.4	771.2	ARB and ENVIRON
GP-50	N	26.0	64.1	51.3	142.5	288.0	285.9	355.8	610.4	681.9	871.2	ARB and ENVIRON
GP-60	N	48.6	98.5	48.7	131.7	271.7	275.1	338.9	593.7	699.1	884.2	ARB and ENVIRON
GP-60	0	21.1	25.4	37.6	75.5	228.7	323.6	467.7	666.4	1058.5	1239.3	KCS7332
SD-7x	N	24.0	4.8	41.0	65.7	149.8	223.4	290.0	344.6	446.8	553.3	ARB and ENVIRON
SD-7x	0	14.8	15.1	36.8	61.1	220.1	349.0	407.1	796.5	958.1	1038.3	ARB and ENVIRON
SD-7x	1	29.2	31.8	37.1	66.2	219.3	295.9	436.7	713.2	783.2	847.7	NS2630[3]
SD-7x	2	55.4	59.5	38.3	134.2	271.7	300.4	335.2	551.5	672.0	704.2	UP8353[3]
SD-90	0	61.1	108.5	50.1	99.1	255.9	423.7	561.6	329.3	258.2	933.6	EMD 16V265H
Dash 7	N	65.0	180.5	108.2	121.2	322.6	302.9	307.7	268.4	275.2	341.2	ARB and ENVIRON
Dash 8	0	37.0	147.5	86.0	133.1	261.5	271.0	304.1	334.9	383.6	499.7	ARB and ENVIRON
Dash 9	N	32.1	53.9	54.2	108.1	197.3	267.3	343.9	392.4	397.3	573.3	SWRI 2000
Dash 9	0	33.8	50.7	56.1	117.4	205.7	243.9	571.5	514.6	496.9	460.3	average of ARB & CN2508[1]
Dash 9	1	16.9	88.4	62.1	140.2	272.8	354.5	393.4	466.4	445.1	632.1	CSXT595[2]
Dash 9	2	7.7	42.0	69.3	145.8	273.0	337.4	376.0	375.1	419.6	493.5	BNSF 7736[2]
C60-A	0	71.0	83.9	68.6	78.6	277.9	234.1	276.0	311.4	228.0	362.7	ARB and ENVIRON

Notes:

1. Except as noted below, these emission rates were originally developed for the ARB Roseville Rail Yard Study (October 2004), and were subsequently adjusted based on an average fuel sulfur content of 0.11% by ENVIRON as part of the BNSF efforts for their analyses for the Railyard MOU (Personal communication from Chris Lindhjem to R. Ireson, 2006).
2. Emission rates added by ENVIRON based on data produced in the AAR/SwRI Exhaust Plume Study (Personal communication from Steve Fritz to C. Lindhjem, 2006)
3. SD-70 emission rates taken from data produced in the AAR/SwRI Exhaust Plume Study (Personal communication from Steve Fritz to R. Ireson, 2006)

APPENDIX E

ESTIMATION OF DIESEL PM EMISSIONS FROM THE HHD TRUCKS TRAVELING BETWEEN RAILYARDS AND MAJOR FREEWAYS

Introduction:

Diesel-fueled heavy-heavy-duty (HHD) trucks (weight >33,001 pounds) traveling between the railyards and major freeways generate certain amount of diesel PM emissions, which contribute the off-site diesel PM emissions. Using the same methodology in estimating the off-site HHD trucks diesel PM emissions, ARB staff estimated the diesel PM emissions of HHD trucks traveling between the railyard gates and the freeways. Estimate of the diesel PM emissions from HHD diesel trucks can be performed based on average speed on the local streets, distances traveled locally between the gates and the freeways, truck count at the railyard gates, and the EMFAC model.

This analysis is conducted for the railyards whose diesel-fueled HHD trucks are a major contributor to the diesel PM emissions. At some railyards, HHD trucks also are idling or queuing outside of the railyards. These activities have been covered by the railyard on-site emission inventories and are not included in this analysis.

Methodology:

Estimating diesel PM emission from HHD diesel trucks can be performed by the following steps:

- Assume the average speed of trucks traveling on local streets between the railyard gates and the entrance/exit ramps of freeways.
- Select the most frequently traveled freeways for each railyard.
- Measure the distances from the gates to the ramps of selected freeways for each railyard using Google Earth Pro mapping tool.
- Use working draft of the EMFAC model to obtain emission factor (grams per mile) associated with truck type, fuel use, and model year (as described in Appendix A: Methodology for Estimating Off-site Diesel PM Mobile Source Emissions).
- Calculate the associated diesel PM emissions.

Step 1: Assume average speed of trucks traveling between the railyard gates and the freeways

The speeds of HHD trucks traveling on local streets range from 5 mph (start from the gate) to 35 mph (enter the freeway) depending on the time of travel, traffic conditions, etc. ARB staff assumes these speeds are averaged at about 20 mph.

Step 2: Select the most frequently traveled freeways for each railyard

This step is based on the assumption that the truck traffic heavily concentrated on one freeway than the others. According to the judges from the railyard operators, ARB staff chose the most frequently traveled freeways for each intermodal railyard, as described in Table E-1.

Table E-1 The most frequently traveled freeways by railyards and the distances from the railyard gates to the freeways

Railyards	County	Frequent Traveled Freeways	Roundtrip Distances from Gates to Freeways (miles)
UP Commerce	Los Angeles	I-710	2.6
BNSF Hobart	Los Angeles	I-710	2.6
BNSF Commerce/Eastern	Los Angeles	I-5	2.1
UP LATC	Los Angeles	I-5	0.7
UP Mira Loma	Los Angeles	SR-60	2.2
BNSF Richmond	Contra Costa	I-580	1.74

Step 3: Measure the distances from the railyard gates to the ramps of selected freeways using Google Earth Pro mapping tool.

The distances of the local streets from the railyard gates to the entrance/exit ramps of the selected freeways are estimated by Google Earth Pro mapping tools. The results are presented in Table 1.

Step 4: Use the working draft of the EMFAC to obtain emission factor

The working draft of EMFAC, rather than EMFAC 2007 was used in the analysis as described in Appendix A. Emission factors based on vehicle type (in this case HHD diesel trucks), fuel type, and speed were developed by EMFAC. These are composite emission factors based on the model year distribution for each county and provided in units of grams of emissions per mile traveled. Finally, a matrix of emission factors by speed and vehicle type was assembled for each county for heavy heavy-duty diesel trucks. The following is an example of such a matrix (Table E-2).

Table E-2 Emission factor (grams per mile) of HHD diesel trucks

Speed (mph)	L.A. County	Contra Costa County
12	2.37	1.32
20	**1.28**	**1.18**
45	0.73	0.71
60	1.10	1.01

Step 5: Calculate the HHD Truck diesel PM emissions

The calculation of diesel PM emissions can be expressed by the following equation:

Total Emission (grams) = EF X (Volume X Distance Traveled)

EF represents diesel PM emission factors. The volume of trucks count at the railyard's gates was provided from the railroad operation data.

The emissions inventory developed by this methodology only included diesel PM emissions from running exhaust, the primary diesel source from on-road mobile emissions. Emissions from other modes such as idling and starts were excluded.

The estimated HHD trucks diesel PM emissions for traveling between railyard gate and major freeways are presented in Table E-3.

Table E-3 Estimated diesel PM emissions of HHD trucks traveling from railyard gates to freeways

Railyard	Route	Distance Traveled**		Truck trips/day	Diesel PM	
		1-way miles	RT miles		grams/day***	tons/year
BNSF Hobart	Gate to I-710*	1.3	2.6	3,533	11,730	**4.72**
UP Mira Loma	Gate to CA-60*	1.1	2.2	321	901	**0.36**
UP Commerce	Gate to I-710*	1.3	2.6	1,026	3,406	**1.37**
BNSF Commerce/Eastern	Gate to I-5*	1.05	2.1	557	1,494	**0.60**
UP LATC	Gate to I-5*	0.35	0.7	512	457	**0.18**
BNSF Richmond	Gate to I-580*	0.87	1.74	153	314	**0.13**
Total						**7.36**

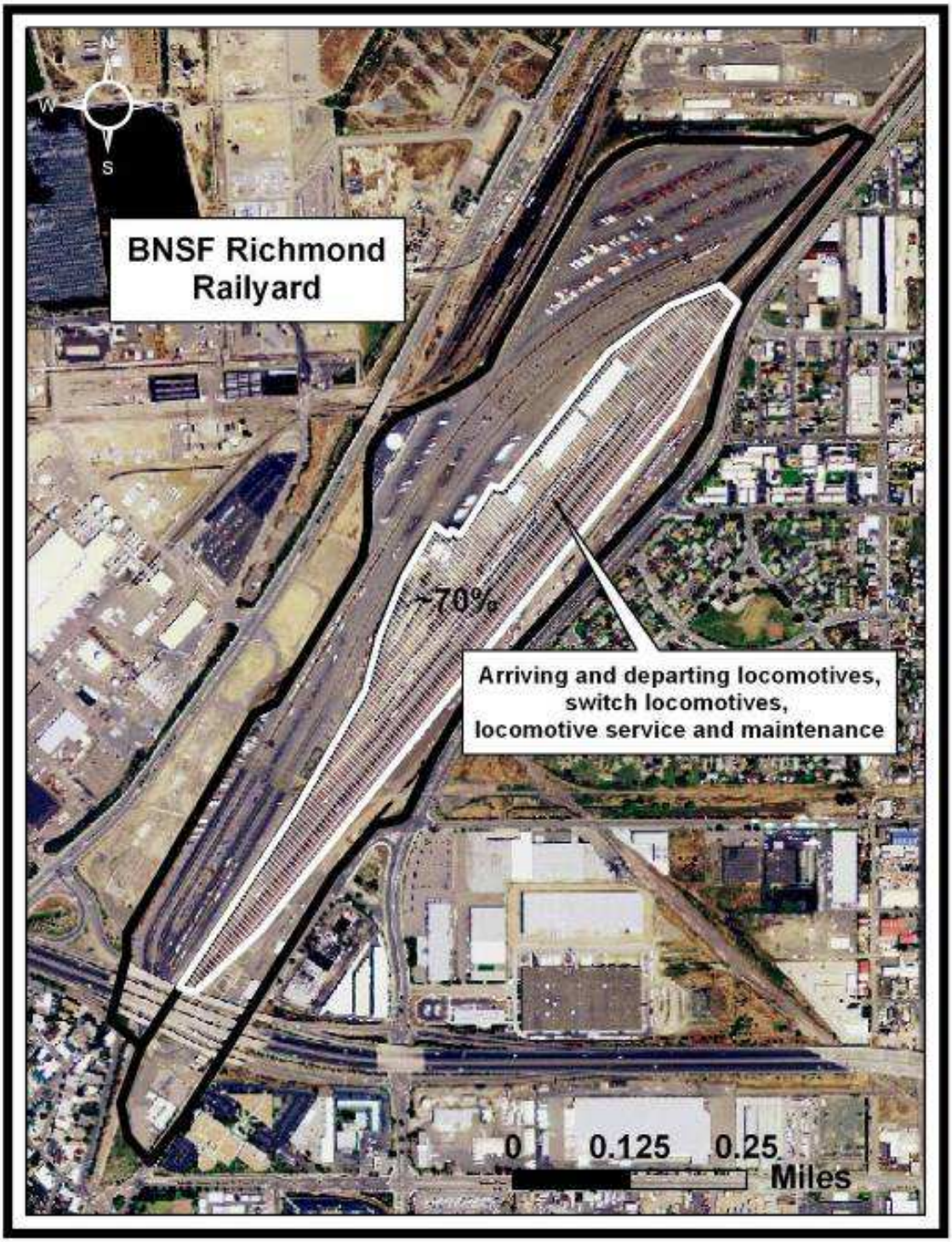
Note: * Assumed all trucks take this route

** Assumed all trucks' speeds are 20 mph from gate to freeway

*** HHD Emission Factors at 20 mph: 1.28 g/mi for LA County and 1.18 g/mi for Contra Costa County

APPENDIX F

SPATIAL ALLOCATIONS OF MAJOR DIESEL PM EMISSION SOURCES AT THE BNSF RICHMOND RAILYARD



Note: The emission inventory for the BNSF Richmond Railyard indicates that about 70% of the emissions are generated by arriving and departing locomotives (about 1.5 tons per year), switching operations (about 1.2 tons per year) and locomotive service and maintenance (about 0.5 ton per year).

APPENDIX G

AERMOD MODEL SENSITIVITY ANALYSIS OF METEOROLOGICAL DATA (ONE- VS. FIVE-YEAR DATA)

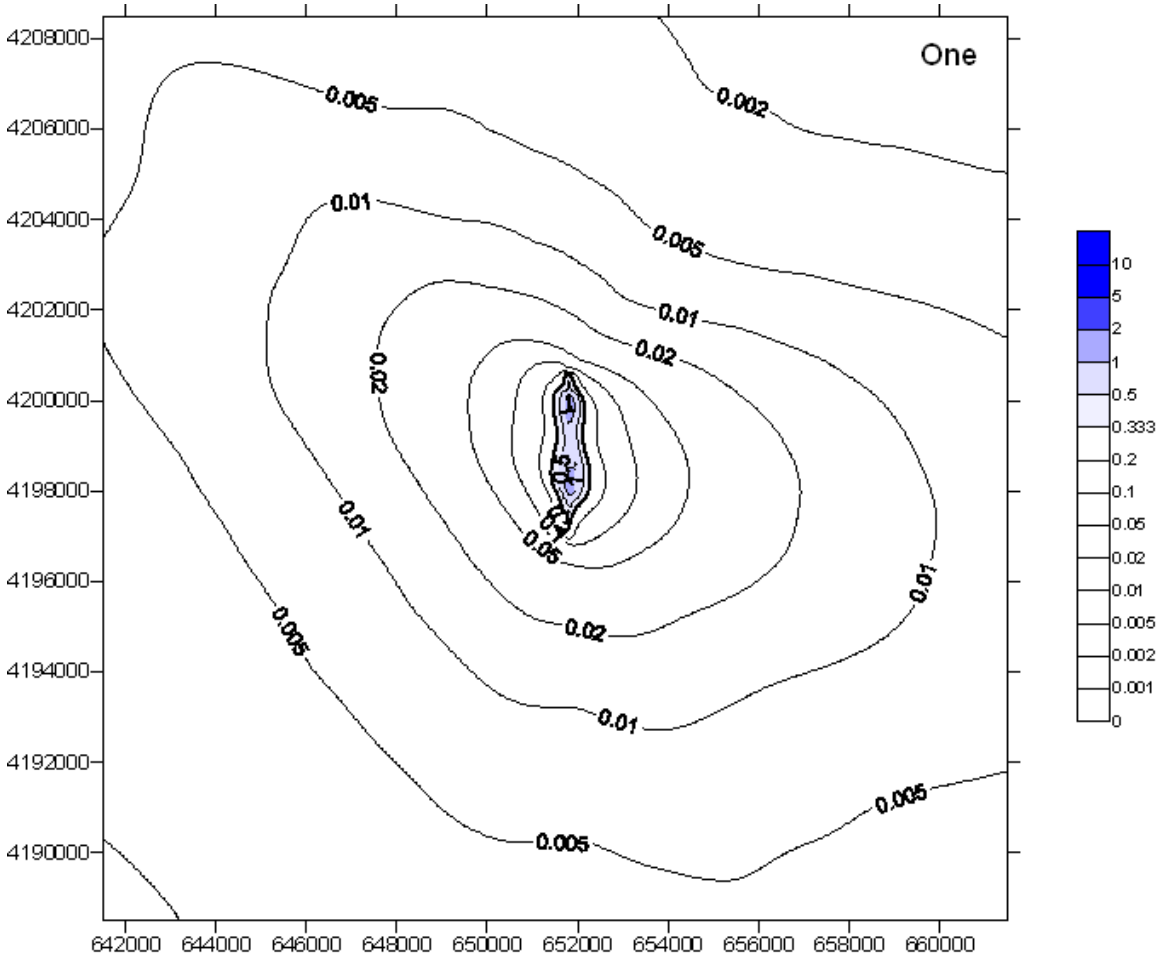


Figure G-1 AERMOD's Simulated Diesel PM Concentrations (due to On-site and Off-site Diesel PM Emissions) around UP Stockton Railyard Using One-year Meteorological Data..

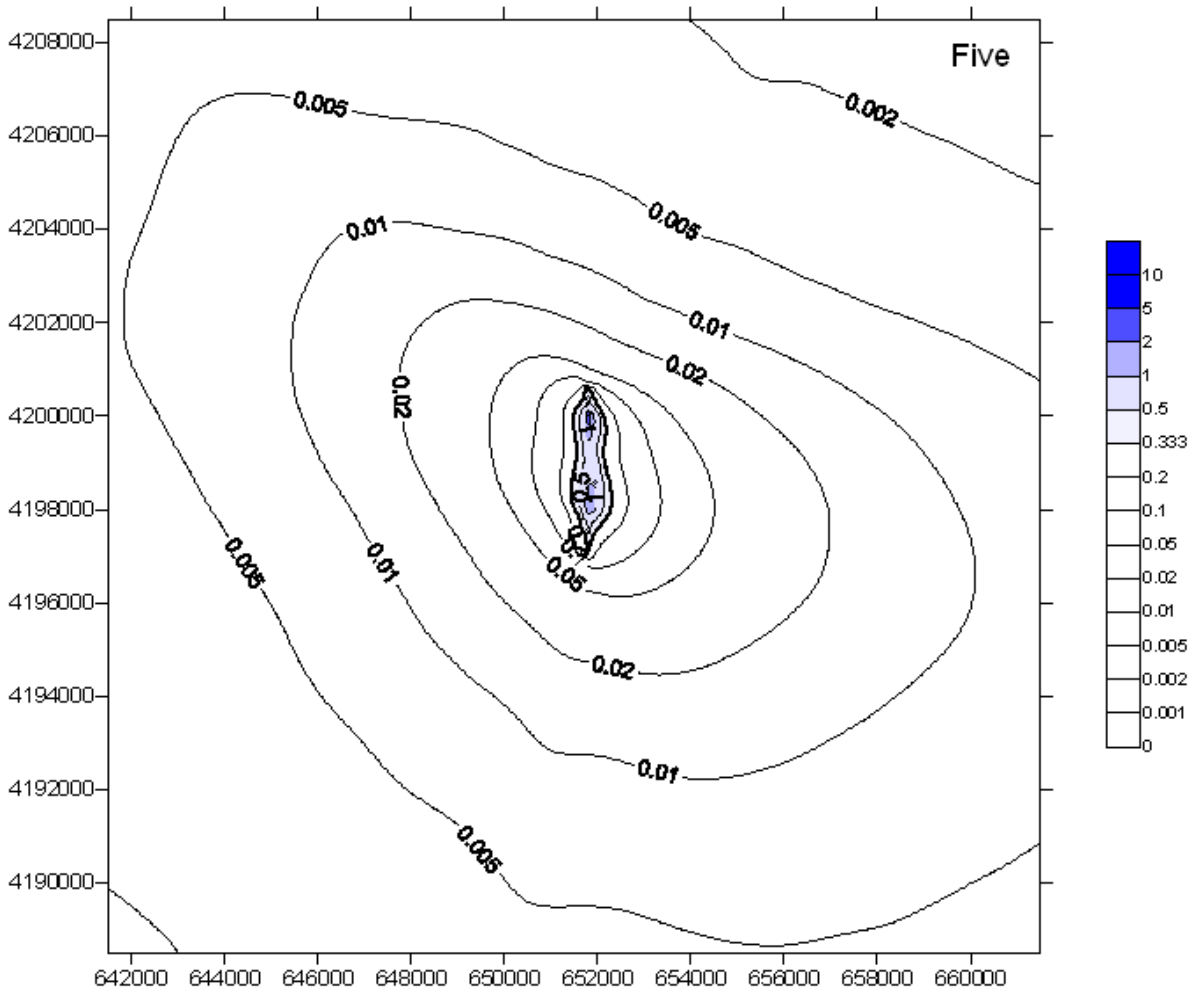


Figure G-2 AERMOD's Simulated Diesel PM Concentrations (due to On-site and Off-site Diesel PM Emissions) around UP Stockton Railyard Using Five-year Meteorological Data.