Review Copy

PORT OF OAKLAND 2005 SEAPORT AIR EMISSIONS INVENTORY

Prepared for

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August 8, 2007

ACKNOWLEDGEMENTS

The authors of this report gratefully acknowledge the contributions of several people for assisting in this study. The Port of Oakland staff that contributed to this report includes Marucia Britto, Project Manager, Anne Whittington, Annie Chu, Len Cardoza, Tim Leong, Joni Mantino, Chris Peterson, Gary Rutland, and Frank Tse. The California Air Resources Board staff contributing this study include Dan Donohoue, Bonnie Soriano, Michelle Houghton, Andy Alexis, Pingkuan Di, Nicole Dolney, Gregory Harris, Todd Sax, Carolyn Suer, Peggy Taricco, Chengfeng Wang, and Seungju Yoon. The Bay Area Air Quality Management District (BAAQMD) staff working on this study included Phil Martien, Tan Dinh, Amir Fanai, Tirlochan Mangat, and Cuong Tran. Ken Levin of the San Francisco Bar Pilots and Allen Steinbrugge of the Marine Exchange of the San Francisco Bay Region helped significantly with the marine vessel activity.

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GLOSSARY

Adjustment factors: Used to adjust emissions or engine load or other situations for non-standard conditions.

Assist mode: Period when a tugboat is engaged in assisting a ship to/from the harbor and to/from its berth.

Auxiliary engine: Used to drive on-board electrical generators to provide electric power or to operate equipment on board the vessel.

Auxiliary power: Typically electric power generated via the auxiliary engine.

Barge: A flat-bottomed craft built mainly for water transport of heavy goods and, in this report, dredge spoils. Most barges are not self-propelled and need to be moved by tugboats towing or towboats pushing them.

Bollard pull class: A power measure of the tug's capacity to push or pull ships.

Brake-specific fuel consumption (BSFC): This is the measure of the engines efficiency in terms of the fuel consumption rate (weight of fuel burned per hour) divided by the engine load or output (e.g. kilowatts). For marine engines a different term, standard fuel oil consumption (SFOC), is sometimes used to describe the identical efficiency measure.

Cargo handling equipment: Equipment used to transfer cargo or containers. Cargo handling equipment is used to move containers from one mode of transportation to another, or from a storage area to a truck chassis, for example. Typical cargo handling equipment at the Port of Oakland include yard trucks, RTG cranes, top and side picks, forklifts, and other general industrial equipment.

Clamshell dredge: Hangs from an onboard crane, or is carried by a hydraulic arm, or is mounted like on a dragline and grabs dredge material.

CO: carbon monoxide.

Cutter head dredge: Also known as a suction dredge, this dredge uses a suction tube with a cutter head at the suction inlet, to loosen the earth and transport it to the suction mouth. The cutter can also be used for hard surface materials like gravel or rock. The dredged soil is usually sucked up by a wear resistant centrifugal pump and discharged through a pipe line or to a barge. From Wikipedia.

Cruise modes: The vessel mode while traveling in the open ocean or in an area without speed restrictions.

Dead weight tonnage (DWT): Dead Weight Tonnage (DWT) is the weight of the ship, all her stores and fuel, pumps and boilers, crews quarters with crew and the cargo. In other words, how much water the vessel displaces when loaded.

Deep draft marine vessel: Deep draft vessels are larger vessels typically with draft in excess of 14 feet measured at the highest waterline and the bottom of the vessel. Other works describe this type of vessel as only Ocean-Going Vessels (OGV), but deep draft is used in this report to distinguish and avoid confusion between these larger vessels and smaller ocean-going tugs, supply vessels, and fishing vessels that could also be considered "ocean-going vessels".

DPM: Diesel particulate matter

Dredging: An excavation activity or operation carried out underwater typically for the purpose of the removal of materials from the bottom of channels and berths to allow vessels with deep drafts.

Emission estimation: Method by which the quantity of a particular pollutant emission is estimated.

Emission factor: The average emission rate of a given pollutant for a given source, relative to a unit of activity. For example, grams per kilowatt of actual power or grams per hour of engine operation.

Emissions inventory: A listing of all the pollutant emissions included in the study.

g/kW-hr: This is the unit for reporting emission or fuel consumption factors, and means the grams per kilowatt-hour of work performed. Work and energy are used synonymously in this context.

HC: hydrocarbon emissions

Hotelling: On-board activities while a ship is in port and at its berth or anchored nearby.

Hydrolyze: To add water to a chemical compound.

Hydrated sulfuric acid: sulfuric acid to which water had been added.

Installed power: The engine power available on the vessel. The term most often refers only to the propulsion power available on the vessel, but could incorporate auxiliary engine power as well.

Intermodal site: Location where cargo is transferred from one form of transportation to another, for example between an ocean-going vessel and a railroad car.

Knot: A nautical unit of speed meaning one nautical mile per hour and is equal to about 1.15 statute miles per hour.

Link: A defined portion of a vessel's, train's, or truck's travel. For example a link was established extending from the November Buoy out in the ocean to the location where the pilot boards the vessel. A series of links defines all of the movements within a defined area or a trip.

Load: The actual power output of the vessel's engines or generator. The load is typically the rated maximum power of the engine multiplied by the load factor if not measured directly.

Load factor: Average engine load expressed as a fraction or percentage of rated power.

Maximum power: A power rating usually provided by the engine manufacturer that states the maximum continuous power available for an engine.

Medium speed engine: A 4-stroke engine used for auxiliary power and rarely, for propulsion. Medium speed engines typically have rated speeds of greater than 250 revolutions per minute.

Mode: Defines a specific set of activities, for example, a tug's transit mode includes travel time to/from a port berth while escorting a vessel.

NOx: nitrogen oxides. Includes all different nitrogen oxide compounds.

Ocean-going vessels (OGV): Vessels equipped for travel across the open oceans. These do not include the vessels used exclusively in the harbor, which are covered in this report under commercial harbor craft. And in this report OGV are restricted to the deep draft vessels that carry containers.

Off-Road activity: Activity that occurs off of established roadways. Activity within a marine terminal yard is considered off-road activity.

On-road activity: Activity that occurs on established roadways.

Operation mode: the current mode of operation for a ship – cruise, RSV, maneuver, or berth.

Pilot Buoy: used to mark a maritime administrative area to allow boats and ships to navigate safely.

PM10: particulate matter emissions less than 10 micrometers in diameter.

PM2.5: particulate matter emissions less than 2.5 micrometers in diameter

Port of Call (POC): A specified port where a ship docks.

Port berth: A location in a port or harbour used specifically for mooring vessels.

Propulsion engine: Shipboard engine used to propel the ship.

Propulsion power demand: Power used to drive the propeller and the ship.

Rated power: A guideline set by the manufacturer as a maximum power that the engine can produce continuously.

Reefer plug: Plug allowing a refrigerator container to plug into an outlet connected to the ship's power generation.

ROG: reactive organic gas; all hydrocarbon compounds that can assist in producing ozone (smog). Includes HC plus aldehyde and alcohol compounds minus methane.

Roll on/roll off vessels: Ships designed to carry wheeled cargo such as automobiles, trailers, or railway carriages that drive or are pulled onto the vessels.

RSZ: Reduced speed zone.

RTG Crane: Rubber tired gantry (RTG) crane is sometimes but rarely called a straddle crane because the crane 'straddles' a row of containers stored in the terminal yard as it drives up and down the row.

Shoaling: Shoaling is term used in this report to describe subsidence of the shore or other filling of the navigation channel near shore.

Ship Lift: Lifting a container (box) from or onto a vessel.

SO_2: Sulfur dioxide.

SOx: Oxides of sulfur. Interchangeable term with sulfur dioxide but include some other minor forms of sulfur oxides.

Spatial allocation: Areas on a map allocating a specific set of activities.

Spatial scope: A specified area on a map that defines the area covered in study.

Slow speed engine: Typically a 2-stroke engine or an engine that run below 250 rpm's.

Standard fuel oil consumption (SFOC): See brake specific fuel consumption (BSFC).

Steam boiler: Boiler used to create steam or hot water using external combustion.

Steam turbines: A mechanical device that extracts thermal energy from pressurized steam, and converts it into useful mechanical work.

Tender: a utility vessel used to service another type of vessel, for example, servicing a clamshell dredge.

Time in mode: The amount of time a vessel remains in a specified mode, for example the amount of time a ship spends in the reduced speed zone.

Tons: Represents short tons (2,000 lbs) unless otherwise noted.

Tonnes: Metric tons (1,000 kg)

Transit mode: The time a tug spends traveling to/from its berth to the pick-up location.

Tug class: A tugboat's Bollard pull class designation.

Two-stroke engine: Engine designed so that it completes the four processes of internal combustion (intake, compression, power, exhaust) in only two strokes of the piston.

EXECUTIVE SUMMARY

The Port of Oakland (Port) 2005 Seaport Air Emissions Inventory (Emissions Inventory) identifies and quantifies air emissions from the Port's maritime activities, organized by the major source categories:

- Deep-Draft Ocean-Going Marine Vessels (OGV)
- Commercial Harbor Craft (dredging and assist tugs)
- Cargo Handling Equipment (CHE)
- Trucking (container movements)
- Locomotives

Since 1927, the Port of Oakland has managed the efficient movement of goods in and out of the region, bringing the benefits of the global marketplace to the San Francisco Bay Area. The Port manages maritime, airport and commercial real estate operations along 19 miles of waterfront on the eastern shore of San Francisco Bay. The Port's seaport is the fourth busiest container port in the United States. The container terminals, which are leased to terminal operators, encompass 19 active deepwater berths and 37 gantry container cranes. The Port is an independent department of the City of Oakland, acting through the Board of Port Commissioners. All Port activities are funded through operating income or through revenue bonds; no state or local tax money is used to support operations.

The Port of Oakland voluntarily chose to prepare an air emissions inventory of its seaport in advance of any regulatory directive. This emissions inventory highlights the Port's commitment to improve understanding of the nature, location and magnitude of emissions from its maritime-related operations. The Port is committed to conducting its operations in the most sustainable and environmentally sensitive manner possible.

The purpose of this inventory is to better understand the emissions that occur from typical Port activities so the Port can better address its impact on air quality. The inventory will:

- Establish a baseline for evaluating changes in Port emissions as air pollution control regulations are phased in.
- Provide an input to regional air quality plans – plans that are required by the Federal and State Clean Air Acts and are designed to map the region's approach to attaining Federal and State ambient air quality standards.
- Inform local, state and federal regulatory decision-makers in their effort to reduce air emissions from Port-related sources and improve air quality.
- Provide air quality background information to be used in future environmental documents.
- Provide Port specific emission inventory data to inform and support special studies such as the West Oakland Health Risk Assessment, currently under development by the California Air Resources Board (ARB).
- As the Port develops an air quality plan for the Seaport, the emissions inventory will provide a technical basis for setting priorities and evaluating the cost-effectiveness and potential benefits of air pollutant control measures.

The inventory provides estimates for emissions of five “criteria” air pollutants, reported as tons per year. The pollutants are:

- Reactive organic gas (ROG)
- Carbon monoxide (CO)
- Nitrogen Oxides (NOx)
- Particulate matter (including diesel) (PM)
- Sulfur dioxides (SOx as SO2)

The particulate matter estimated in this report is primarily diesel particulate matter (DPM), which is also a toxic air contaminant that has been listed by ARB. A small percent of particulate matter emissions, typically less than 5% of the total, come from boilers and LPG-powered engines, and thus are not DPM.

Introduction, Scope and Coordination

This is an inventory of the air emissions generated by maritime activities conducted by the Port of Oakland’s tenants. On the water side, the spatial domain of the inventory includes Port-related marine vessel transit from dockside out through the Golden Gate Bridge, to the first outer buoys beyond the Pilot Buoy, approximately 30 miles away from the Port. On the landside, the spatial scope of the inventory includes nine marine terminals, one rail yard, and the road traffic between those facilities and the nearest freeway interchanges. The Port area was defined approximately by the boundaries of I-80, I-880, and the Howard Terminals (Berths 67 and 68) adjacent to Jack London Square. Within this defined geographic area, three significant areas were specifically excluded: the Schnitzer Steel terminal, the Union Pacific rail yard, and the former Oakland Army Base located between Maritime Street and I-880. These areas were not controlled or operated by the Port of Oakland in 2005. Figures 1-1 and 2-1 in the body of the report illustrate the spatial scope of the inventory.

With the exception of a limited roll-on and roll-off activity at Berth 34, the Port of Oakland operated almost exclusively as a container port in 2005. The Port discontinued much of the roll-on and roll-off activity during 2005. All 1,916 calls were by deep-draft vessels designed as container ships, or built for other uses but converted to transport containers. On the land side, Port terminals operated as a collection of intermodal sites where cargo handling equipment transferred containers to and from vessels to truck or rail transportation.

ENVIRON International, with assistance from the Sierra Nevada Air Quality Group, prepared the emissions inventory for the Port. ENVIRON assembled the emissions inventory by analyzing the time-in-mode, load or speed, and engine characteristics of the marine vessels and other equipment used to transport container cargo. The time-in-mode characteristic allowed for the emissions inventory to be spatially (locationally) defined. Input data from previous studies and literature reviews, or ARB input data or models, were used when more precise estimates could not be generated during the period of this study.

ENVIRON and the Port worked closely with ARB and the Bay Area Air Quality Management District (BAAQMD) in preparing this inventory, coordinating through weekly conference calls which included discussion of many input factors and review of emissions inventory methodologies. Additionally, in January 2007 the Port released to the public a draft working document presenting the Port-proposed methodology for estimating emissions for each source category, along with ARB's comments on the proposed methodology. Public comment on the methodology was accepted through a Port-sponsored meeting on January 31, 2007; no comments directly related to the methodology were received.

The Port and its contractors provided ARB with detailed spatial information on particulate emissions so the inventory could be used as input to the dispersion modeling that ARB will perform for the West Oakland Health Risk Assessment.

Technical Approach to Major Source Categories

Emissions were estimated for the five source categories as described below, and a summary of the emission results are presented in Table ES-1.

Ocean-going Marine Vessels. Ocean-going vessel emissions were estimated in several operating modes: cruising, cruising in the reduced speed zone (RSZ) inside the Bay, maneuvering (lower speed operation between the Bay Bridge and their berths in the Inner or Outer Harbors), and hotelling (vessels at berth being loaded and offloaded and at anchor in the Bay). Separate mode estimates are important because of location, especially the proximity to on-shore areas like West Oakland. Emissions sources included the vessels' main propulsion engines, auxiliary engines, and small auxiliary boilers. Except for the boilers, all emission sources in ocean-going vessels were diesel engines.

About three-fourths of the ocean-going vessels that called at the Port of Oakland in 2005 were classified as "larger" vessels (750 feet or longer). The age of vessels ranged from new to 35 years. Newer vessels that were five years old or less made about one-third of the vessel calls.

Harbor Craft. Smaller marine vessels are included in a category described as "Commercial Harbor Craft". Vessels in this category are associated with Port maritime operations and consist primarily of assist tugs and a few small boats that supported maintenance dredging. One or two tugs assist all vessels during the maneuvering mode as they enter and leave the Port. At least eight tug companies provided assist services, some located in the immediate vicinity of the Port and others in San Francisco and Richmond. Information from several data sources was used to characterize the tug fleet and installed equipment. The inventory includes tug emissions estimates in two operating modes, vessel assist and transit to and from the vessel assist point. Emissions sources include tug main propulsion and auxiliary diesel engines.

The inventory also addresses emissions from operation and maintenance dredging, which occurs annually to maintain safe depths in Federal channels and at Port berths. Dredging activity was low in 2005 compared to average years. Emissions were estimated from dredges, dredge tenders, crew and work boats, and tugs that push barges containing dredged material to disposal or reuse areas. Dredging equipment is typically powered by diesel engines, though in 2005 most maintenance dredged materials were removed by an electric powered dredge, which was at the Port deepening the berths to -50 feet.

Cargo Handling Equipment. ENVIRON collected specific activity information for cargo handling equipment used in the Port of Oakland in 2005 to move containers within maritime and rail yards. ENVIRON and ARB determined annual emissions for each piece of equipment according to engine characteristics (model year, rated power, and equipment type) and equipment operation (hours of operation and fuel consumption rates). Yard trucks (sometimes called hostlers), side picks and top picks were the most prevalent types of equipment. Other equipment included rubber tired gantry cranes, forklifts, and tractors. Nearly 90% of the equipment was powered by diesel engines and many units had been retrofitted with emissions control devices or repowered under a Port incentive program. About 10% of the cargo handling units were fueled by liquid petroleum gas (LPG).

An important input to calculating emissions from cargo handling equipment is load factor, which describes the average relative load in-use as a fraction of maximum power. Load factors can be difficult to discern because the duty cycle of equipment can vary widely during normal operation, with periods of high power operation interspersed with periods of extended zero-load idling. The load factor methodology as used in the emissions estimates, therefore, represents an approximate estimate for overall activity reflecting typical engine loads during normal equipment operation. Emissions estimates for container handling equipment are reported as a range in Section 4 to reflect the uncertainty in the average load.

Trucking. Maritime operations create a demand for a significant number of truck trips, including short trips within the Port moving containers from marine terminals to other locations. Trucks arrive at the Port terminals primarily via freeway interchanges or rail yards, and leave through the same general exits. Even if trucks arrive via surface streets, the trips primarily pass through the intersections that define the primary freeway interchanges. The spatial scope of the truck emissions inventory was therefore defined to include truck routes from the marine terminals to each of three freeway interchanges and the two rail yards. This inventory does not include emissions from Port trucks operating on freeways.

ENVIRON's general approach to estimate truck emissions was to determine truck travel by estimating the number of truck trips to and from the marine terminals, the trip mileage to and from the terminals, and the average link and trip speed. Input activity data used to develop the emission estimates was derived from several sources. To estimate the truck trips, the Port of Oakland conducted an in-depth survey with the terminal operators to determine the gate counts by configuration of each truck (as a tractor only or the tractor with a trailer) at the entrance and exit to the terminals. ENVIRON then estimated truck trips from truck gate count data and container lift data provided by the port.

Emissions from trucks depend on the age distribution of the transport trucks as well as site-specific conditions. Age distribution plays a significant role because of regulations over the past decades that make newer trucks significantly cleaner than older trucks. In the past, some studies have shown that Port trucks tend to be older than average. In 2006, as part of the emissions inventory effort, the Port conducted a specially designed study, reviewed by ARB, to determine a Port of Oakland specific truck age distribution. The results of this study showed the near nonexistence of post-1999 trucks (trucks younger than 6 years) at the Port of Oakland. The age distribution of the fleet serving the Port was primarily between model years 1993 and 1999, inclusive, accounting for 80% of all truck trips.

ENVIRON estimated emissions for four truck operating modes: idling at terminal queues, in-terminal idling, in-terminal driving, and over-the-road driving to and from the rail yard and freeway exits. ENVIRON used the most recent version (at the time of this study, January 2007) of the EMFAC2007 model to estimate emission rates for the various modes, as presented in Section 5. For consistency with previous ARB studies, a pre-release beta version of EMFAC was used for the truck emissions presented in Table ES-1.

Locomotive. The Oakland International Gateway (OIG) rail yard is a Port of Oakland terminal operated under a lease by Burlington Northern Santa Fe (BNSF) railway. BNSF uses the OIG as a near dock transfer point for Port of Oakland maritime traffic and only Port containers are handled at the yard. Locomotives and trains enter the general port area from the north via the Union Pacific (UP) lines, and leave in the same direction via tracks going north through Richmond and onto BNSF lines out of the Bay Area. The Union Pacific rail yard (UP Railport) that sits adjacent to the Port terminals serves as an intermodal yard for freight movements through the port, but it is not included in the Port’s emissions inventory because it is independently operated and also handles non-Port cargo. UP has provided the ARB with an independent analysis of the emissions from its Oakland facility.

Because different locomotive and engine models have different emission characteristics, it was important to characterize the types and models of the locomotives that arrive/depart and are serviced at OIG. ENVIRON estimated the locomotive fleet fractions for different locomotive types and models using data provided by BNSF. The number of engines moving through the yard was determined from a BNSF-supplied train arrival and departure database. One switching engine is usually assigned to the OIG yard with very similar engine models used for this purpose, and its operations were included in this emission estimates.

Results

The results of the Port of Oakland Seaport Emissions Inventory are summarized in Table ES-1.

Table ES-1. Port of Oakland emissions summary by emission source category – tons in 2005.

Emission Source Category	ROG	CO	NOx	PM	SO2
Ocean-going vessels (OGV)	117	235	2,484	219.5[1]	1,413
Harbor Craft	22	83	345	13.4[2]	3
CHE	53	408	766	21.7[1, 2]	7
Truck	49	149	334	15.9[2]	2
Locomotive	7	11	76	2.0	2
Total	**248**	**886**	**4,005**	**272.5**	**1,427**

[1] A small portion of the particulate in these categories includes boiler or LPG engine emissions; most of the emissions (208.5 tons from OGV and 21.2 tons from CHE) are from diesel exhaust.

[2] Alternative emission estimates, primarily for assist tugs, cargo handling equipment and trucks, are presented in sections 3, 4 and 5 of the report, respectively, to reflect technical uncertainty inherent in making emissions estimates of complex activities and the sensitivity of the estimate to site-specific versus general inputs.

Ocean-going vessels constitutes the largest source category for all pollutants, producing 80-85% of estimated particulate matter emissions and the major portion of other pollutants within the scope of this emissions inventory. Table ES-2 shows a more detailed assessment of ocean going vessel emissions by mode of operation. Trucks, harbor craft, and cargo handling equipment each produced 5-10% of the estimated Port-related particulate matter emissions. Locomotives from the one rail yard included in this study produced a small fraction of the total emissions.

It is important to keep in mind that location of emissions is often as significant as the total quantity because emissions generated close to community receptors will have a greater effect on human health risk on a per ton basis. The impact of the various source categories on West Oakland air quality will not necessarily be directly proportional to the magnitude of their emissions because proximity to the community is not addressed in this emissions inventory. For example, the particulate matter emissions from ocean-going vessels in cruising mode, which occurs outside the Golden Gate, will have less impact to sensitive receptors in Oakland than emissions that occur closer to shore during the maneuvering or hotelling modes. The greater the distance is between the emission source and affected area, the lower the pollutant concentration is at a sensitive receptor.

Table ES-2. OGV emissions summary by mode, using ARB-specified activity emission factors – tons in 2005.

Emission Mode	ROG	CO	NOx	PM	SO2
OGV – Cruise	16	46	588	52.4	383
OGV – RSZ	27	63	647	60.2	395
OGV – Maneuver	53	58	458	43.6	157
OGV – Berth	21	65	767	61.3	464
OGV – Anchorage	1	2	24	2.0	15
OGV subtotal	**117**	**235**	**2,484**	**219.5**	**1,413**

An emissions inventory is best understood as an estimate of the quantity of pollutants that a group of sources produce in a given area, over a prescribed period of time. Emissions inventories should be used with care and in conjunction with other information and tools to evaluate and assess air quality problems.

1. INTRODUCTION

1.1 Purpose and Background

The Port of Oakland (Port) has prepared this 2005 Seaport Air Emissions Inventory (emissions inventory) for the purpose of identifying and quantifying the air quality impacts from the maritime operations of the Port and its tenants. With a baseline inventory, the Port will be better able to target its air quality improvement measures at emissions reductions within the major categories of maritime equipment:

- Deep-Draft Ocean-Going Marine Vessels (OGV)
- Commercial Harbor Craft (dredging and assist tugs)
- Cargo Handling Equipment (CHE)
- Trucking (container movements)
- Locomotives

The Port voluntarily chose to prepare an air emissions inventory of its seaport to help in air quality planning and to meet its commitment to develop and implement a criteria pollutant reduction program that defines measurable reductions within specific time periods, aimed at reducing or off-setting Port-related emissions in West Oakland from its maritime-related operations.[1] Because annual emissions from operations vary over time due to changes in cargo volume and to the phasing in of regulations that control emissions, the most recent year for which complete data was available – calendar year 2005 – was chosen as a baseline for future comparisons.

This emissions inventory highlights the Port's commitment to improve understanding of the nature, location and magnitude of emissions from its maritime-related operations.

1.2 Considerations When Using Emissions Inventories

Emissions inventories are used for multiple purposes: to analyze air quality, to develop pollutant control strategies or plans, and to track and communicate progress toward air quality goals. Emissions inventories are essential tools, but they have some inherent shortcomings that are often overlooked and lead to misconceptions about their use and value. The term "inventory" is something of a misnomer because it implies greater precision in "counting" emissions than is really the case. An emissions inventory is better understood as an estimate of the quantity of pollutants that a group of sources produce in a given area, over a prescribed period of time. The methods of making estimates are usually very technical in nature, a characteristic that makes the limitations of emissions inventories less transparent to the general public.

The accuracy of emissions estimates varies due to a number of factors. Even a well-conducted, detailed and professional inventory, such as this one, does not have access to direct emissions measurements from the specific, individual sources being studied. As a result, it is necessary to rely on surrogate information to characterize sources, describe source activities, and specify

[1] Oakland Army Base Redevelopment Area Final Environmental Impact Report, Mitigation Monitoring and Reporting Program (Mitigations 4.4-3 and 4.4-4), 2002.

pollutant emission rates. Emissions estimation methodologies are continuously in flux, changing and evolving over time as better and more accurate information becomes available. Historically, emissions inventory updates have revealed previously overlooked information about sources and source activity that has substantially changed overall emissions estimates. For example, because of new information made available in 2006, the Air Resources Board (ARB) changed its on-road vehicle emission model, EMFAC, resulting in higher per-truck diesel particulate emissions rates than those originally used to estimate truck emissions from the Ports of Los Angeles and Long Beach in 2004. As a result, emissions inventories conducted even a few years apart may not be directly comparable. Another important consideration in interpreting emissions inventories is the somewhat counter-intuitive fact that there can be a poor correlation between the magnitude of emissions and an air quality impact. The importance of a given ton of emissions may differ from another ton because of the location at which it is emitted, because of the meteorological conditions that affect its dispersion, or because of the chemical reactions that occur in the atmosphere. Emissions inventories should be used with care and in conjunction with other information and tools to evaluate and assess air quality problems.

1.3 Important Features of the Port of Oakland Seaport Emissions Inventory

Some features of the Port emissions inventory that should be kept in mind throughout this report are described below.

Scope

The inventory estimates emissions from the Port's, tenants' and other maritime operations that occurred in the calendar year 2005. It is not intended to represent emissions in other years, or emissions outside the geographic domains identified for each major source category, as described below in "Technical Approach". Tenants for which emissions were estimated include shipping lines, marine terminal operators, and the railyard operator. Non-tenant maritime operations for which emissions were estimated include truckers, dredgers, tugs, and other assist vessels.

Sources

The inventory focuses on the largest sources of air emissions from maritime operations, which, except for ship boilers, are all diesel engines powering ocean-going vessels, harborcraft assisting those vessels and dredging vessel berths, cargo handling equipment at marine terminals and railyards, and locomotives and trucks engaged in transport of maritime cargo containers. The inventory does not address other sources, such as gasoline-powered, light-duty vehicles, that operated at the Port.

1.4 Criteria Air Pollutants

The inventory provides estimates for emissions of five "criteria" air pollutants described here, reported as tons per year.[2]

Reactive Organic Gases	Generally colorless gases that are emitted during combustion or through evaporation. They react with other chemicals in the ambient air to form ozone or particulate matter, both of which can have adverse health effects at higher concentrations
Carbon Monoxide	Colorless gas that is a product of incomplete combustion. Has an adverse health effect at higher concentrations.
Nitrogen Oxides	Nitrogen oxides include nitric oxide and nitrogen dioxide. Nitrogen dioxide is a light brown gas formed during combustion from reactions with both the nitrogen in the fuel or the combustion air. Nitrogen dioxide has adverse health effects at higher concentrations. Both nitrogen dioxide and nitric oxide participate in the formation of ozone and particulate matter in the ambient air.
Particulate Matter	Solid or liquid particles that form from a variety of chemical reactions during the combustion process. Solid particulate may also be emitted from activities that involve abrasion or friction. Have adverse health effects at higher concentrations.
Sulfur Dioxide	Gas that is formed during combustion of a fuel that contains sulfur. Has adverse health effects at higher concentrations and participates in the formation of particulate matter in the ambient air.

1.5 Particulate Matter

The particulate matter estimated in this report is primarily diesel particulate matter, which is a toxic air contaminant as listed by the ARB. A small portion of particulate emissions was from non-diesel LPG fueled cargo handling equipment, as noted in Section 4.

1.6 ARB Health Risk Assessment

The ARB, in cooperation with the Bay Area Air Quality Management District (BAAQMD), is conducting modeling studies to estimate the health risks from diesel exhaust in West Oakland. The Port and the Union Pacific Railroad are both providing information on their local marine and rail operations for these health risk assessments, while ARB and BAAQMD are compiling information on other sources of diesel emissions (including non-Port marine operations) that may affect the West Oakland community. A draft report is expected to be ready in late 2007.

Therefore, the inventory was closely coordinated with the ARB and BAAQMD, and major refinements were made to the inventory during its development so its estimates of diesel particulate matter could be used for the West Oakland health risk assessment. The most important refinements were:

[2] The term "criteria" pollutant is applied to pollutants for which an ambient air quality standard has been set, or which are chemical precursors to pollutants for which an ambient air quality standard has been set.

- Emissions were temporally and spatially distributed so they could be used as input to the ARB's air quality dispersion model. These spatial distributions will be discussed in the health risk assessment report that will be prepared by ARB, but are not addressed in this report.
- For some source categories, primarily assist tugs and cargo handling equipment, both ARB and Port of Oakland-specific emissions estimates were included in order to provide emissions consistent with the emissions estimation methodologies used by ARB in previous studies. As a result, this Port inventory contains a range of annual emissions estimates for these categories, rather than a single value.

1.7 Technical Approach

This report outlines the maritime emissions inventory from mobile sources at the Port of Oakland in 2005 and includes the input data and methodology used in estimating emissions. The emissions inventory includes the following major source categories:

- Deep-Draft Ocean-Going Marine Vessels (OGV)
- Commercial Harbor Craft (dredging and assist tugs)
- Cargo Handling Equipment (CHE)
- Trucking (container movements)
- Locomotives

This is an inventory of the air emissions generated by maritime activities conducted by the Port of Oakland's tenants. On the water side, the spatial domain of the inventory includes Port-related marine vessel transit from dockside out through the Golden Gate Bridge, to the first outer buoys beyond the Pilot Buoy, approximately 30 miles away from the Port. On the landside, the spatial scope of the inventory includes nine marine terminals, one rail yard, and the road traffic between those facilities and the nearest freeway interchanges. The Port area was defined approximately by the boundaries of I-80, I-880, and the Howard Terminal (Berths 67 and 68) adjacent to Jack London Square. Within this defined geographic area, three significant areas were specifically excluded: the Schnitzer Steel terminal, the Union Pacific rail yard, and the former Oakland Army Base located between Maritime Street and I-880. These areas were not controlled or operated by the Port of Oakland in 2005. Figures 1-1 and 2-1 illustrate the spatial scope of the inventory.

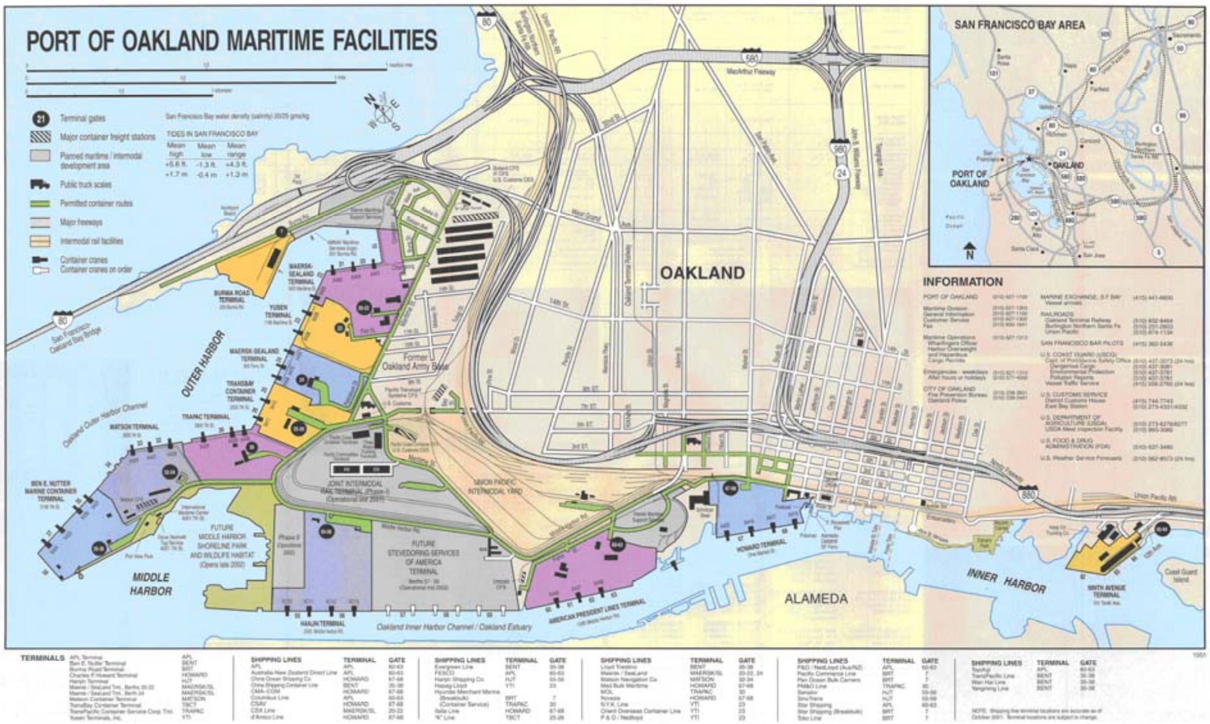

Figure 1-1. Port of Oakland Maritime Facilities – 2005.

The inventory was prepared by ENVIRON, the consultant hired by the Port, by analyzing all maritime activity in 2005, including the time in different modes of operation, the load or speed, and the engine characteristics of all equipment and vessels used in the Port's maritime operations. To obtain this data, Port, State, and terminal and rail operator records were used, along with special studies that are included in the appendices. Previous studies and literature reviews, and ARB input data or models estimates were used when more precise estimates could not be generated during the period of this study. ENVIRON also provided the Port and ARB with detailed spatial and temporal allocations for each emission source.

ENVIRON and the Port worked closely with ARB and the BAAQMD in preparing this inventory, coordinating through weekly conference calls, which included discussion of many input factors and review of emissions inventory methodologies. Additionally, in January 2007 the Port released to the public a draft, working document presenting the Port-proposed methodology for estimating emissions for each source category, and ARB's comments on the proposed methodology. ARB requested that the Port inventory be consistent with methodologies used by ARB in previous studies for similar facilities. As a result, most emissions estimates in this report use ARB inputs and methodologies. However, for some source categories where the parties agreed that legitimate technical uncertainty existed on how to calculate emissions, the ARB agreed to the inclusion of Port of Oakland-specific inputs. For these source categories, primarily assist tugs and cargo handling equipment, this emissions inventory includes a range of estimates as a sensitivity analysis.

The Port and its contractors provided detailed spatial information on particulate emissions so this inventory could be used as input to the dispersion modeling that ARB would perform for the West Oakland health risk assessment.

1.8 Report Organization

This emissions inventory report is organized into an Executive Summary, seven sections, and the appendices.

- The Executive Summary briefly describes the methodologies used to estimate air emissions for all Port activities, and a summary of the results (Tables ES-1 and ES-2)
- Section 1 contains this introduction to the report.
- Section 2 describes deep-draft ocean-going marine vessels.
- Section 3 describes operation and maintenance dredging activity and assist tugs.
- Section 4 describes cargo handling equipment.
- Section 5 describes the Port of Oakland on-road truck activity associated with container movements.
- Section 6 describes locomotive emissions.
- Section 7 contains the summary and results of the report.
- Section 8 provides the references used in developing the emissions inventory.
- A glossary defines the technical terms used in the report.
- The appendices provide detail on the methodologies used to derive the data.

2.0 DEEP-DRAFT OCEAN-GOING MARINE VESSELS (OGV)

2.1 Deep-Draft Ocean-Going Marine Vessel Activity and Inventory

This section documents the emission estimation methods and results for large deep-draft ocean-going vessels (OGV) calling at Port of Oakland terminals in 2005. ENVIRON followed the EPA guidance for best practices (ICF Consulting, 2006) for maritime emissions inventory and Air Resources Board (ARB) guidance provided in weekly conference calls from October 2006 until June 2007. This section includes information supplied by ARB specifically for this study.

Ocean-going vessels (OGV) are the primary emissions source for the Port of Oakland marine traffic, and this study is limited to the vessel activity during 2005. OGVs are large ships carrying import and export containers and form the basis for the Port's throughput. These ships use propulsion engines for movements, auxiliary engines for electrical power and small boilers for steam and hot water, all of which produce emissions. The methodology used for estimating emissions was to multiply the total time by the engine by the load factor and by the emission factors derived for these sources. Each vessel has unique characteristics of speed, engine type and power that affect the estimate of time and engine load for each vessel call.

The 1,916 vessel calls at the Port of Oakland in 2005 were primarily container ships (1,812 calls) with a few calls by general cargo (86), roll on/roll off (17), and integrated tug and barge (1) vessels as characterized by the Lloyds (2006) classification. However, as confirmed by the Port of Oakland Wharfingers, all of these ships were either a container ship that may also carry other cargo, or ships that were originally built for other uses but were converted to transport containers. When selecting the input parameters for the emissions calculations, this study uses the container ship category for all vessel calls in 2005, except for the few roll on/roll off vessels.

The ship size can be defined by three different methods:

- Dead weight tonnage (DWT),
- Container capacity in twenty-foot equivalent units (TEU), or
- Number of refrigerated (reefer) plugs available.

Each of these size measurements may affect one emission source or another. For example, the number of reefer plugs could affect the auxiliary engine loads of the vessel, while the DWT or TEU capacity could affect the overall size of the vessel and therefore the propulsion power demand. Table 2-1 describes general ship characteristics using all three size measurements for vessels calling at the Port of Oakland in 2005.

Table 2-1. Ocean-Going Vessels – 2005 Port of Oakland vessel calls by three different ship size measures.

Dead Weight Tonnage	Calls	TEU	Calls	Reefer Plugs	Calls
<20,000	69	<2000	206	<250	474
<40,000	614	<3000	599	<375	1034
<60,000	1226	<4000	995	<500	1457
<80,000	1761	<5000	1454	<1000	1867
<100,000	1866	<6000	1738	<1400	1869
<120,000	1916	<7000	1851		
		<9000	1914		
		Unknown	2	Unknown	47

Source: Lloyds (2006)

Vessels called at regular and irregular frequencies. Many vessels had regular routes between Hawaii or Asian ports and the Port of Oakland, while others made infrequent calls. A few vessels that have regular routes to Hawaii called at Oakland as many as 26 times in 2005. Most of the calls were from vessels calling between 3 and 11 times in 2005, accounting for nearly 80% of the calls in 2005. Table 2-2 outlines the number of calls by individual vessels in 2005, using the number of calls.

Table 2-2. Ocean-Going Vessel - Port of Oakland vessel calls in 2005.

Number of Calls in 2005	Ship Count	Subtotal Calls	Cumulative Calls
1	74	74	74
2	62	124	198
3	43	129	327
4	31	124	451
5	22	110	561
6	25	150	711
7	15	105	816
8	21	168	984
9	29	261	1245
10	33	330	1575
11	12	132	1707
12	2	24	1731
13	2	26	1757
14	0	0	1757
15	0	0	1757
16	0	0	1757
17	1	17	1774
18	0	0	1774
19	1	19	1793
20	0	0	1793
21	0	0	1793
22	1	22	1815
23	0	0	1815
24	1	24	1839
25	1	25	1864
26	2	52	1916

Source: Port of Oakland Wharfinger, 2006

The age distribution of the vessels calling at the Port is shown in Table 2-3. Most were relatively new, but a vessel as old as 34 years also called. The median age of vessels calling the Port of Oakland in 2005 was 8 years old.

Table 2-3. Ocean-Going Vessels – Port of Oakland vessel age distribution in 2005.

Model Year	Count of Calls	Individual % of Calls	Cumulative % of Calls
2005	86	4.5%	4.5%
2004	96	5.0%	9.5%
2003	110	5.7%	15.2%
2002	132	6.9%	22.1%
2001	143	7.5%	29.6%
2000	96	5.0%	34.6%
1999	39	2.0%	36.6%
1998	159	8.3%	44.9%
1997	147	7.7%	52.6%
1996	94	4.9%	57.5%
1995	116	6.1%	63.6%
1994	34	1.8%	65.3%
1993	54	2.8%	68.2%
1992	87	4.5%	72.7%
1991	71	3.7%	76.4%
1990	17	0.9%	77.3%
1989	27	1.4%	78.7%
1988	36	1.9%	80.6%
1987	22	1.1%	81.7%
1986	89	4.6%	86.4%
1985	5	0.3%	86.6%
1984	5	0.3%	86.9%
1983	21	1.1%	88.0%
1982	15	0.8%	88.8%
1981	1	0.1%	88.8%
1980	45	2.3%	91.2%
1979	11	0.6%	91.8%
1978	29	1.5%	93.3%
1977	2	0.1%	93.4%
1976	0	0.0%	93.4%
1975	17	0.9%	94.3%
1974	0	0.0%	94.3%
1973	66	3.4%	97.7%
1972	25	1.3%	99.0%
1971	19	1.0%	100.0%

Source: Port of Oakland Wharfinger, 2006 and Lloyds, 2006

ENVIRON excluded from this study the privately owned Schnitzer facility, which lays within the boundaries of the Port of Oakland terminals and generally sees bulk carriers calling for scrap steel. Because this facility is not owned or controlled by the Port of Oakland, this report does not account for any vessel calls to the Schnitzer terminal.

The spatial domain of this study includes transit activity between the outer buoys, beyond the Pilot Buoy, and the berths at the Port as shown in Figures 2-1 and 2-2. Based on discussions with the Marine Exchange (2006a), Port of Oakland Wharfinger (2006), Port of Oakland

(2006a), and San Francisco (SF) Bar Pilots (2006), a schematic of the transit activity for vessels calling at the Port of Oakland can be described as shown in Table 2-4. These entries correspond to the schematic link descriptions shown in Figures 2-1 and 2-2. The number of links described here may be more numerous than needed for a basic estimate; however, these links provide the detailed spatial allocation of emissions required for dispersion modeling. Because the purpose of this emissions inventory was to estimate the impact of Port of Oakland vessel traffic on the San Francisco Bay Area air quality near the populated areas, the inventory was limited to the spatial area defined in Figure 2-1 where well defined shipping lanes could be defined for that domain, and emissions closer to shore affect the populated areas more significantly. Emissions beyond this spatial area could be evaluated in subsequent studies, as needed to more completely determine the Port's direct and indirect impacts to the Air Basin.

Generally, vessel activity is by four modes of operation; cruise, reduced speed zone (RSZ), maneuvering, and hotelling.

- The cruise mode occurs in the open ocean where there are fewer navigational challenges and where ships typically operate at their design speed.
- The RSZ mode requires ships to slow down and stay within prescribed lanes as shown on Figure 2-1 and 2-2. For ships arriving in the SF Bay, the RSZ mode occurs after a SF bar pilot takes command of the vessel at the Pilot Buoy until the vessel slows to a very low maneuvering speed near the Port. The RSZ mode is similar in reverse order for ships leaving the Port.
- The maneuvering modes for the Port of Oakland traffic occur between the Bay Bridge and the berths.
- Lastly, the hotelling mode occurs when the vessel is stopped at berth or at anchor in the Bay.

The methodology used for estimating emissions was to multiply the total time by the engine by other load adjustments and by the emission factors derived for these sources. The number of vessel calls and the time per call in each of the four operational modes constitutes the time in mode. Each vessel has unique characteristics of speed, engine type and power that affect the estimate of time and engine load for each vessel call.

The time in mode and load for propulsion engines was calculated based on the vessel speed and the distance (length) of each transit mode. The SF Bar Pilots (2006) estimated the RSZ average speed and maneuvering modes typical time as described in Table 2-4. ENVIRON determined the cruise speed from the Lloyds (2006) design speed for each vessel. ENVIRON determined the time in mode from the speed and distance along each link to estimate the propulsion and auxiliary engine activity for cruise and RSZ modes. The Wharfingers (2006) provided berthing time information for each call.

The SF Bar Pilots (2006) suggested that during fair weather and low traffic periods, predominately smaller ships may use an alternative route between the Golden Gate and Bay Bridges by transiting south of the Harding Rock buoy, or even south of Alcatraz. Because sufficient data were not available to describe the number of vessel calls using the shorter alternative route, the shorter route was supplied in Table 2-4 only as information about the potential alternative route. The longer, more frequently used route around the Harding Rock was used in this emissions inventory. The alternative route would shorten the RSZ transit link time, so the use longer default routes used in this analysis resulted in higher emissions. The longer route was used as the default condition because all vessels can always use this route, and the more direct alternative route is limited to certain vessel types and weather conditions.

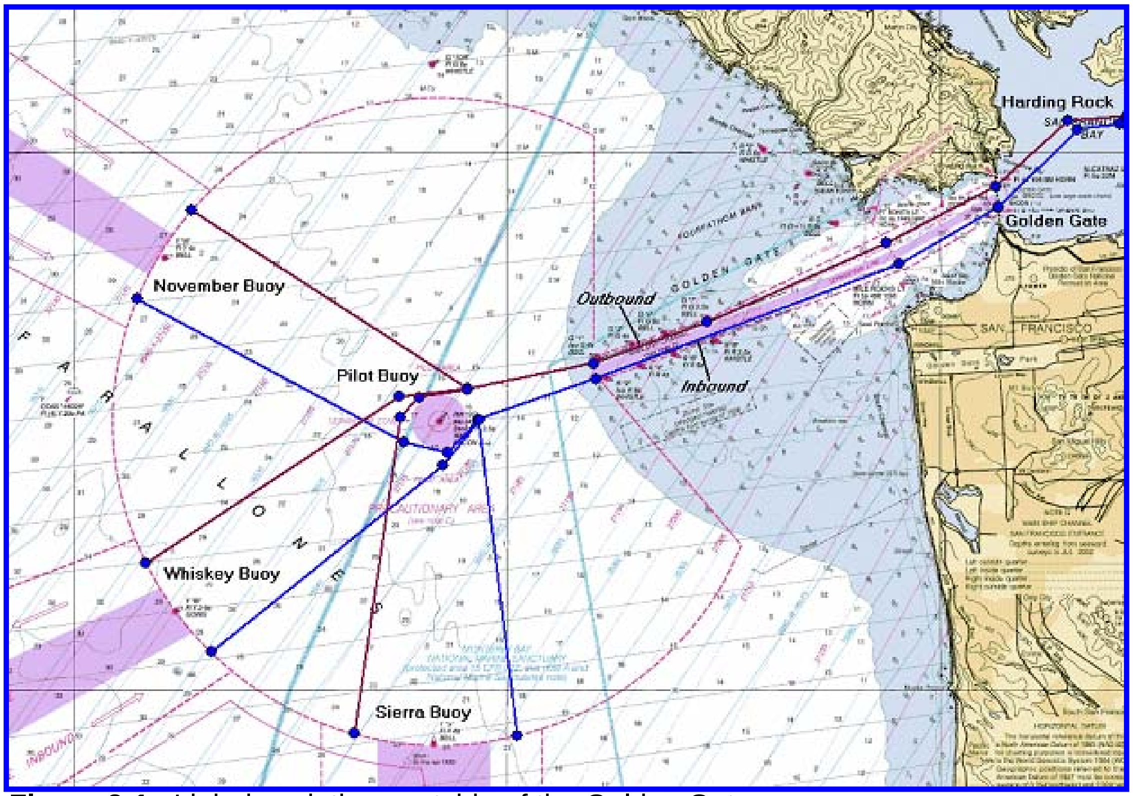

Figure 2-1. Link descriptions outside of the Golden Gate.

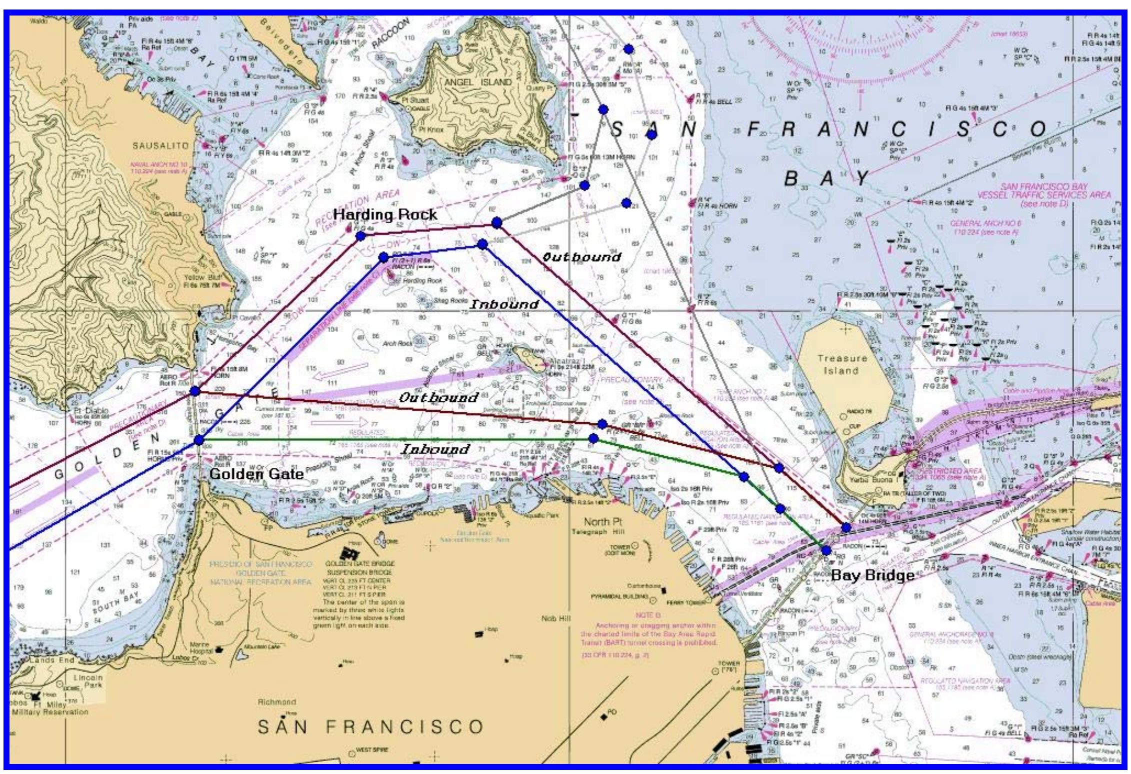

Figure 2-2. Transit link descriptions in San Francisco Bay including a more direct alternative route.

Table 2-4. Ocean Going Vessels – Transit link descriptions.

Transit into Port				
Direction	**Link Start**	**Link End**	**Distance (nautical miles)**	**Speed (knot)**
In – From Asia or Northern Ports	November Buoy	Pilot Boards	7.2	Cruise
In – From Hawaii	Whiskey Buoy	Pilot Boards	6.5	Cruise
In – From Southern Ports	Sierra Buoy	Pilot Boards	5.8	Cruise
In – All	Pilot Boards	Pilot Buoy	1.7[2]	10
In – All	Pilot Buoy	Golden Gate	8.7	13.5
In – All[1]	Golden Gate[1]	Harding Rock	2.0	13.5
In – All[1]	Harding Rock[1]	Bay Bridge	4.5	13.5
In – All (alternative route) [1]	Golden Gate	Bay Bridge	5.3	13.5
Maneuvering Modes				
Direction	**Link Start**	**Link End**	**Time (hrs)**	**Load**
In/Out – Inner Harbor Terminals (Small Ships)	Bay Bridge	Dock	0.833 / 0.833	2%
In/Out – Inner Harbor Terminals (Large Ships – Turning Basin)	Bay Bridge	Dock	1.42 / 0.833	2%
In/Out – Outer Harbor Terminals (Small Ships)	Bay Bridge	Dock	0.75 / 0.75	2%
In/Out – Outer Harbor Terminals (Large Ships – Turning Basin)	Bay Bridge	Dock	1.33 / 0.75	2%
Shifts (small number of calls have shifts from one terminal to another)	Oakland	Oakland	0.75	2%
Transit Out of Port				
Direction	**Link Start**	**Link End**	**Distance (nautical miles)**	**Speed (knot)**
Out – All[1]	Bay Bridge[1]	Harding Rock	4.8	13.5
Out – All[1]	Harding Rock[1]	Golden Gate	1.8	13.5
Out – All (alternative route) [1]	Bay Bridge[1]	Golden Gate	5.5	13.5
Out – All	Golden Gate	Pilot Buoy	8.9	13.5
Out – All	Pilot Buoy	Pilot Departs	1.7[2]	10
Out – To Asia or Northern Ports	Pilot Departs	November Buoy	5.9	Cruise
Out – To Hawaii	Pilot Departs	Whiskey Buoy	6.6	Cruise
Out – To Southern Ports	Pilot Departs	Sierra Buoy	7.1	Cruise

[1] SF Bar Pilots (2006) suggested that most ships use the Deep Water Traffic Lane north of the Harding Rock Buoy, though some ships under certain conditions may take the more direct alternative route. (This alternative rourte was not used in this study and was provided for information only)

[2] Assumes 10 minutes at slower speed for the pilot to board and depart safely. Distance in this mode was subtracted from the cruise mode. Distances were measured from east of Pilot Buoy.

Based on the SF Bar Pilots' (2006) best judgment, the maneuvering time is longer for the Inner Harbor berths and for larger vessels, defined here as greater than 750 ft in length. The larger ships require more time to turn and may need to turn only in prescribed areas, such as the Inner Harbor's turning basin. Therefore, as shown in Table 2-4, the SF Bar Pilots (2006) estimated the maneuvering time for larger ships to be longer than that for smaller ships. Also, maneuvering time is shorter for the Outer Harbor terminal calls than the Inner Harbor terminal calls because of the shorter distance from the Bay Bridge and more water area available for turning directly at the Outer Harbor berths. Vessels calling at the Port of Oakland are primarily larger (1,481 calls) ships with smaller ships responsible for only 435 of the 1,916 calls.

ENVIRON estimated the activity along each link using the number of vessel movements along each segment for the 2005 vessel calls. The purpose of defining these links was to provide emissions that were accurately spatially allocated and to determine the distance along each link to estimate the time in mode. For the most part, it was straightforward to determine the total vessel movements for most segments because each call required transiting along a set route as described in Table 2-4. A special California State Lands Commission (2006) data source provided the last and next port of call from which the direction (North, West, or South) outside of the pilot buoy was determined. The direction south from the Pilot Buoy is due south, whereas the western route is southwest and the northern route is northwest. Based on these general directions, ENVIRON rendered a judgment of the direction to or from the San Francisco Bay as shown in Table 2-5 to determine the link of the cruise modes. The berths where the vessel called and the ship length determined the maneuvering mode movements.

Table 2-5. Ocean-Going Vessels – Port direction from the San Francisco Bay.

Last or Next Port of Call	Direction	Trips In or (Out)
US northern continental ports including Alaska, Canada, and all Asia	N	613 (1163)
US Hawaii, Guam, New Zealand, Fiji, Tahiti	W	193 (235)
US Southern continental ports, Mexico, Panama, Chile and other South American ports, and Caribbean and Europe through the Panama canal	S	1110 (518)

ENVIRON determined emissions for each link, using the equation below, accounting for the engine rated power, typical load factor, and time at that load. ENVIRON determined emissions separately for propulsion and auxiliary engines, and for boilers, using emission factors provided by ARB. The rated power is the maximum power that the engine can produce. The load factor is the fraction of the actual to the rated power that the engine operates for a given mode.

Emissions per vessel/mode = (Rated Power) x (Load Factor) x (Time) x (Emission Factor)

Emissions total = Σ {All vessel calls and modes}

ENVIRON determined the time in each link from the link length and estimated speed. The load factor also depended on the vessel's maximum speed and the actual vessel speed in each mode.

2.2 Input Data and Use

The basic input data for calculating emissions from large ocean-going vessels include vessel calls in 2005, vessel installed power and speed, and estimates of load and time during the operation modes.

1) Vessel Port Calls
2) Vessel Type

3) Vessel Characteristics
    a) Cruise speed (knots)
    b) Auxiliary Power (kW)
4) Engine Characteristics
    a) Rated Power
    b) Engine Type (slow 2-stroke, medium 4-stroke, or steam)
5) Model Year
6) Berthing Time
7) Anchorage Vessel Calls and Time
8) Route Into and Away from SF Bay (north, west, or south)

Vessel Calls

The vessel calls for the Port of Oakland in 2005 were provided from two data sources, California State Lands Commission (SLC, 2006) and the Port of Oakland Wharfinger (2006) database. The SLC collects vessel calls and records last and next ports of call. The SLC vessel call data is self-reported and is used to track ballast water exchanges. The information is not reported promptly, so a significant lag can sometimes occurred between the actual port call and the report for that port call. The Wharfinger data was recorded at the dock and included the dock arrival and departure time, thereby allowing the berth hotelling time by vessel call to be calculated. ARB determined, from data provided by the Coast Guard, the hotelling time by vessel at anchor away from berth for a subset of the vessel calls to the Port.

ENVIRON used the Wharfinger data as the primary source of vessel call information. The SLC data was only used to determine the next and last ports of call to allocate the direction of trips outside of the Pilot Buoy. The data handling procedure for vessel calls is described in more detail in Appendix A.

When the next or last port of call was another Bay Area port (Carquinez, Sacramento, San Francisco, or Stockton), the transit links were assumed to be to and from Oakland out past the Pilot Buoy. In 2005, out of 1916 total vessel calls, there were 26 vessels that went to another Bay Area port after calling at Oakland, and 6 vessels that called at another Bay Area port prior to coming to Oakland. Vessel movements to or from San Francisco or into and out of the northern portion of the bay, before or after calls to Oakland, were not included in these estimates. Therefore, in these cases, the Port of Oakland was considered the primary port and calls to other ports were allocated as activity specific to those other ports. The calls to the Port of Oakland were all modeled as if they were from the open ocean to the Port and back to the open ocean, even if the vessel made a call to another Bay Area port before or after arriving at Oakland. As noted above, emissions from vessel movements to or from other Bay ports before or after calling at the Port of Oakland were not included in this Port of Oakland emissions inventory.

Propulsion Power and Load

Propulsion power and vessel speed were derived from the Lloyds (2006) database, which reports design features for each vessel. Data handling procedures are described in Appendix B. To obtain estimates of maximum power and speed, the survey data from the Port of Los Angeles emission inventory study (Starcrest, 2005) were used to adjust the Lloyds estimates as shown in the equations below.

Vessel Propulsion Power = Lloyds Power / (0.968)

Vessel Maximum Speed = Lloyds Vessel Speed / (0.968)

The load factors for the propulsion power over any given link were determined from the classic Stokes Law cubic relationship for speed and load. The proportional relationship of load to the vessel speed can be expressed as in the following equation where the 100% load factor would correspond to the vessel operating at its maximum speed.

$$\text{Load Factor} = (\text{Vessel Speed} / \text{Vessel Maximum Speed})^3$$

From the Port of Los Angeles study (Starcrest, 2005), the cruise speed of the vessel was estimated to be 0.937 of the maximum speed. This calculation of the load factor at the cruise speed resulted in a load factor of 0.823 during cruise conditions.

Auxiliary Power and Load

As described in Appendix C, the auxiliary power was derived from auxiliary generator capacity taken from the Lloyds database and supplemented by other available data and estimates.

ENVIRON proposed the use of the load factors shown in Table 2-6 to describe the vessel activity in the Port of Oakland. These load factors were derived from the EPA Best Practices (ICF, 2006) estimates.

Table 2-6. Ocean Going Vessels – Auxiliary engine load factors assumptions (Not used in this study).

Ship-Type	Cruise	Reduced Speed Zone (RSZ)	Maneuvering	Hotel
Container Ship	0.13	0.25	0.50	0.17

Source: ICF Consulting, 2006.

ARB (2005a) determined load factors from ship surveys conducted in California, shown in Table 2-7, which are similar to but exhibit differences from the ICF (2006) load factors shown in Table 2-6. For consistency with other ARB reports, and because they were based on California surveys, the ARB load factors were used in the Port of Oakland emission inventory. Most of the ship calls to the Port of Oakland were from container vessels, so the use of the ARB load factors affects the emission estimates primarily for reduced speed zone (RSZ) modes (between the Pilot Buoy and the Bay Bridge) compared with the alternative estimates proposed by ICF on behalf of EPA.

Table 2-7. Ocean-Going Vessels – Auxiliary engine load factors.

Ship-Type	Cruise	Reduced Speed Zone (RSZ)	Maneuver	Hotel
Container Ship	0.13	0.13	0.50	0.18
RORO	0.15	0.15	0.45	0.26

Source: ARB, 2005a

2.3 Emission Factors

Emission factors depend on the type of engine and fuel used in the vessel for propulsion or auxiliary engines. Three types of engines can be used on ships; slow speed engines (2-stroke and typically lower than 250 rpm), medium speed engines (4-stroke and used primarily for auxiliary engines), and steam boilers coupled with steam turbines. ENVIRON determined from Lloyds data that the primary propulsion engines used on vessels calling at the Port of Oakland were slow speed engines (1,706 vessel calls), steam boilers (200 calls), and medium speed engines (10 calls). ENVIRON assumed that all vessels use medium speed engines in their auxiliary engines based on experience and limited survey information.

ARB provided a set of emission factors to be used in this study for consistency with other work performed for the San Pedro Bay ports and elsewhere in California. These emission factors are shown in Table 2-8. One area of uncertainty in estimating emissions from OGV is the particulate matter (PM) emission factors, including the factors shown in Table 2-8. This is because there is a smaller set of data for particulate emissions than for other pollutants. During weekly coordination conference calls with the Port of Oakland and BAAQMD staff, ARB (2007) described in detail the available data and noted that, while the range of PM emission rates vary from 1.7 to 1.1 g/kW-hr, the preponderance of the data indicated that the 1.5 g/kW-hr emission factor shown in Table 2-8 is justified.

Table 2-8. Ocean Going Vessels – Emission factors.

ARB Provided Emission Factors (g/kW-hr)					
Engine Type	**Fuel Type**	**HC**	**CO**	**NOx**	**PM**
Slow Speed	Residual Oil	0.6	1.4	18.1	1.50
Medium Speed Propulsion	Residual Oil	0.5	1.1	14.0	1.50
Medium Speed Auxiliary	Residual Oil	0.4	1.1	14.7	1.50
Medium Speed Auxiliary	Marine Distillate (0.5% sulfur)	0.4	1.1	13.9	0.38
Steam Boiler	Residual Oil	0.1	0.2	2.1	1.50

Sources: ARB (2006a)

ARB (2005a) determined from ship surveys that 71% of container vessels used residual oil and 29% used distillate in their auxiliary engines. Because it was difficult to determine which vessels use the residual and distillate fuels, ENVIRON used a weighted average set of emission factors for all auxiliary engines. ENVIRON estimated the average emission factor for auxiliary engine emissions by multiplying the medium speed auxiliary emission factors using residual oil by 71%, and the medium speed auxiliary emission factors using marine distillate by 29%, and adding the two together.

Low Load Adjustment Factors

Emission factors for OGV were derived from data at high operational loads. When estimating emissions, adjustment factors are used to adjust the emission factors, derived at higher operation loads, for conditions when engines are operating at very low loads where the engine is not as efficient. The Port of Los Angeles (Starcrest, 2005 also ICF, 2006) study used the low load adjustments shown in Table 2-9 for estimating emissions from propulsion engines in OGV.

Table 2-9. Ocean Going Vessels – Low load adjustment factors for propulsion engines.

Load %	HC	CO	NOx	PM[1]	SO2
2	31.62	10.00	4.63	7.29	1.00
3	17.21	6.67	2.92	4.33	1.00
4	11.18	5.00	2.21	3.09	1.00
5	8.00	4.00	1.83	2.44	1.00
6	6.09	3.33	1.60	2.04	1.00
7	4.83	2.86	1.45	1.79	1.00
8	3.95	2.50	1.35	1.61	1.00
9	3.31	2.22	1.27	1.48	1.00
10	2.83	2.00	1.22	1.38	1.00
11	2.45	1.82	1.17	1.30	1.00
12	2.15	1.67	1.14	1.24	1.00
13	1.91	1.54	1.11	1.19	1.00
14	1.71	1.43	1.08	1.15	1.00
15	1.54	1.33	1.06	1.11	1.00
16	1.4	1.25	1.05	1.08	1.00
17	1.28	1.18	1.03	1.06	1.00
18	1.17	1.11	1.02	1.04	1.00
19	1.08	1.05	1.01	1.02	1.00
20	1.00	1.00	1.00	1.00	1.00

[1] – not used in this Port of Oakland study
Source: Table 2.21 from Starcrest, 2005

As recommended by ARB, the Port of Oakland emissions from propulsion engines were adjusted based on the low load adjustment factors shown in Table 2-9, except for the PM adjustment shown. A 2% average load was used to estimate emissions for the maneuvering mode (accounting for activity between the Bay Bridge and berth). For the 13.5 knots reduced speed zone modes (between the Bay Bridge and the Pilot Buoy), the minimum load factor used was 11%. The reduced speed zone load factor was derived specifically for each vessel as the cube root of the ratio of actual speed, 13.5 knots, and the maximum speed of the vessel. Of all vessels calling at Oakland, the maximum speed of the fastest vessel was estimated to be 28.3 knots (The maximum 26.5 knots cruise speed from Lloyds data was divided by the Starcrest (2005) factor of 0.937 to estimate the maximum speed of that vessel). For slower vessels, the reduced speed zone load factor was higher than the 11% load calculated for the fastest vessel. The low load adjustments in Table 2-9, except for the PM adjustments in Table 2-10, were applied to the reduced speed zone and the maneuvering modes.

Table 2-10. Ocean Going Vessels – Low load PM adjustment factors used in the Port of Oakland emissions inventory.

Load %	PM Adjustment
1	9.82
2	5.60
3	4.03
4	3.19
5	2.66
6	2.29
7	2.02
8	1.82
9	1.65
10	1.52
11	1.40
12	1.31
13	1.22
14	1.15
15	1.09
16	1.03
17	1.00
18	1.00
19	1.00
20	1.00

Source: ARB (2006a)

Table 2-10 above contains the low load adjustment of PM emissions from propulsion engines used in the Port of Oakland inventory. While it is an engineering principle that an upward emissions adjustment should be made for low load conditions because engines operate less efficiently under those conditions, there is considerable uncertainty about the magnitude of this adjustment, especially for particulate. The PM adjustment factors in Starcrest (2005), shown in Table 2-9, were based on an EEA (2000) study of particulate emission rates (in g/kW-hr) as a function of load below the nominal 20% load point. The data used in the EEA (2000) study to determine the low load adjustment below 10% load was dominated by tugs and Coast Guard cutters using older smaller marine diesel engines burning low sulfur distillate fuel at idle engine loads. It is uncertain if the correlating factors that EEA found would apply appropriately to the more modern and larger slow speed engines burning high sulfur fuels that are used on container ships. The maneuvering mode adjustment constitutes one of the largest uncertainties in the preparation of maritime emissions inventory.

ARB concluded that the low load adjustment factor for particulate in Table 2-10 represented the best estimate of the effect of low load PM emissions at this time, until further data can be gathered. The ARB adjustment factor shown in Table 2-10 is lower than the factor one would estimate directly from the EEA correlations below 20%, as shown in Table 2-9.

The maneuvering mode in this study encompasses a number of operations within one average load. Maneuvering emissions were calculating using average emission rates and average adjustment factors. Individual operations during maneuvering include low speed propulsion and vessel turns away from dock as well as engine idling at dock prior to shut down and after the initial start up. In addition, cold start emissions could be significant but have yet to be considered as an explicit operational mode, and anecdotal accounts indicate that some load testing of the propulsion engine may occur in the vessel prior to departure from the berth. Emissions and engine loads during all maneuvering activity should be further evaluated to explicitly analyze engine operations, now collectively estimated under the more general description of the maneuvering mode.

Low load adjustment factors only affect propulsion engine emissions because no single (typically each vessel usually has a set of three or more auxiliary engines to provide auxiliary power) auxiliary engine operates below 20% load.

Boiler Emissions

Boilers are used on board modern vessels for heat, hot water, and other needs. Using the time in mode of the ships for each link, ENVIRON used 0.0125 metric tonnes of fuel consumed per hour (ICF Consulting, 2006) to estimate total activity for boilers. ICF Consulting (2006) also provided emission factors for boilers that combined with the fuel consumption rate were used to estimate emission rates from boilers. Both the emission factors (in terms of emissions per unit of fuel consumed) and the emission rates (emissions per hour) for boilers are shown in Table 2-11.

Table 2-11. Auxiliary boiler emission factors and emission rates.

Estimate	Units	HC	CO	NOx	PM	SO2
Emission Factors	Kg / metric tonne of fuel	0.38	4.6	12.3	1.3	54
Emission Rates	Kg / hour (using 0.0125 tonnes/hour)	0.005	0.058	0.154	0.016	0.68

Source: ICF Consulting, 2006

A recent study by the Chamber of Shipping (2007) estimated boiler fuel consumption at 0.14 to 0.18 metric tones per hour based on their assessment of the activity of these units. Therefore, the overall activity and emissions could be more than a factor of 10 higher than modeled here. Future studies are needed to better understand the activity and emissions of auxiliary boilers.

2.4 Emission Results

The estimated total emissions from the Port of Oakland ocean-going vessels are presented in Table 2-12 by each mode (cruise, reduced speed zone, maneuvering, and berthing) and by link (individual spatially-defined segment or area). The emission results for propulsion and for auxiliary engines were estimated using the ARB emission factors and are summarized in Table 2-12. The columns labeled *Main* include emissions from propulsion of the vessel by either diesel-powered propulsion engines or by boilers. Because ARB considers diesel particulate emissions to differ in toxicity from boiler particulate emission, the diesel-only particulate emissions from the main engines are provided at the bottom of Table 2-12. This figure excludes the propulsion boiler particulate emissions.

In addition, vessels calling at the Port of Oakland have small auxiliary boilers on-board, and emissions from those boilers are shown in Table 2-13.

Table 2-12. Emissions totals for OGV calling at the Port of Oakland in 2005 by mode for main and auxiliary engines – tons in 2005.

	HC			CO			NOx			PM			SO2		
Mode	**Main[1]**	**Aux[2]**	**Total**	**Main**	**Aux**	**Total**	**Main**	**Aux**	**Total**	**Main**	**Aux**	**Total**	**Main**	**Aux**	**Total**
At Berth	0.0	24.1	24.1	0.0	62.9	62.9	0.0	760.7	760.7	0.0	60.6	60.6	0.0	434.5	434.5
At Anchor	0.0	0.7	0.7	0.0	1.8	1.8	0.0	23.7	23.7	0.0	1.9	1.9	0.0	13.8	13.8
Cruise In North – Pbuoy	3.1	0.1	3.2	7.2	0.3	7.5	92.8	2.6	95.5	8.6	0.2	8.8	64.4	1.4	65.8
Cruise Out Pbuoy –North	6.6	0.2	6.9	15.5	0.5	16.0	200.2	4.8	205.0	16.6	0.4	17.0	116.4	2.5	118.9
Cruise Pbuoy – South	2.4	0.1	2.5	5.6	0.2	5.8	72.1	2.1	74.1	6.5	0.2	6.7	47.9	1.1	49.0
Cruise South – Pbuoy	6.1	0.2	6.3	14.2	0.5	14.7	183.8	4.5	188.3	15.2	0.4	15.6	106.8	2.4	109.1
Cruise Pbuoy – West	0.5	0.0	0.5	1.1	0.1	1.2	13.4	0.8	14.3	2.4	0.1	2.4	22.2	0.4	22.7
Cruise West – Pbuoy	0.4	0.0	0.4	0.8	0.1	0.9	10.0	0.6	10.5	1.7	0.1	1.8	16.0	0.3	16.3
RSZ Bay Bridge – Harding	3.6	0.5	4.1	7.5	1.0	8.6	82.5	9.9	92.4	7.5	0.9	8.4	52.0	5.2	57.2
RSZ Golden Gate - Harding	1.5	0.2	1.7	3.1	0.4	3.6	34.4	4.1	38.6	3.1	0.4	3.5	21.7	2.2	23.9
RSZ Golden Gate – Pbuoy	6.7	0.9	7.6	14.0	1.9	15.9	153.0	18.4	171.3	14.0	1.6	15.6	96.5	9.6	106.2
RSZ Harding – Bay Bridge	3.4	0.4	3.8	7.1	1.0	8.0	77.4	9.3	86.7	7.1	0.8	7.9	48.8	4.9	53.7
RSZ Harding - Golden Gate	1.4	0.2	1.5	2.8	0.4	3.2	31.0	3.7	34.7	2.8	0.3	3.2	19.6	2.0	21.5
RSZ PBuoy-GG	6.6	0.9	7.4	13.7	1.9	15.6	149.5	18.0	167.5	13.6	1.6	15.3	94.4	9.4	103.8
Maneuvering Entering	35.9	3.5	39.3	26.4	9.6	36.0	157.9	125.9	283.8	16.7	10.2	26.9	21.6	73.3	94.9
Maneuvering Leaving	21.7	2.1	23.9	16.0	5.9	21.9	95.6	77.4	173.0	10.2	6.3	16.5	13.2	45.1	58.3
Maneuvering Shifts	0.0	0.0	0.1	0.0	0.0	0.1	0.2	0.6	0.8	0.1	0.0	0.1	0.1	0.3	0.5
Pilot Boarding	2.5	0.2	2.8	3.4	0.5	3.9	22.6	4.7	27.3	2.7	0.4	3.2	10.1	2.5	12.6
Pilot Disembarking	2.5	0.2	2.8	3.4	0.5	3.9	22.6	4.7	27.3	2.7	0.4	3.2	10.1	2.5	12.6
Total	105.0	34.6	139.5	141.8	89.5	231.3	1,399.0	1076.5	2,475.5	131.7	87.0	218.6	761.8	613.3	1375.2
Diesel PM only										121.5	87.0	208.5			

1 – ROG to HC ratio is 0.8347 for residual fuels per Andrew Alexis, ARB 2007.
2 – ROG to HC ratio is 0.8785 for distillate fuels per Andrew Alexis, ARB 2007, averaging to 0.8474 for auxiliary engines using both fuel types.

Table 2-13. Emissions totals for auxiliary boilers on OGV calling at the Port of Oakland – tons in 2005.

Mode	HC[1]	CO	NOx	PM	SO2
At Berth	0.207	2.510	6.711	0.709	29.465
At Anchor	0.008	0.096	0.256	0.027	1.130
Cruise In North – Pbuoy	0.001	0.013	0.034	0.004	0.151
Cruise Out Pbuoy –North	0.002	0.019	0.050	0.005	0.218
Cruise Pbuoy – South	0.000	0.004	0.010	0.003	0.043
Cruise South – Pbuoy	0.000	0.005	0.012	0.005	0.053
Cruise Pbuoy – West	0.001	0.018	0.047	0.001	0.207
Cruise West – Pbuoy	0.001	0.011	0.030	0.001	0.131
RSZ Bay Bridge – Harding	0.004	0.043	0.114	0.012	0.503
RSZ Golden Gate - Harding	0.001	0.018	0.048	0.005	0.211
RSZ Golden Gate – Pbuoy	0.007	0.080	0.214	0.023	0.941
RSZ Harding – Bay Bridge	0.003	0.040	0.107	0.011	0.471
RSZ Harding - Golden Gate	0.006	0.078	0.210	0.005	0.921
RSZ PBuoy-GG	0.001	0.016	0.043	0.022	0.188
Maneuvering Entering	0.013	0.152	0.406	0.043	1.785
Maneuvering Leaving	0.008	0.097	0.260	0.027	1.141
Maneuvering Shifts	0.000	0.001	0.002	0.0003	0.011
Pilot Boarding	0.002	0.020	0.054	0.006	0.238
Pilot Disembarking	0.002	0.020	0.054	0.006	0.238
Total	**0.3**	**3.2**	**8.7**	**0.9**	**38.0**

1 – ROG to HC ratio is 0.8347 per Andrew Alexis, ARB 2007.

3.0 COMMERCIAL HARBOR CRAFT (DREDGING AND ASSIST TUGS)

This section describes the emissions estimation methodologies and results for two regularly occurring activities at the Port of Oakland: 1) operation and maintenance dredging and disposal, and 2) container vessel assists. Other than a few small boats that assist dredging operations, tugs are the only category of commercial harbor craft that are a part of the Port's maritime emissions inventory. This inventory does not include dredging and vessel assist activities at the privately owned Schnitzer Steel bulk terminal berths. Pilot boat emissions are also excluded.

The Air Resources Board considers emissions from dredges and some related equipment to be "Portable Equipment", while tugs and the other small vessels discussed in this section are considered to be "Commercial Harbor Craft." The emissions summary presented in Table 3.10 at the end of this section uses these classifications.

3.1 Operation and Maintenance Dredging and Disposal

Background and Limitations

Operation and maintenance (O&M) dredging is conducted annually at the Port of Oakland to maintain the depth of channels and berths and to ensure safe navigation. O&M dredging removes new material that is deposited into the Bay by stream and urban runoff as well as eliminates shallow areas created by the redistribution of bottom sediments through a process known as "shoaling." To protect sensitive marine species, O&M dredging is limited to a 4-month "window" that extends from August 1 through November 30 each year.

The Port and the US Army Corps of Engineers (USACE) contract separately for O&M dredging at the Port's berths and the Federal channel, respectively. Historically, dredging has been conducted by a diesel-powered clamshell dredge, accompanied by a tender, and supported by several boats. Material removed from the bottom is transferred into barges by the dredge. The barges, sometimes referred to as scows, are then pushed by a diesel-powered tug to a disposal or reuse site. After the barge is emptied, the tug returns with the empty barge to pick up a new load.

The base year 2005 was an atypical year for O&M dredging in terms of the total volume of material dredged, the equipment used to conduct dredging, and the choice of disposal sites. The Port dredged only 43,520 cubic yards, versus a long-term annual average of 123,000 cubic yards during the previous five years (Port of Oakland, 2006b). The USACE removed 276,000 cubic yards, versus its 2001-2005 annual mean of 310,000 cubic yards (USACE, 2006). Because its Federal channel maintenance dredging was conducted in conjunction with the Port's –50 Foot Deepening Project, the USACE's contractor used an electric cutter head dredge instead of a diesel clam shell dredge. In addition, half of the federal material was disposed of within the Port area, at the Middle Harbor Enhancement Area, rather than at a remote site. These circumstances greatly reduced O&M dredging emissions in 2005 compared to an average year. In more typical years, excavation of O&M dredging material was conducted with a diesel-powered dredge and the material was taken to either the in-bay Alcatraz disposal site (for the Port's berth sediments) or to the Deep Ocean Disposal Site (DODS) for the USACE channel sediments.

Methodology

To estimate emissions, O&M dredging was divided into two activities: 1) dredging (the removal of materials from the bottom of channels and berths), and 2) disposal (the transport of dredge materials from the dredging area to disposal sites). Emissions from these activities were summed to form the final total emissions estimate.

Dredging

Because the USACE used an electric-powered cutter head dredge to remove materials from Federal channels, it produced essentially zero dredging emissions in 2005. However diesel equipment was used for dredging at the Port's berths.

Dredging equipment included the following:

- A clamshell dredge with main and auxiliary diesel engines,
- A dredge tender with main and auxiliary diesel engines,
- A workboat and a crew boat each with a single diesel engine and an auxiliary engine.
- A barge or scow into which the dredged material was loaded for disposal or reuse. The barge had no engines.

The basic equation used to calculate emissions from each of the engines involved in dredging is:

$$Equip_{Emiss} = EF \times Time_{hrs} \times Engine_{bhp} \times LF \times 1/(453.6 \times 2000)$$

Where:

$Equip_{Emiss}$ is the engine's emissions in tons per year,
EF is the engine emission factor in grams per brake horsepower-hour,
$Time_{hrs}$ is the annual operating hours,
$Engine_{Bhp}$ is the brake horsepower rating of the engine,
LF_{wt} is the time weighted load factor, based on different engine operating modes during a round trip, stated as a ratio of 1, and
$1/(453.6 \times 2000)$ is the conversion of annual grams to annual tons.

Dredged Materials Disposal

Most dredged material is disposed of by removing it to a reuse or disposal area. A diesel powered tug pushes the loaded scow or barge to the disposal area and, after unloading, pushes the empty barge back to the Port. The tug has two main propulsion engines and one or two auxiliary engines, only one of which is assumed to operate at a time.

The basic equation used to calculate main propulsion and auxiliary engine emissions from the tug is:

$$Tug_{emiss} = EF \times_{Engine\ Bhp} \times Time_{hours} \times LF_{wt} \times Trips \times 1/(453.6 \times 2000)$$

Where:

Tug $_{emiss}$ is the tug emissions in tons per year,

EF is the tug main propulsion or auxiliary engine emission factor in grams per brake horsepower-hour,

Engine $_{Bhp}$ is the combined brake horsepower rating of a tug's main propulsion engines and the brake horsepower rating of one of the auxiliary engines,

Time is the tug operating time per round trip in hours,

Trips is the annual number of round trips per tug,

LF $_{wt}$ is the time weighted load factor, based on different engine operating modes during a round trip, stated as a ratio of 1, and the load factor for the auxiliary engine stated as a ratio of 1, and

1/(453.6 x 2000) is the conversion of annual grams to annual tons

Once it reaches the disposal area, a barge or scow is unloaded in one of two ways, by gravity or mechanically. Unloading at a Bay or ocean disposal site is accomplished by gravity - that is, by opening the bottom of the barge and allowing material to flow out. At reuse sites, the scows are mechanically unloaded for distribution. The Montezuma Wetlands Restoration Project near Collinsville, which received about half the Federal material in 2005, uses a dedicated shore-powered electric "off-loader" to draw the wet material out of the barge and pump it "upland" for distribution. One reuse site, Winter Island, which is also near Collinsville and which received a little more than half the Port's material in 2005, uses a diesel-powered offloading system.

In addition to contracting for maintenance dredging of the federal channel entering the Port of Oakland, the USACE permits all San Francisco Bay dredging and disposal activities. ENVIRON used the protocol established by the USACE to monitor General Conformity emissions to assign emissions responsibility to the Port of Oakland. At "passive" sites, like the in-bay disposal area near Alcatraz, the USACE assigns emissions from the entire round trip to the Port. For disposal at reuse sites, like Montezuma and Winter Island, the USACE splits trip emissions to the reuse site 50/50 between the Port and the reuse site. In addition, any emissions from offloading materials are assigned to the reuse site. Except for Winter Island, all off-loading in 2005 was done by gravity or electric-powered equipment. Winter Island used a crane and bucket off-loader with relatively small, late model diesel engines that produced an estimated 0.3 tons of NOx and less than 0.01 ton of PM in 2005.

<u>Input Data and Emissions</u>

Dredging

Key input data for estimating dredging emissions included the equipment used by the Port's contractors, equipment emissions and load factors, the volume of material removed, and the hours of operation. For equipment description and emissions factors, ENVIRON used information and assumptions from prior studies (Weiss & Associates, 2003; ICF Consulting, 2006; and ARB, 2004a), and ARB load factors and emission factors (ARB, 2006a). The Port provided the volume of dredge material removed in 2005. ENVIRON estimated hours of operation by dividing the volume of material dredged by the capacity of the clamshell dredge, assuming the dredge was operating at 90% of its rated capacity. Input data and assumptions for dredging Port berths are summarized in Table 3-1 and emissions are estimated in Table 3-2.

Table 3-1. Commercial Harbor Craft – O&M dredging - key data and variables.

Equipment	Power (hp)	Load Factor	Capacity (cubic yard/hr)	Emission factors (g/hp-hr)				
				ROG	CO	NOx	PM	SO2
Clamshell dredge	1142	0.75	275	0.20	1.86	9.69	0.18	0.07
Dredge Aux. Engine	160	0.43		0.20	1.19	7.46	0.17	0.07
Tender	336	0.45		0.20	1.12	7.46	0.17	0.07
Tender Aux Engine	14	0.43		0.20	1.19	7.46	0.17	0.07
Crew boat	212	0.45		0.20	1.12	7.46	0.17	0.07
Crew boat Aux. Engine	54	0.43		0.20	1.19	7.46	0.17	0.07
Work boat	197	0.43		0.20	1.12	7.46	0.17	0.07
Work boat Aux. Engine	17	0.43		0.20	1.19	7.46	0.17	0.07

Sources: Weiss & Associates, 2003; ICF Consulting, 2006; and ARB, 2006a

Table 3-2. Commercial Harbor Craft – O&M dredging emissions – tons in 2005.

Program	Equipment	Hours	ROG	CO	NOx	PM	SO2
Port berths	Clamshell dredge	176	0.03	0.31	1.61	0.03	0.01
	Dredge Aux. Engine	176	0.00	0.02	0.10	0.00	0.00
	Tender[1]	176	0.01	0.05	0.33	0.01	0.00
	Tender Aux Engine	176	0.00	0.00	0.01	0.00	0.00
	Crew boat[2]	44	0.00	0.00	0.03	0.00	0.00
	Crew boat Aux. Engine	44	0.00	0.00	0.01	0.00	0.00
	Work boat[2]	44	0.00	0.00	0.02	0.00	0.00
	Work boat Aux. Engine	44	0.00	0.00	0.00	0.00	0.00
Annual tons			**0.05**	**0.39**	**2.11**	**0.04**	**0.02**

[1] Assumed continuous tending of the dredge barge.
[2] Assumed 2 hours of operation per 8-hour day of dredging.

Disposal

ENVIRON used data and information collected by a USACE contractor to estimate emissions from dredge material disposal in 2005. (GAIA, 2005) The USACE information included typical tug main engine horsepower ratings, trip-specific load factors, average scow size and loads, site-specific travel time to various disposal areas, and scow loading and unloading time. The USACE collected this information as part of their effort to closely track disposal and reuse emissions from the –50 Foot Deepening Project at the Port of Oakland. This project used the same disposal areas as the O&M dredging programs. The USACE and the Port provided actual data on the distribution of materials by disposal area in 2005. ENVIRON used emissions factors for all engines, and load factors for auxiliary engines, from the ICF Consulting (2006) report done for the EPA, cited above. Because ENVIRON did not collect tug specific information on tug engines, the methodology for these tug trips does not account for engine model year or deterioration. Table 3-3 summarizes the key input data and assumptions.

Table 3-3. Commercial Harbor Craft - Dredged material disposal, input data and estimates – tons in 2005

Variable		Alcatraz	Port Reuse or Disposal	Montezuma and Winter Island Tugs	Winter Island Offloader Main/Aux.	Aux. Engine
One-way Nautical Miles to Reuse/Disposal Location		6.0	3.8	47.0		
Travel Time[1] (hours)	Loading	6.8	6.8	8.0		
	Loaded Travel	0.9	0.6	7.1		
	Unloading	0.5	6.8	1.5	12.0	
	Unloaded Travel	0.6	0.4	5.1		
	Total Travel Time	8.86	14.6	21.7		
Load Factors	Loading[2]					
	Loaded Travel[3]	0.83	0.83	0.83		
	Unloading					
	Unloaded Travel	0.83	0.83	0.83		
Weighted Load Factor		0.15	0.06	0.47	0.75 / 0.43	0.43
Average Scow Load[4] (cubic yards)		2,720	2,550	2,550		
ROG Emission Factor (g/bhp-hr)		0.37	0.37	0.37	0.20 / 0.31	0.20
CO Emission Factor (g/bhp-hr)		0.82	0.82	0.82	1.30 / 0.70	1.27
NOx Emission Factor (g/bhp-hr)[5]		9.70	9.70	9.70	6.0 / 5.4	7.46
PM Emission Factor (g/bhp-hr)		0.42	0.42	0.42	0.20 / 0.25	0.17
SO2 Emission Factor (g/bhp-hr)		0.07	0.07	0.07	0.07	0.07

[1] - Travel times to Winter Island, Hamilton and SFDODS calculated based on average haul speed to Montezuma; travel time to Port reuse based on 5 knot moving speed. Unloading time for SFDODS and Alcatraz assumes bottom dump. GAIA, 2006. Winter Island unloading time from Dutra, 2006.

[2] - Load factor set to zero per discussion at IPR; Port of Oakland (Len Cardoza) indicates that tugs shut down while scow is being loaded and unloaded.

[3] - Based on information provided by Mark Guinn at Brusco to Susanne von Rosenberg of GAIA

[4] - 85% of bin count shown to allow for bulking, 80% capacity to DODS or Alacatraz due to spill control requirements - GAIA, 2006. Average scow load for Winter Island from Dutra, 2006.

[5] - Emission factors and load factors from "Best Practices in Preparing Port Emissions Inventories", Prepared for EPA by ICF Kaiser for EPA, June 23, 2005, Tables 2-16 to 2-18. Tugs are assumed to have Category 2 engines. Conversion factor from g/Kw-hr to g/bhp-hr=1.341. SO2 and PM10 emission factors corrected as necessary for lower sulfur diesel fuel using data and methods in "Proposed Regulatory Amendments Estending California Standards for Motor Vehicle Diesel Fuel to Diesel Fuel Used in Harbor Craft and Locomotives", Appendix F, October 1, 2004 http://www.arb.ca.gov/regact/carblohc/appf.pdf. Winter Island offloader EFs are Tier 1 zero emissions rates from EPA's Exhaust & Crankcase Emissions Factors for Non-road Engines, EPA 420-P-04-009, April, 2004.

Source: USACE monitoring of dredge disposal emissions, GAIA Consultants, 2005-2006.

Emissions from the transport of materials to the various disposal areas are summarized, below, in Table 3-4. Most emissions occurred from the transport of material to Montezuma and Winter Island because of the volume of material and the distance to the disposal site.

Table 3-4. Commercial Harbor Craft - O&M dredged material disposal emissions – tons in 2005.

Program Component	Tug Main or Aux HP	Volume (cy)	Trips	ROG	CO	NOx	PM	SO2
Alcatraz								
Port berths	3,000	19,250	8	0.01	0.06	0.31	0.01	0.00
	110		8	0.00	0.00	0.02	0.00	0.00
Federal channel	3,000	0	0	0.00	0.00	0.00	0.00	0.00
	110		0	0.00	0.00	0.00	0.00	0.00
Totals				**0.01**	**0.06**	**0.31**	**0.01**	**0.00**
Port Reuse or Disposal								
Port berths	3,000	24,270	10	0.12	0.61	3.17	0.06	0.02
	110	-	10	0.00	0.02	0.12	0.00	0.00
Offloader engines	500	116 hours		0.01	0.06	0.29	0.01	0.00
	250	116 hours		0.00	0.01	0.08	0.00	0.00
Federal channel	None	138,000	Distributed in Middle Harbor Enhancement Area with electric suction dredge					
Totals				**0.14**	**0.70**	**3.66**	**0.07**	**0.03**
Montezuma and Winter Island Reuse								
Federal channel	3,000	138,000	54	0.68	3.38	17.64	0.31	0.13
	110	0	54	0.01	0.07	0.46	0.01	0.00
			Totals	**0.69**	**3.46**	**18.10**	**0.32**	**0.13**
Total 2005 Disposal Emissions				**0.84**	**4.22**	**22.07**	**0.40**	**0.16**

Dredging Emission Summary Results

Table 3-5 summarizes emissions presented in Table 3-2 (dredging) and Table 3.4 (dredged material disposal). The 2005 O&M emissions were dominated by the disposal of dredge materials. O&M dredging emissions were substantially less than in a more representative year because of the use of an electric dredge in the federal channel and the lower volume of material dredged by the Port of Oakland in 2005.

Table 3-5 O&M dredging and disposal emissions – tons in 2005.

Year	Activity	ROG	CO	NOx	PM	SO2
2005	Dredging	0.05	0.39	2.11	0.04	0.02
	Disposal	0.84	4.22	22.07	0.40	0.16
	Total	0.89	4.60	24.18	0.44	0.18

3.2 Assist Tug Activity and Characteristics

Background

This section describes the emissions estimation methods and results for the base year 2005 for the operation of the tugs that assist container cargo vessels to berth at and depart from the Port of

Oakland. The role of the assist tugs is to ensure safe navigation, which is particularly important in windy weather and when vessels turn to reverse direction within the Inner or Outer Harbors. As discussed elsewhere, cargo vessels operating in the San Francisco Bay have qualified pilots on board to guide each vessel to and from its destination. In most cases, the pilot requires two tugs to meet each cargo vessel bound for the Port of Oakland, in the federal channel near the Bay Bridge, and accompany that vessel until it is tied up at its berth. When the vessel is ready to leave, the process is reversed and the tugs accompany the vessel back to the Bay Bridge. However, data obtained by ENVIRON shows that many outgoing vessels have only one tug assigned.(Marine Exchange, 2006b) This section addresses two types of tug operations, the actual vessel assist operation described, above, and the tugs' transit trip from its base to meet the vessel it is assisting.

The fleet of available tugs operating on the Bay varies over time as tug operators shift their equipment in and out of the Bay Area in response to the market. ENVIRON estimates that there could be 60-70 tugs operating for any given period, performing a variety of services including vessel escort, berthing, and departure assist at Bay Area and river ports and refineries; dredging support; and towing or pushing a wide variety of barges and other equipment. Many tugs are not equipped or certified to provide assist services to container vessels calling at the Port of Oakland.

There are a number of variables that affect actual tug emissions during an assist event. Among the most important are the following:

- The number of tugs assisting a vessel,
- The horsepower ratings of assist tug propulsion engines, which vary from tug to tug by a factor of three or more,
- The load carried by the tug's main propulsion engines, which varies substantially during the assist, and
- The time required to complete the assist operation, which varies by a factor of almost two, depending on where the vessel is berthing or departing.

Assist tugs are not assigned randomly. Cargo vessels vary greatly in size and maneuverability, and tugs have different power levels, rudders and other equipment. To ensure safe navigation, it is important that tugs be properly powered and equipped to handle the vessels they are assisting. The San Francisco Bar Pilots publish a guideline document that sets minimal requirements for tugs based largely on the length and draft of the vessel they will assist (Bar Pilots Guidelines, 2005). Tugs are classified from "A" to "D" based on their minimum Bollard Pull, both ahead and astern. Bollard Pull is a measure of tug efficiency that goes beyond horsepower rating to consider other aspects of tug design, such as whether it is a "tractor tug", has twin or single propellers, the type of rudder, and has thrusters. The Bar Pilots Guidelines specify minimum tug assist capabilities for various areas of the Bay, depending on the nature of the assist and local conditions. For the Port of Oakland, the Guidelines divide assist vessels into five groups based on their length and draft, and prescribe the minimum class of tugs required for each vessel. As might be expected, larger vessels require larger, more powerful tugs with higher Bollard Pull ratings.

There is no central process for assigning tugs to vessels as they arrive at or depart from the Port of Oakland. Agents working for individual shipping lines hire assist tugs from the individual tug companies that have equipment that has been certified by the Bar Pilots to provide assist services. The pilot on board the vessel verifies that the tug or tugs that meet each vessel have the required capabilities, but the Bar Pilots do not maintain a central record of the assignment of individual tugs.

Vessel call data specific to the Port of Oakland is available and described elsewhere in this report. In addition, ENVIRON obtained a report from the Marine Exchange that showed the number of tugs that accompanied each vessel arrival and departure (Marine Exchange, 2006b). But the lack of a central system for assigning tugs made it impossible to identify the specific tug assigned to each call or to compile a data base on the actual fleet of tugs that performed assist services in 2005.

Approach and Methodology

ENVIRON took the following general approach to estimating assist tug emissions during the assist phase of their operation at the Port of Oakland:

- Developed a database for a surrogate fleet of assist tugs that is reasonably representative of those that actually operated in the San Francisco Bay in 2005,
- Grouped tugs by Bollard pull class and calculated a mean horsepower rating and emission factor for each assist tug classification,
- Assigned assist tugs to vessel calls based on the classification of the tugs; that is the tugs' capability to provide assist services to the vessels of different sizes that actually called at the Port of Oakland in 2005,
- Assigned the average number of tugs to incoming and outgoing vessels based on the Marine Exchange report cited above, 1.91 tugs per incoming assist and 1.55 tugs per each outgoing assist, and
- Applied to assist tugs the average in-bound and out-bound maneuvering times that were used for vessels elsewhere in this report, that is; the average time required to transit between the Bay Bridge and the berth for the Inner and Outer Harbors.

The ARB asked ENVIRON to use the updated emissions estimation methodologies and information that were developed for the ARB's Off-Road Model and for pending rulemaking on Commercial Harbor Craft (ARB, 2006a). The ARB methodology requires the use of new emission factors that are specific to main propulsion and auxiliary engine model year, and applies both a deterioration rate and a fuel correction factor.

The basic equation used to calculate emissions from each group of assist tugs is the following:

$$Tug\ Group_{Emiss} = AEF \times Time_{hrs} \times Engine_{bhp} \times LF \times 1/(453.6 * 2000)$$

Where:

$Tug\ Group_{Emiss}$ is the tug group emissions in tons per year,
and
AEF is the main engine and/or auxiliary engine emission factor in grams per brake horsepower-hour, adjusted for model year, deterioration rate and fuel, and averaged by tug class,

Time $_{hrs}$ is the annual operating hours for the tugs in each group, based on the number of vessel calls, the average maneuvering time per call, and the average number of tugs assigned to each inbound and outbound assist,
Engine $_{Bhp}$ is the weighted average main propulsion and/or auxiliary engine brake horsepower rating of the engines in each tug group,
LF $_{wt}$ is the time weighted load factor for the maneuvering phase for the main engine and/or auxiliary engine, taken from the literature or the ARB methodology, stated as a ratio of 1, and
*1/(453.6 * 2000)* is the conversion of annual grams to annual tons.

ENVIRON also calculated the emissions from tugs transiting to and from their base of operations to the Bay Bridge meeting location. The tugs in the database are based at various locations on the Oakland waterfront on Port land, in Alameda in the Inner Harbor, in San Francisco, and in Richmond. The report from the Marine Exchange indicated which tug company provided the assist for each incoming and outgoing vessel call. ENVIRON used a similar approach to calculating emissions as that used for assist operations, except that operating time in the transit phase was estimated by dividing the transit distance traveled by an assumed average transit speed.

More detail on the key steps in the approach is provided below.

Characterizing the Assist Tug Fleet

In the absence of a central record that identified individual assist tugs and their activities, ENVIRON created a data base for a "surrogate" fleet of tugs that is reasonably representative of the fleet of tugs that actually provided assist activities in 2005. An important source of information on specific tugs and their engine characteristics was a 2002 list of tugs obtained by ENVIRON from GAIA, Inc. (GAIA, 2002). The GAIA list contained information on main and auxiliary engines, including their age and engine horsepower ratings. Because of the requirements of the ARB's methodology, tugs were not included in the database unless information was available on the model year of their main engines.

ENVIRON used the GAIA list as a starting point and updated it with information from the Marine Exchange, tug company websites, the San Francisco Bar Pilots, and the Bay Area Air Quality Management District (BAAQMD). The Marine Exchange listed individual tugs that are "certified" to provide escort or assist services to the Port of Oakland (Marine Exchange, 2006b). Tugs not on this list were excluded. Tug operator websites were checked to ensure that the individual tugs on the list were still operating in San Francisco Bay and were being marketed as providing vessel assist services. The websites also provided some data on main engines and their horsepower ratings. The San Francisco Bar Pilots provided information on standard practices and guidelines that established the minimum classification for tugs escorting different sized vessels (S.F. Bar Pilots, 2006). The BAAQMD provided updated emissions information for tugs that had main propulsion or auxiliary engines retrofitted or repowered under the Carl Moyer Program since 2002 (BAAQMD, 2006).

Overall, the tug database contains information on 27 tugs of various sizes that are equipped and certified to provide assist services to the Port of Oakland. Each tug in the representative fleet has two main propulsion engines with horsepower ratings from 600 to 3600 horsepower for each engine. If the tug's auxiliary engine horsepower rating was identified in the GAIA list or other sources, it was used. The ARB conducted a statewide survey on tugs and installed equipment, but it did not produce enough data for Bay Area tugs to use to characterize auxiliary engines in this inventory. Therefore, ENVIRON filled in other auxiliary engine horsepower ratings by assuming default average ratings based on the literature (ICF Consulting, 2006). Auxiliary horsepower ratings ranged from 81 to 155 horsepower.

The emission factor for SO_2 was based on ARB's fuel consumption methodology and assumes an average of 225 ppm sulfur, as found in ARB's survey of vessel operators for the San Francisco Bay Area (ARB, 2004a).

Managing Variability in Tug Characteristics and Assist Operations

The emissions estimation methodology described, above, assumes linear relationships between annual emissions on the one hand, and engine horsepower, engine load factor and hours of operation on the other. A two-fold change in any one of these factors doubles, or halves, the emissions estimate. Changes in two or more factors compound the change in the result. Given this sensitivity, ENVIRON has used site-specific information and assumptions wherever possible to produce a more accurate emissions estimate.

Tug propulsion engine horsepower levels vary considerably and larger vessels require larger tugs. ENVIRON used the Bar Pilot classification system for tugs to group the tugs in the database, determine their average horsepower ratings and emission factors by group, and assign tugs by class to vessel calls based on the length of the vessel. Table 3-6 shows tug groups, average horsepower ratings, and emission factors.

Table 3-6. Commercial Harbor Craft - Composite horsepower and emissions factors (EF) for assist tugs by class.

Main Engines Average Power (hp) and Emission Factors (g/hp-hr)						
Tug Class	**Average Power**	**Adjusted NOx EF**	**Adjusted ROG EF**	**Adjusted CO EF**	**Fuel Adjusted SO2**	**Adjusted PM EF**
A	4,344	11.41	0.69	2.82	0.09	0.44
B	3,125	11.30	0.72	2.79	0.08	0.48
C	2,775	15.46	1.08	3.32	0.08	0.68
D	1,507	10.86	0.77	2.61	0.08	0.50
Auxiliary Engines Average Power (hp) and Emission Factors (g/hp-hr)						
Tug Class	**Average Power**	**Adjusted NOx EF**	**Adjusted ROG EF**	**Adjusted CO EF**	**Adjusted SO2 EF**	**Adjusted PM EF**
A	128	11.13	0.85	3.30	0.09	0.59
B	110	11.27	0.98	3.25	0.08	0.67
C	92	14.10	1.13	3.60	0.08	0.75
D	110	10.07	0.93	3.09	0.08	0.66

Source: Emission factors from ARB (2006a) and ARB (2004a).

Based on observations of vessels assists in Oakland, higher power activities occur for a relatively small portion of the 45-50 minute assist time cycle. Assist tugs escort vessels at speeds of 8 knots or less. Under normal wind conditions tugs use higher engine power surges only to slow some vessels as they approach the turning location, assist in making the 180 degree turn needed to reverse course for berthing or departure, and position a vessel during the last stages of berthing. On the outgoing assist, the tug or tugs help the vessel separate from the berth, unless the vessel is equipped to provide its own separation and then follow the vessel out the channel to the drop off point near the Bay Bridge.

ENVIRON used an average load factor of 0.31 from the literature for tug propulsion engines during assist operations (ICF Consulting, 2006). According to the reference, this load factor was developed during a field study of vessel assists in Southern California. A well-designed and conducted field study would yield a more accurate, Port of Oakland-specific load factor.

The ARB has developed a statewide average load factor for tugs of 0.5, estimated from fuel consumption data. The ARB feels its load factor is appropriate for the Port of Oakland emissions inventory. Table 3-8 below shows emissions estimates based on both load factors.

ENVIRON used Port of Oakland specific data to estimate the time tugs spent in the assist mode. While all assists generally start and end near the Bay Bridge, the time required to berth varies between the Inner and Outer Harbors. ENVIRON, therefore, divided vessel calls into inbound and outbound legs to and from the Inner and Outer Harbors, respectively. Port specific time and distance considerations were also considered in estimating emissions from tugs transiting to and from their berths to the assist pick up location. Table 3-7 summarizes the time factors for both the assist and transit modes.

Table 3-7. Commercial Harbor Craft - Time spent in Assist and Transit Modes by group for 2005.

Group and Location	Group Vessel Calls	Group Assist Hours	Group Transit Hours	Transit location
Group 1 < 167.6 m (550')	47			
Group 1 Inner Harbor	47	39	146	Inner harbor to home
Group 1 Outer Harbor	0	0	0	Outer harbor to home
Group 2, 167.6 to 228.6 m (550-750')	386			
Group 2 Inner Harbor	287	239	893	Inner harbor to home
Group 2 Outer Harbor	99	74	213	Outer harbor to home
Group 3, 228.6 to 274.3 m (750-900')	537			
Group 3 Inner Harbor	207	172	644	Inner harbor to home
Group 3 Outer Harbor	330	248	711	Outer harbor to home
Group 4, 274.3 to 304 m (900-1000')	879			
Group 4 Inner Harbor	575	479	1789	Inner harbor to home
Group 4 Outer Harbor	304	228	655	Outer harbor to home
Group 5, >304 m (>1000')	66			
Group 5 Inner Harbor	48	40	149	Inner harbor to home
Group 5 Outer Harbor	19	14	41	Outer harbor to home
Vessel Calls for All Groups	1916			
Inner Harbor calls	1164			
Outer Harbor calls	752			
% calls to Inner Harbor	61%			
% calls to Outer Harbor	39%			
Transit Hours	5,242			
Transit Hours for IH vessel calls	3,622			
Transit Hours for OH vessel calls	1,620			

Emission Summary for Tug in Assist Mode

Emissions estimates for the tug assist mode of operation are shown in Table 3-8.

Table 3-8. Commercial Harbor Craft - Emissions from tugs in assist mode by scenario – tons in 2005.

Assist Scenario	Tug Engine	ROG		CO		NOx		PM		SO2	
		ARB Estimates	*ENVIRON Estimates* [1]	ARB Estimates	*ENVIRON Estimates* [1]	ARB Estimates	*ENVIRON Estimates* [1]	ARB Estimates	*ENVIRON Estimates* [1]	ARB Estimates	*ENVIRON Estimates* [1]
Inner Harbor - In Bound	Propulsion	3.44	*2.14*	13.39	*8.30*	55.20	*34.22*	2.22	*1.38*	0.41	*0.25*
	Auxiliary	0.12	*0.12*	0.42	*0.42*	1.45	*1.45*	0.08	*0.08*	0.01	*0.01*
	Subtotal	3.56	*2.25*	13.81	*8.72*	56.65	*35.68*	2.30	*1.46*	0.42	*0.27*
Inner Harbor - Out Bound	Propulsion	2.81	*1.74*	10.91	*6.76*	44.98	*27.89*	1.81	*1.12*	0.33	*0.21*
	Auxiliary	0.09	*0.09*	0.34	*0.34*	1.18	*1.18*	0.06	*0.06*	0.01	*0.01*
	Subtotal	2.90	*1.83*	11.25	*7.10*	46.16	*29.07*	1.88	*1.19*	0.34	*0.22*
Outer Harbor - In Bound	Propulsion	2.27	*1.41*	9.00	*5.58*	36.75	*22.79*	1.47	*0.91*	0.28	*0.17*
	Auxiliary	0.07	*0.07*	0.28	*0.28*	0.95	*0.95*	0.05	*0.05*	0.01	*0.01*
	Subtotal	2.34	*1.48*	9.28	*5.86*	37.70	*23.73*	1.52	*0.96*	0.29	*0.18*
Outer Harbor - Out Bound	Propulsion	1.84	*1.14*	7.33	*4.54*	28.73	*17.81*	1.19	*0.74*	0.23	*0.14*
	Auxiliary	0.22	*0.22*	0.01	*0.01*	0.06	*0.06*	0.00	*0.00*	0.04	*0.04*
	Subtotal	2.07	*1.37*	7.33	*4.55*	28.79	*17.87*	1.19	*0.74*	0.27	*0.18*
Tug Assist Emissions		**10.87**	***6.93***	**41.67**	***26.23***	**169.30**	***106.35***	**6.89**	***4.34***	**1.32**	***0.84***

1 - The ENVIRON load factor for main propulsion engines is 0.31, the ARB load factor is 0.5; an auxiliary engine load factor of 0.43 was used in both calculations

Assist Tugs in Transit Operational Mode

Tugs must travel some distance to meet incoming vessels at the Bay Bridge and to return to their bases after completing their assists. This transit mode is part of routine operations and needs to be considered to complete the assist tug inventory. The report ENVIRON obtained from the Marine Exchange that showed the number of tugs accompanying each vessel call also identified the companies providing the tug assists (Marine Exchange, 2006b). After obtaining the location of each tug operator's berthing area, ENVIRON estimated the distance from each tug operator's base to the Bay Bridge to meet in-bound vessels, and from a central location within the Inner and Outer Harbors, respectively, to return to their bases after assisting. The estimates were reversed to account for the trip back to their bases after assisting departing vessels. It was assumed that each tug makes this round trip for each vessel assist assignment. However since tugs may occasionally continue from an assist assignment to another activity, this assumption may slightly overestimate transit mode emissions. The mean distances were divided by an assumed average speed of 10 miles per hour to estimate average travel times per trip. The travel times were multiplied by the number of vessel calls to estimate total annual transit time for each group. Table 3-7, above, summarizes transit times.

As noted earlier, the same basic equation used for calculating assist mode emissions was used for transit emissions, except that the ARB's load factor of 0.5 was applied. This load factor seems reasonable as an average for a typical transit trip, which would involve a combination of low and high speed travel and waiting time at idle at the pickup point. Transit mode emissions are summarized in Table 3-9. Transit operations are estimated to produce approximately 60% of all assist tug emissions. Tug operators that berth in the Inner or Outer Harbors conducted well over 70% of the assists in 2005.

Table 3-9. Commercial Harbor Craft – Assist tug emissions in transit mode – tons in 2005.

	ROG	CO	NOx	PM	SO2
Totals	10.51	36.83	151.27	6.05	1.35

3.3 Emission Summary for all Commercial Harbor Craft

Finally, Table 3-10 shows the emissions calculated in this section summarized by ARB's emissions inventory categories.

Table 3-10. Commercial Harbor Craft emissions by source categories – tons in 2005.

Emission Source Categories	ROG		CO		NOx		PM		SO2	
	ARB Estimates	*ENVIRON Estimates[1]*	ARB Estimates	*ENVIRON Estimates[1]*	ARB Estimates	*ENVIRON Estimates[1]*	ARB Estimates	*ENVIRON Estimates[1]*	ARB Estimates	*ENVIRON Estimates[1]*
Harbor Craft										
Tugs vessel assist	**10.87**	***6.93***	**41.67**	***26.23***	**169.30**	***106.35***	**6.89**	***4.34***	**1.32**	***0.84***
Tugs transit to vessel assist	10.51	10.51	36.83	36.83	151.27	151.27	6.05	6.05	1.35	1.35
Tugs dredged materials disposal transport	0.84	0.84	4.22	4.22	22.07	22.07	0.40	0.40	0.16	0.16
Dredge tender	0.01	0.01	0.05	0.05	0.34	0.34	0.01	0.01	0.00	0.00
Crew boat-dredging	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00
Work Boat-dredging	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00
Sub-total Harbor Craft	**22.29**	**18.35**	**82.72**	**67.28**	**343.05**	**280.09**	**13.35**	**10.80**	**2.84**	**2.36**
Portable Equipment										
Dredge	0.04	0.04	0.33	0.33	1.71	1.71	0.03	0.03	0.01	0.01
Total All	**22.3**	***18.4***	**83.1**	***67.6***	**344.8**	***281.8***	**13.4**	***10.8***	**2.9**	***2.4***

1 - The ENVIRON load factor for main propulsion engines is 0.31, the ARB load factor is 0.5; an auxiliary engine load factor of 0.43 was used in both calculations

4.0 CARGO HANDLING EQUIPMENT

4.1 Cargo Handling Equipment Activity and Inventory

This section documents the emission estimation methods and results for cargo handling equipment (CHE) operated at Port of Oakland terminals and the rail yard in 2005. This inventory does not include CHE in the privately owned Schnitzer facility and Union Pacific railyard. Union Pacific has provided the ARB with an independent analysis of emissions from its Oakland facility.

The approach used to estimate CHE emissions was to determine annual emissions for each piece of equipment by terminal according to engine characteristics (model year, rated power, and equipment type) and equipment operation (hours of operation and fuel consumption rates). The equipment population and operation estimates were derived from terminal and rail yard surveys conducted in April 2006 by the Port of Oakland (the survey form is provided in Appendix D). For other input estimates, the inventory guidance documentation published by ARB (2005c) was used. The CHE emission estimates reported in this section were provided by ARB (2007) using the activity input data collected through the Port survey.

This inventory includes CHE emission estimates using ARB input and methodology, as well as an alternative emission estimate calculated with Port of Oakland specific load factor data. Because load factor is a key input used to calculate CHE emissions and it is poorly understood due of the lack of survey data and engineering studies, the Port and ARB agreed to include one CHE sensitivity case, where the average in-use Port surveyed load factors were determined from a sample of fuel consumption estimates. ENVIRON and the Port used fuel consumption survey results to estimate the average CHE load factor for Port operations in 2005. The sensitivity range represented by the ARB approach, which is consistent with methodologies used in previous ARB studies for similar facilities, and the alternative emission estimates using the Port specific load factor, therefore provide for an uncertainty range with which to better understand emissions from this mobile source category.

The CHE emission estimates were developed in accordance with ARB OFFROAD emission model methodology. For equipment in which on-road engines were used, ARB certifications have been used to modify the emission rates. For equipment with additional emission control devices, ARB presumably incorporated into the emission estimation the control efficiencies derived from the ARB (2006b) for those devices.

The basic equation used to calculate emissions from cargo handling equipment is the following:

$$E_p = EF_{p,t} * (1 - CF) * LF * n * hp * hrs$$

where: E_p = annual emissions of pollutant "p"
and
EF = emission factor (g/hp-hr)
CF = control factor (% reduction) by pollutant
LF = load factor (average load expressed as a % of rated power)
n = equipment population

hp = rated power (hp)
hrs = hours of activity per year (hr/year)
p = pollutant species (ROG, CO, NOx, PM10, SO_2)
t = equipment type

Emission factors depend on the fuel type, model year, rated power, cumulative hours/age, and retrofit control factor, if applicable.

4.2 Input Data and Use

Surveys sent out to each terminal at the Port and the two rail yards were returned with the following detailed information for each piece of CHE. This information was used as inputs for the emissions estimation

1. Equipment Type
2. Engine Type
3. Engine Model Year
4. Engine Retrofit Type/Repower
5. Chassis
6. Chassis Model Year
7. Fuel Type
8. Annual hours of operation
9. Rated horsepower
10. Cumulative hours of operation
11. Fuel consumption per piece of equipment

The CHE was grouped into equipment type categories as defined by ARB (2005c). The results for the marine terminals are summarized in Table 4-1. As reported by ARB, yard trucks were found to be the most prevalent cargo handling equipment type.

Table 4-1. Cargo Handling Equipment – Population by type (OIG rail yard included).

Equipment Type	Equipment Type Detail	Population	Percent
Material Handling Equipment	Side Pick	29	5.2%
	Top Pick	79	14.2%
Rubber Tired Gantry (RTG) Cranes		36	6.5%
Forklifts		52	9.3%
Other, General Industrial Equipment		1	0.2%
Yard Trucks		359	64.6%
Total		**556**	**100%**

Over 90% of Port of Oakland CHE is diesel powered with a few dozen pieces of equipment using liquefied petroleum gas (LPG) or gasoline powered engines. All gasoline powered CHE was of 25 rated horsepower or less and used sporadically, and the Port and ARB agreed to ignore these small source categories that are difficult to quantify. Table 4-2 summarizes CHE population by fuel type and shows the number of emission control devices and repowered engines present in the fleet.

The Port of Oakland conducted a "Container Terminal Equipment Repowering Program" from 2000 through 2005 to provide financial incentives for terminal operators to repower and/or retrofit their yard equipment and to switch to ultra low sulfur diesel fuel.

Table 4-2. Cargo Handling Equipment – Population by fuel type with emission control device and repower summary data (OIG rail yard included).

Fuel Type	Total CHE Equipment	Percent of Total	Emission Control Devices or Repower	Population	Fraction by Type
Diesel	522	94	Dual Oxidation Catalyst	150	27%
			Diesel Particulate Filter	2	<1%
			Repowered	16	3%
			No control device or repower	354	64%
LPG	34	6	Repowered	22	4%
			No control device or repower	12	2%
Totals	**556**			**556**	

Table 4-3 summarizes the average horsepower and annual use by equipment type and power range. Actual annual hours of operation for each piece of equipment were used to estimate emissions.

Table 4-3. Cargo Handling Equipment – Average horsepower and actual hours of operation by equipment type and horsepower range (Marine terminals and OIG rail yard included).

ARB General Equipment Type Designation	Upper End Power Range (hp)	Number of Equipment	Average Power (hp)	Average Annual Operation (hrs)
Container Handling Equipment (Side Pick, Top Pick)	120	2	120	416
	175	11	164	1,137
	250	23	227	1,524
	500	72	303	1,779
RTG and Other Cranes	250	4	225	492
	500	14	337	1,574
	750	8	546	462
	>750	10	1000	2,600
Forklifts	50	3	47	1,000
	120	25	77	811
	175	15	173	1,053
	250	8	202	431
	500	1	270	1,040
Other, General Industrial Equipment	175	1	150	52
Yard Trucks	175	95	172	1,505
	250	264	204	1,480
Total	**---**	**556**	**---**	**---**

4.3 Cargo Handling Equipment Emission Factors

Because ARB's OFFROAD emissions computer model for cargo handling equipment was not publicly available, emission factors and emission estimates were provided by ARB (2007) using the activity input data collected from the Port survey.

4.4 Load Factor Survey Results

One of the more uncertain estimates in the offroad equipment emission calculation is the load factor. Load factors are difficult to discern because the duty cycle of equipment can vary widely over the course of equipment operation, including periods of high power operation interspersed with periods of short or extended zero load idling. The load factor methodology as used in the emissions estimates, therefore, represents an approximate estimate for overall activity reflecting typical engine loads during normal equipment operation.

The load factor could be determined from instrumented data recorded during the operation of the equipment, which is costly to obtain because it requires collection of detailed engine operating parameters during normal operation. However, another method to estimate the average load factor for a piece of equipment is to compare its fuel consumption to the maximum fuel consumption for the same piece of equipment at the rated power.

The Port of Oakland conducted a survey of fuel consumption per piece of equipment under normal operations. The survey responses included fuel consumption estimates for about 35% of Port of Oakland CHE identified in the Port's CHE surveys conducted in February 2006. Some terminal operators provided equivalent estimates for many pieces of equipment in a given fleet, and thus did not represent each piece individually. ENVIRON calculated the load factor by comparing the actual fuel consumption with the maximum fuel consumption, as shown in the equation below. The maximum fuel consumption rate was estimated using the brake specific fuel consumption (BSFC) rates from ARB (2000).

$$LF = FC / MFC / 7.1 \text{ lb/gal}$$

$$MFC = hp * BSFC$$

where: LF = Load factor
and
FC = actual fuel consumption (gal/hr)
MFC = maximum fuel consumption (lb/hr)
hp = rated horsepower
BSFC = brake specific fuel consumption (lb/hp-hr)

Table 4-4. Cargo Handling Equipment – Load factor by diesel equipment type.

Equipment Type	ARB Default Engine Load Factor	Port of Oakland Surveyed Load Factor
RTG Cranes	43%	25%
Excavators	57%	---
Forklifts	30%	44%
Container Handling Equipment	59%	26%
Other, General Industrial Equipment	51%	27%
Sweeper/Scrubbers	68%	---
Tractors/Loaders/Backhoes	55%	---
Yard Trucks	65%	36%

Source: ARB 2005c and this study

As shown in Figure 4-1, ARB (2005c) load factor estimates are generally higher than the load factors surveyed for equipment operating at the Port. Only forklifts were found to operate at higher average loads than ARB estimates. ENVIRON estimated the average load factor using the population weighted results, along with an uncertainty range based on the unique individual survey estimates. In cases where ARB (2005c) load factors were found to overestimate actual Port CHE load factors, estimated emissions could be higher than actual emissions.

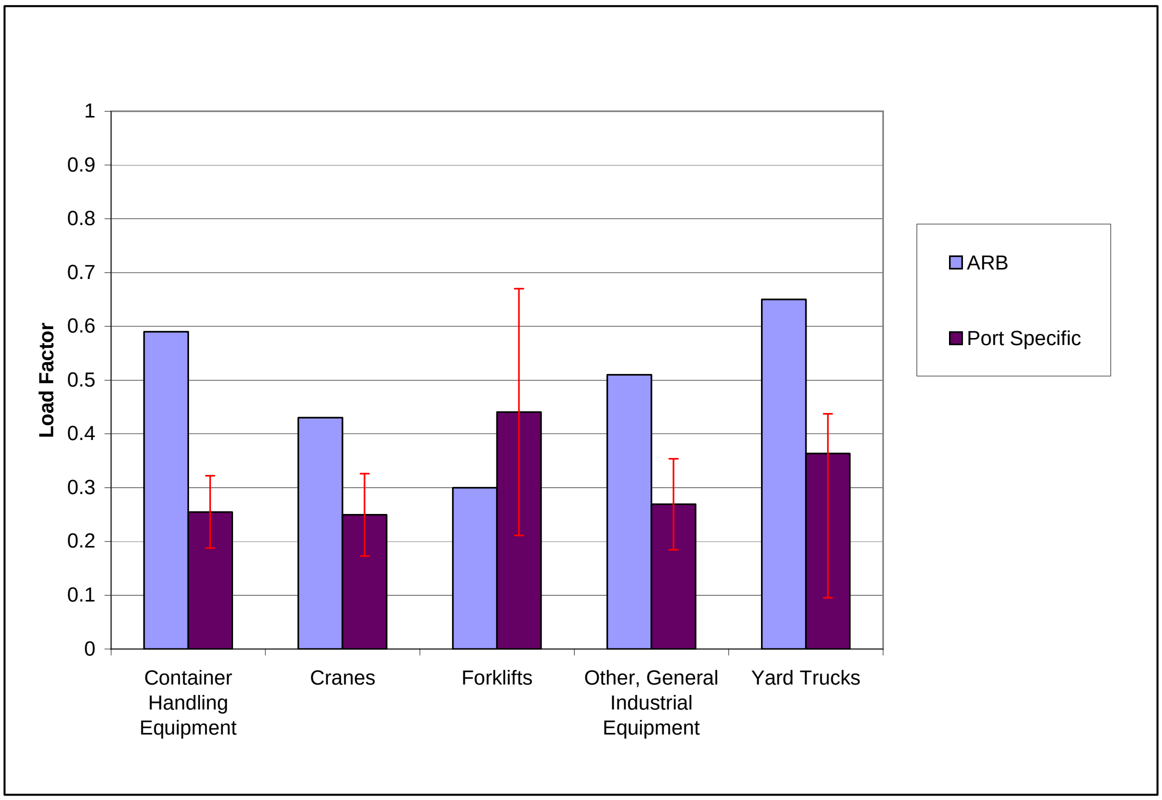

Figure 4-1. Comparison of ARB (2005c) load factors and Port of Oakland fuel consumption survey load factors by equipment type based on ARB (2000) fuel consumption estimates. (Note: Load factor ranges for Port surveyed load factors represent 90% confidence intervals on unique individual survey data.)

While not conclusive, the results of the fuel consumption surveys highlight the uncertainty in the load factor. The load factor is used directly in the emission estimates for cargo handling equipment, so the emission results are also uncertain. The Port and ARB agreed to provide an uncertainty range of CHE emissions using the ARB default and the Port surveyed load factors presented here. ARB (2007) provided emission summaries using both load factors estimates.

The use of and the magnitude of the load factor in emission calculations is itself uncertain because the method relies on only one average load factor to represent all activity. Mobile source equipment operates over a large range of loads, and the transient loads during the use of this equipment can lead to higher or lower emissions than one might estimate from using one average continuous load. For instance, engine idling produces emissions under no load, so the appropriate load factor cannot be precisely determined for equipment that idles a high proportion of time in use. Therefore, the emissions range due to the load factor sensitivity presented in this work provides an understanding of the potential uncertainty in emissions estimates from this equipment. Future studies will be needed to provide more specific load factors for different types of CHE under site specific operating conditions.

4.5 Cargo Handling Emission Results

Using the surveyed equipment population, activity, and other input data, ARB (2007) calculated emissions for the Port of Oakland cargo handling equipment (CHE) using the OFFROAD emissions computer model. Table 4-5 presents emission results for the CHE emissions using the ARB load factors and the Environ load factors based on surveys at the Port of Oakland.

Table 4-5. Cargo Handling Equipment – Port of Oakland cargo handling equipment emissions using ARB and ENVIRON specific load factors – tons for 2005.

Emission Source Category	ROG		CO		NOx		PM		SO2	
	ARB Estimates	***ENVIRON Estimates*[1]**	**ARB Estimates**	***ENVIRON Estimates*[1]**	**ARB Estimates**	***ENVIRON Estimates*[1]**	**ARB Estimates**	***ENVIRON Estimates*[1]**	**ARB Estimates**	***ENVIRON Estimates*[1]**
ARB – diesel	34	19	135	76	696	380	21.19	11.92	7	4
ARB – LPG	19	14	273	165	70	41	0.53	0.35	0	0
ARB Totals	**53**	**33**	**408**	**241**	**766**	**422**	**21.7**	**12.3**	**7**	**4**

[1] CHE - ARB's calculation use default load factor used in previous studies and ENVIRON's calculation use the results of a CHE fuel consumption survey conducted at the Port in 2006 to estimate the average load factor for the Port CHE operations.

5.0 ON-ROAD TRUCK ACTIVITY

Port of Oakland maritime operations create a demand for truck trips transporting containers between marine terminals and the freeways or nearby rail yards. Trucks arrive at or depart from the Port area via three freeway interchanges: Maritime/West Grand Street, Seventh Street and Adeline/Market Street. Even if trucks arrive via surface streets, they must pass through these three access points to enter the Port area. The Port operations also include truck trips associated with moving intermodal cargo containers between the marine terminals and the Oakland International Gateway and Union Pacific rail yards, both of which are located in the Port area. ENVIRON therefore defined the study area for this air emissions inventory to include truck routes between the marine terminals and each of the three freeway interchanges or the two rail yards.

This section describes the typical annual truck activity demands, average truck characteristics and travel modes, and estimates spatially allocated emissions for activity that occurred in 2005. To better characterize truck activities, the Port and ENVIRON conducted special studies to verify the truck counts and age distribution of the truck fleet serving the Port terminals. It was beyond the scope of this report to develop specific travel demand models or collect specific activity data, including determining routes of individual trucks trips, and ultimate destinations for each truck trip. ARB is currently conducting a study of diesel emissions that will include all truck traffic (both Port and non-Port related) on freeways surrounding the West Oakland neighborhood.

ENVIRON used truck activity and the ARB EMFAC model to estimate emissions from the trucks idling and moving in the Port area. ENVIRON used the most recent version (at the time of this study, January 2007) of the EMFAC2007 model, Version 2.3, to estimate truck emissions. For consistency with other studies, ARB requested that ENVIRON also used a pre-release beta version of EMFAC2007 to calculate emissions. This section presents both estimates.

5.1 Emission Calculation Methodology

The general approach used to estimate truck emissions was to characterize the truck trips to and from the marine terminals by estimating the trip mileage, average speed per road link and the number of trips. A link is a term used by transportation modelers to describe a segment of roadway, and a vehicle trip may be described by assuming a vehicle travels on a collection of road links that piece end to end to make a longer trip. ENVIRON conducted the basic truck emission estimates using the following equation.

$$E_p = n_{\text{Truck Trip}} * \text{Miles}_{\text{Trip}} * EF$$

where: E_p = emissions of pollutant "p"
n = number of trips
Miles = trip mileage or hours at idle
EF = emission factor (g/mile, g/hour).
(Requires trips to be defined by speed)

ENVIRON gathered input activity data from several distinct sources. Truck trips were determined for each terminal and rail yard and applied to one of various routes within the Port area. The necessary input data were as follows:

1. Truck trips
   a) Marine terminal (to and from freeway; to and from rail yard)
   b) Rail yards (to and from freeway; to and from marine terminal)

2. Trip mileage (routes)
   a) Outside of the terminals and rail yards
   b) Within the terminal and rail yards

3. Idle time
   a) Outside terminals and rail yards entrance queues
   b) Within terminal and rail yards

4. Emission factors derived from the EMFAC2007 model based on
   a) Age distribution
   b) Average trip speed by road link
   c) Idle emission rate

5.2 Truck Trip Counts

The most basic measure of truck activity is the number of truck trips through each terminal facility, where a trip includes both an entrance and an exit by the truck cab. To estimate the truck trips, the Port of Oakland conducted an in-depth survey with the terminal operators to determine the gate counts by configuration of each cab (tractor) at the entrance and exit to accurately determine the number of truck trips to the terminals. The survey asked for the gate counts at the entrance and exits of the terminals by the following truck configurations:

- Cab (tractor) and chassis (trailer) with container
- Cab (tractor) with bare chassis (trailer without container)
- Cab (tractor) only (also called a bobtail)

All container facilities, either marine terminals or rail yards, keep accurate counts of loaded truck entrances and exits at their gates. However, some terminals may not record entrances and exits of unloaded trucks (bare chassis or bobtails) or trucks hauling empty containers that may have been temporarily stored in the yards. Such truck trips may not have been counted at the terminal entrance or exit, but need to be accounted for in an emissions inventory.

The Port of Oakland also records ship lifts for each terminal. Ship lifts are considered very reliable data because payments to operators are based on the number of lifts. The ship lifts represent the number of containers (boxes) moved onto or off a ship. The truck gate counts together with the ship lift records provided sufficient data to estimate truck patterns and truck trips. Truck journeys follow distinct patterns within a terminal in nearly all instances. Figure 5-1 illustrates this pattern and incorporates the following operations:

- Loaded trucks drop off a container inside the yard.
- Some of these containers being dropped off may be empties that are stored on the terminal for later pick-up and loading at an outside facility. Thus, not all containers entering the terminals are loaded onto a ship but may exit the terminals again.
- The number of truck trips can exceed the number of ship lifts, but could also be lower than the number of lifts when a large fraction of loaded trucks both enter and exit to terminal.
- Some trucks entering with a container drop it off, and then pick-up a container before exiting. The remainder of these loaded truck trips leave as a bobtail or a cab with an empty chassis.
- Trucks leaving the terminal with a container consist of trucks that previously dropped off a container at the terminal, or trucks that entered the terminal without a container (bobtail or cab with an empty chassis).
- Trucks entering the terminal, either as a bobtail or as a cab with chassis, pick-up a container that was unloaded from a ship or one of the empty containers stored on site.

ENVIRON estimated truck trips from truck gate count data and container lift data provided by the Port. The comparison and testing of the truck trip data with container throughput data assured the accuracy of the truck count data. The survey totals for truck counts and the final adjusted truck counts totals are shown in Table 5-1. In particular, the data on trucks that leave the terminals without a container was uncertain. Therefore, some truck gate counts have been adjusted to align with ship lifts and to balance the reported incoming and outgoing trucks. In each instance when an estimate was uncertain, the higher estimate was chosen which led to the number of trips being 13% higher than the terminals' survey. The truck trips to the UP rail yard (UP Railport) were not provided to the Port. Because the number of truck trips from the marine terminals to the UP rail yard was necessary to estimate truck emissions from the Port operation, the truck trips to the UP Railport were assumed (with ARB's approval) to be the same number of trips as that for the BNSF-operated Oakland International Gateway (OIG) terminal. The UP Railport may have additional truck trips between the rail yard and freeway interchanges, which are trips associated with UP's transport of domestic cargo. Truck trips related to UP's domestic cargo are not included in the data presented in Table 5-1.

Table 5-1. On-road Trucking – Truck count (in gate plus out gate) totals for 2005.

Terminal Type	Raw Survey Results	Adjusted Truck Trips
Marine	2,310,227	2,620,483
Rail[1]	456,144	912,288

[1] Rail survey results were available from only one rail yard (OIG) so were assumed the same for UP Railport.

ENVIRON estimates that the remaining uncertainty of the number of truck trips is likely within 10% of the total estimated truck trips and may be biased slightly high due to the adjustments. Uncertainties were highlighted in the survey results when, for example, truck counts in and out did not balance or chassis counts in and out did not balance. A schematic of the truck movements through terminals that highlights the potential reasons for truck trips is shown in Figure 5-1. The estimate is more likely to be biased high compared to what actually occurred because ENVIRON intentionally used a higher estimate when there was any question of the number of truck trips matching the container lift data. The reasons for uncertainty to occur were many and include the following that could either raise or lower the number of truck trips estimated from the lift data alone:

- Differences in operations from terminal to terminal,
- Uncertainty in truck counts, in particular of those with empty containers, empty chassis or trucks entering or leaving the terminal for other purposes and not hauling a loaded container (potentially higher number of truck trips than lift data),
- Trucks that may carry two 20-foot containers (potentially lower number of truck trips than lift data),
- An increase or decrease in empty container or chassis storage over the year (either higher or lower number of truck trips), and
- Trans-load containers that are loaded onto another vessel and never leave the terminal by truck (potentially lower number of truck trips than lift data).

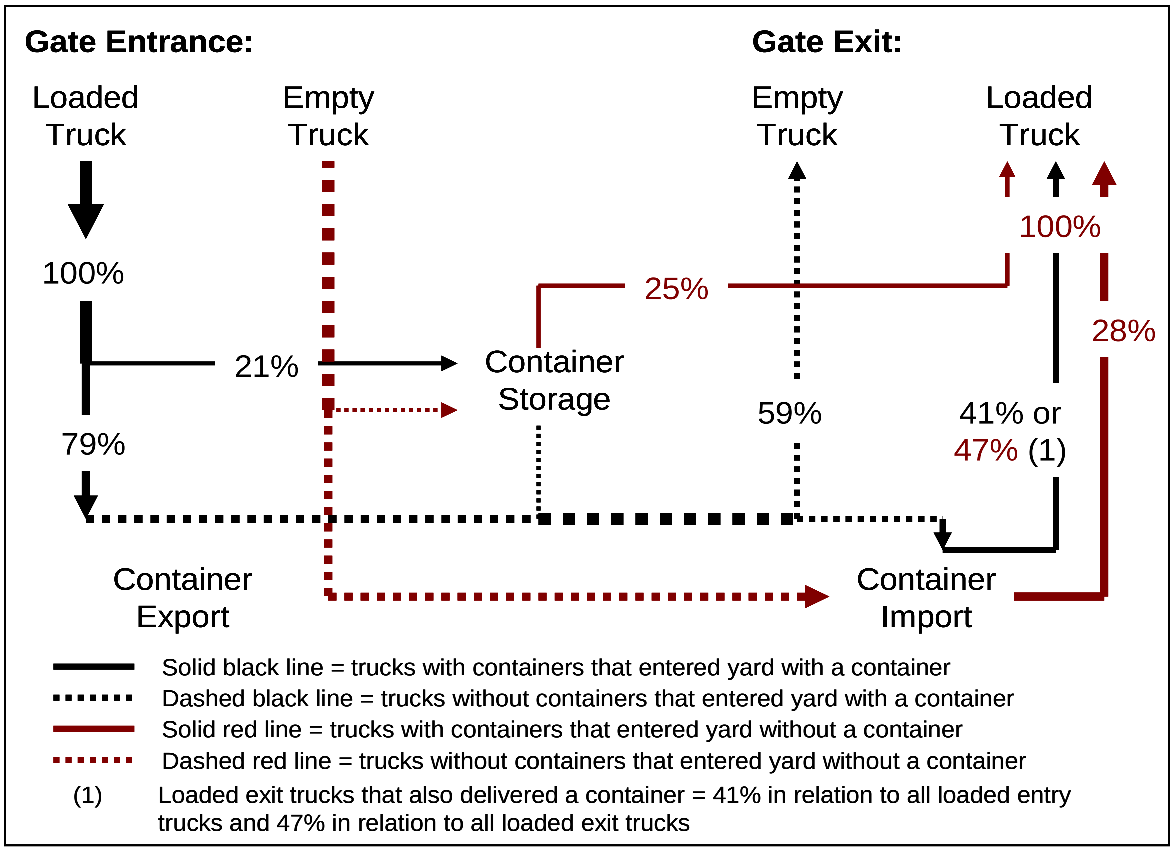

Figure 5-1. Truck travel patterns at the Port of Oakland.

5.3 Truck Trip Definitions

Under the scope of this study, truck trips originate from or are destined to one of the three freeway interchanges, or result from round trips between the rail yards and marine terminals. A truck may take a limited number of possible routes, outlined below. It is beyond the scope of this project to identify precise estimates for each of the possible routes or trip types, so a simplified but accurate method was used to estimate the truck trips so that vehicle miles traveled (VMT) and average speed of the trips could be determined.

Trip Types

1. Freeway to marine terminal and back to freeway,
2. Freeway to marine terminal, to rail yard, and back to freeway,
3. Freeway to rail yard, to marine terminal, and back to freeway,
4. Freeway to rail yard, to marine terminal, to rail yard, and back to freeway,
5. Rail yard, to marine terminal, to rail yard round trip, and
6. Freeway to rail yard, to freeway (considered to be unrelated to Port travel demand).

The trip estimation can be further simplified by reducing the number of trip types to #1 and #5 by combining other trip types into these two.

Data on the number of truck trips to and from rail yards to the freeway (trip type #6) without a trip to the marine terminal was not readily available. However, these trips are considered unrelated to the Port operations and are not within the scope of this study. This trip type would have occurred exclusively to and from Union Pacific's rail yard facility (UP Railport) where some of the freight is domestic and never moves through the Port of Oakland marine terminals. Union Pacific evaluated their yard's emission inventory as part of a separate study, and did not provide the Port with this study information. However, because some of the container traffic through UP Railport does move through the Port, it was necessary to estimate the truck trips to this yard associated with the marine terminal operations. ENVIRON, with the acceptance of ARB, estimated that the same number of trips to the BNSF-operated OIG rail yard was representative of the number of trips to and from UP Railport and the marine terminals. The trips to and from rail yards, estimated from twice the BNSF OIG gate counts, were assumed to be round trips to marine terminals (trip type #5) based on discussions with BNSF staff. BNSF staff noted that very little, if any, traffic through the OIG yard is unrelated to the marine terminals' activity.

The approach used in this study assumed that the truck travel directly to rail yards from the freeway (truck trip #3) then onto a marine terminal prior to exiting the study area approximately equals the truck travel that arrives directly to a marine terminal and exits to a freeway via a rail yard (truck trip #2), or that both types of trips are an insignificantly small fraction of the total travel. The approach also assumed that more complex trip types (#2, #3, and #4) are identical to a combination of a marine-freeway trip (trip type #1) and a round trip between the marine terminal and rail yard (trip type #5). In this manner, all activity was accounted for, though it may have lacked specificity in terms of modes or routes taken. Further and extensive surveys would be necessary to determine the truck trips more precisely, and given the changing nature of goods movements, these surveys may not provide a better or more robust measure of future activity.

The trip calculations are shown algebraically in the equations, below.

Trip Type #1 = Sum(Marine Terminal Trips) – Sum(Port-related Rail Trips)

Trip Type #5 = Sum(Port-related Rail Trips) = Sum(Rail Trips) – Sum(Rail to/from Freeway Trips unrelated to the Port = Trip Type #6)

ENVIRON subtracted the truck trips through the two rail yards from the total inner and outer harbor terminals to determine the fraction of trips directly from or to the freeway interchanges and the fraction making round trips to the rail yards. About 35% of the marine terminal truck trips were estimated to be trips to the rail yards. ENVIRON applied this trip fraction to the trip counts at each marine terminal to estimate the different routes of travel.

ENVIRON modeled the truck trips to the freeway interchanges as routing to one of three freeway interchanges. According to surveys conducted at the Port (CCS, 2003), 57% of truckers use 7th Street, 41% use Grand/Maritime, and 14% use the Adeline/Market freeway interchange. Because these fractions total more than 100% (likely because different routes were sometimes used for trips into and out of the Port and reported twice), the truck travel estimate was prorated to 51.0%, 36.5%, and 12.5% for 7th Street, Grand/Maritime, and Adeline/Market, respectively. ENVIRON then distributed the freeway marine terminal trips to these three routes accordingly for each terminal. Trucks would more likely use interchanges closer to a given terminal to reduce the overall mileage and travel time. Therefore, ENVIRON, with ARB approval, estimated the allocation of routes for each terminal, shown in Table 5-2, so that the sum of the truck route entrances and exits from all terminals matched the CCS port-wide allocation.

Table 5-2. On-road Trucking – Distribution of truck trips between freeway and Port terminals.

Terminal	Adeline/ Market Street	7th Street	Grand/Maritime Street
Berth 20 – 24	0 %	20 %	80 %
Berth 25 – 26	0 %	40 %	60 %
Berth 30	0 %	65 %	35 %
Berth 32 – 34	0 %	65 %	35 %
Berth 35, 37 – 38	0 %	65 %	35 %
Berth 55 – 56	0 %	65 %	35 %
Berth 57 – 59	5 %	65 %	30 %
Berth 60 – 63	40 %	40 %	20 %
Berth 67 – 68	100 %	0 %	0 %

The truck trips for on-road vehicles that transport containers to and from the Port could go to either of the two rail yards or any of the freeway interchanges. Therefore, ENVIRON defined trips to and from each freeway interchange and each rail yard. Figure 5-2 shows the numbered links from each terminal and rail yard within the boundary of the Port area. Dowling Associates, Inc. estimated travel distances and average trip speeds for each of the 33 defined road links. Their methods and estimates are described in Appendix E.

ENVIRON defined trips by summing the road links to or from the terminals and the rail yards and freeway interchanges. Trips defined in this manner allowed ENVIRON to calculate both the mileage and average speed for each truck trip as shown in Table 5-3 by summing the mileage and travel time for all links that comprise each trip.

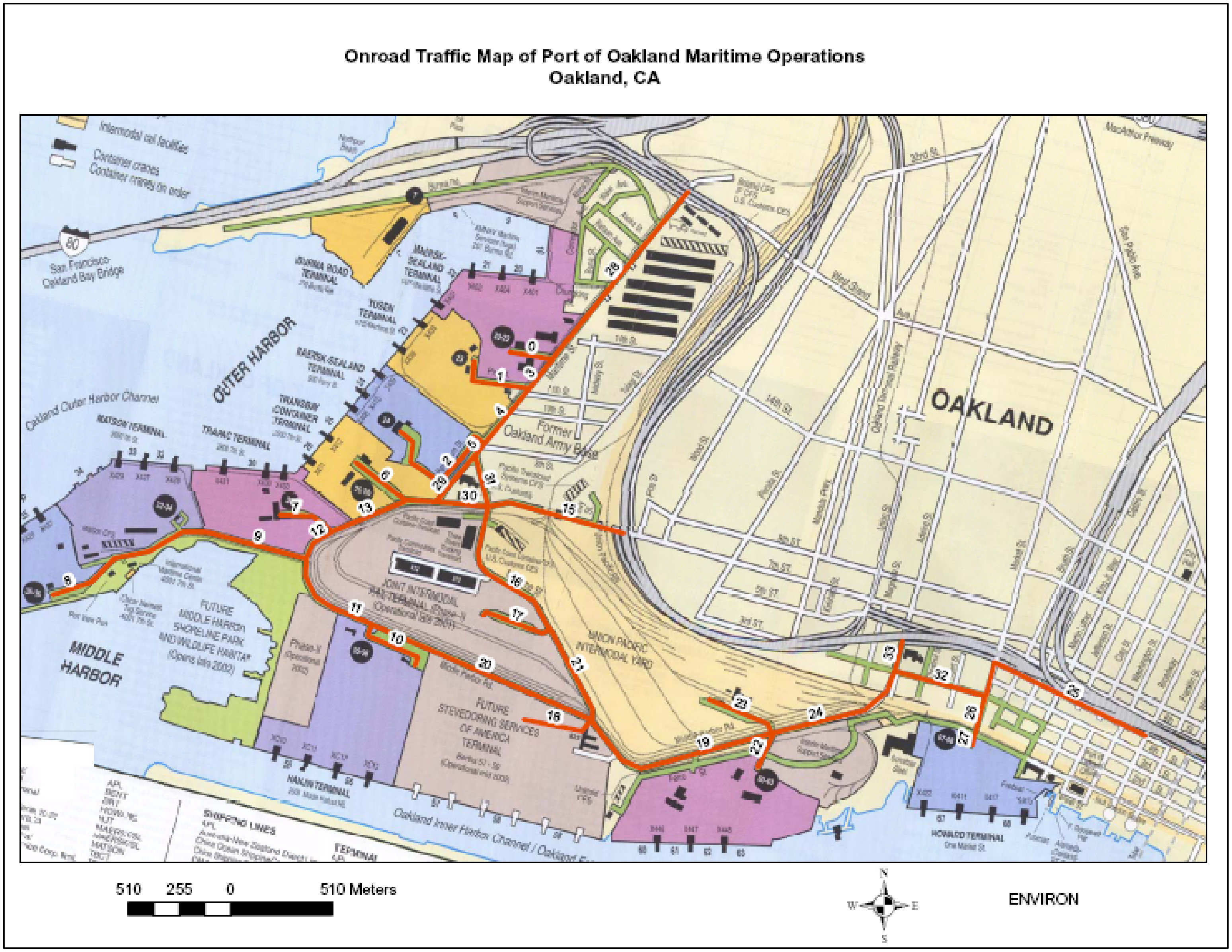

Figure 5-2. On-road links within the Port of Oakland.

Table 5-3. On-road Trucking – Description of potential truck travel.

Trip ID	Terminals	Trip Beginning/ End	Road Link Segments	Total Length (feet)	Average Speed (mph)
T1	Berths 20-22	West Grand	0, 28	3,864	29
T2	Berths 20-22	7th	0, 3, 4, 5, 31, 15	5,466	28
T3	Berths 20-22	Adeline	0, 3, 4, 5, 31, 16, 21, 19, 24, 33	13,542	30
T4	Berths 20-22	BNSF	0, 3, 4, 5, 31, 16, 17	7,694	25
T5	Berths 20-22	Union Pacific	0, 3, 4, 5, 31, 16, 21, 19, 23	11,877	28
T6	Berth 23	West Grand	1,3,28	5,310	29
T7	Berth 23	7th	1,4,5,31,15	5,728	27
T8	Berth 23	Adeline	1,4,5,31,16,21,19,24,33	13,804	29
T9	Berth 23	BNSF	1,4,5,31,16,17	7,956	24
T10	Berth 23	Union Pacific	1,4,5,31,16,21,19,23	12,139	27
T11	Berth 24	West Grand	2,4,3,28	7,391	28
T12	Berth 24	7th	2,5,31,15	5,789	23
T13	Berth 24	Adeline	2,5,31,16,21,19,24,33	13,865	27
T14	Berth 24	BNSF	2,5,31,16,17	8,017	21
T15	Berth 24	Union Pacific	2,5,31,16,21,19,23	12,200	25
T16	Berths 25-26	West Grand	6,14,29,5,4,3,28	7,866	29
T17	Berths 25-26	7th	6,14,30,15	4,569	26
T18	Berths 25-26	Adeline	6,14,30,16,21,19,24,33	12,645	29
T19	Berths 25-26	BNSF	6, 14,30,16,17	6,797	23
T20	Berths 25-26	Union Pacific	6,14,30,16,21,19,23	10,980	27
T21	Berth 30	West Grand	7,13,14,29,5,4,3,28	9,323	28
T22	Berth 30	7th	7,13,14,30,15	6,026	25
T23	Berth 30	Adeline	7,12,11,20,19,24,33	13,578	31
T24	Berth 30	BNSF	7,12,11,20,21,17	9,792	28
T25	Berth 30	Union Pacific	7,12,11,20,19,23	11,913	29
T26	Berths 33-35	West Grand	8,9,12,13,14,29,5,4,3,28	12,430	33
T27	Berths 33-35	7th	8,9,12,13,14,30,15	9,133	32
T28	Berths 33-35	Adeline	8,9,11,20,19,24,33	15,599	35
T29	Berths 33-35	BNSF	8,9,11,20,21,17	11,813	34
T30	Berths 33-35	Union Pacific	8,9,11,20,19,23	13,934	34
T31	Berths 55-56	West Grand	10,11,12,13,14,29,5,4,3,28	12,001	29
T32	Berths 55-56	7th	10,11,12,13,14,30,15	8,704	27
T33	Berths 55-56	Adeline	10,20,19,24,33	11,920	30
T34	Berths 55-56	BNSF	10,11,12,13,14,30,16,17	10,932	24
T35	Berths 55-56	Union Pacific	10,20,19,23	10,555	27
T36	Berths 57-59	West Grand	18,21,16,31,5,4,3,28	11,590	30
T37	Berths 57-59	7th	18,21,16,15	7,604	27
T38	Berths 57-59	Adeline	18,19,24,33	7,814	26
T39	Berths 57-59	BNSF	18,21,17	4,028	20
T40	Berths 57-59	Union Pacific	18,19,23	6,149	22
T41	Berths 60-63	West Grand	22,19,21,16,31,5,4,3,28	15,012	31
T42	Berths 60-63	7th	22,19,21,16,15	11,026	29
T43	Berths 60-63	Adeline	22,24,33	4,400	26
T44	Berths 60-63	BNSF	22,19,21,17	7,450	24
T45	Berths 60-63	Union Pacific	22,23	2,735	17
T46	Berths 67-68	West Grand	27,26,32,24,19,21,16,31,5,4,3,28	19,674	31
T47	Berths 67-68	7th	27,26,32,24,19,21,16,15	15,688	29
T48	Berths 67-68	Adeline	27,26,32,33	4,070	24
T49	Berths 67-68	BNSF	27,26,32,24,19,21,17	12,112	26
T50	Berths 67-68	Union Pacific	27,26,32,24,23	7,397	24

To determine the distance and speed for truck trips on terminal grounds within the fence line, the Port of Oakland conducted a survey of the terminal operators to estimate the travel distance and average speed for trucks moving within the terminal. The survey included both average queuing time at terminal gate entrances and estimates of idle time on the terminal property while containers are removed or retrieved for transport, during security inspections, and during identification and administrative processing. Table 5-4 provides the average on-terminal activity parameters used to determine the emissions within the terminal.

Table 5-4. On-road Trucking – Average on-terminal activity parameters.

Mode	Average Estimate
Idle Gate Queue (hrs)	0.20
Idle in Terminal (hrs)	0.52
Distance (miles)	2.22
Speed (mph)	13.87

5.4 Emission Factors and Age Distribution

Emissions rates from trucks depend on the age distribution of the transport trucks as well as site-specific conditions such as humidity, temperature, and, especially, average speed. Age distribution plays a significant role because of recent regulations that significantly reduce criteria pollutant emissions from newer trucks. In particular, with the model years 1991 and 2003, steep declines in NOx and PM emission rates occurred.

Figure 5-3 shows a sample of the emission factors (specific for 25 mph average speed) by model year for heavy-duty trucks. It is evident that the age distribution of the fleet of vehicles affects the emissions of the truck fleet serving Port terminals because older model year trucks have significantly higher emissions.

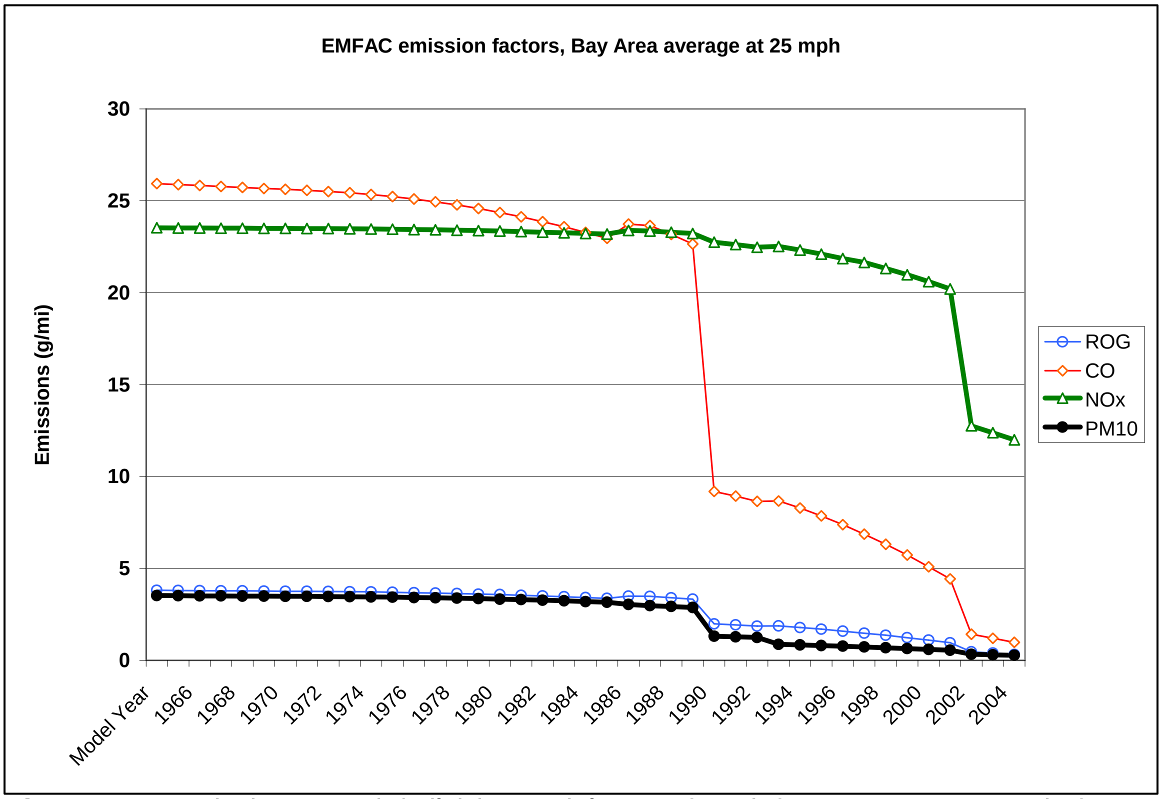

Figure 5-3. Emission rates (g/mile) by model year of truck for an average speed of 25 mph. Source: EMFACE2007, Version 2.3.

Common wisdom for ports is that on-road trucks serving the ports are usually older and near the end of their useful life. The older trucks serve at ports because of lower annual mileage, proximity to repair facilities, and the low profit margin in port business. Because unique conditions at the Port of Oakland may exist, ENVIRON and Dowling Associates conducted a license plate identification study in October 2006 to estimate a Port-specific distribution of truck model years. The study is described in Appendix F. The Air Resources Board coordinated with the Department of Motor Vehicles to provide ENVIRON and Dowling Associates the truck model years corresponding to the license plate numbers collected.

The Port of Oakland specific truck age distribution based on the license plate samples is shown in Figure 5-4. This locally derived, Port-specific age distribution was used in order to derive emission rate estimates from EMFAC2007. Apparent from this sample of the age distribution, was the near absence of post-2000 trucks (trucks younger than 6 years). The sampled age distribution of the fleet serving the Port was primarily between model years 1993 and 1999, inclusive, accounting for 80% of all truck trips. Very few trucks were found to be certified to the 2004 emission standards that entered the market in 2002. [1]

[1] The major U.S. engine manufactures had agreed to introduce the 2004 engine standard two years ahead of schedule in a consent decree with the EPA to mitigate for unlawful tampering of engines in earlier model years.

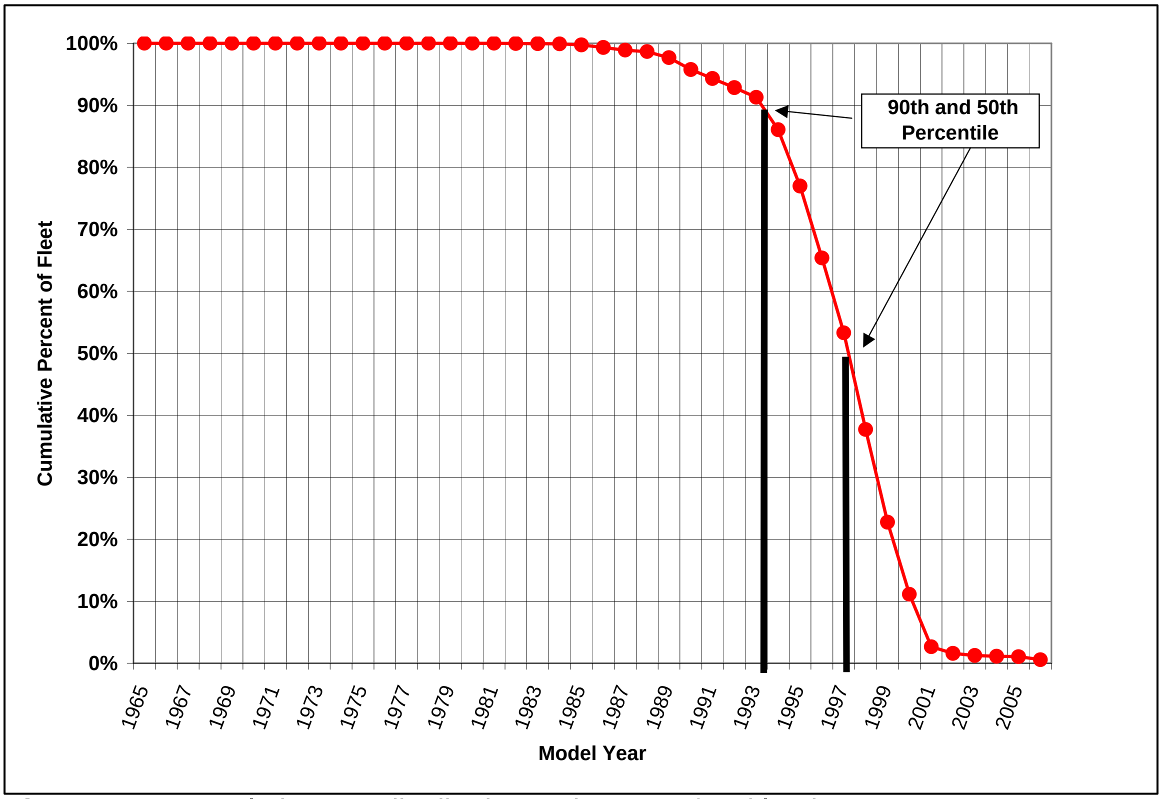

Figure 5-4. Cumulative age distribution at the Port of Oakland.

The sampled Port of Oakland truck age distribution differed from that reported for the San Pedro Bay, California ports. The Port of Los Angeles study (Starcrest, 2005) and the Bay Area average EMFAC model registered vehicle population and vehicle miles traveled (VMT)-weighted age distributions are shown in Figure 5-5. While the Port of Los Angeles distribution shows a similar pattern in that there are very few trucks five years old or newer, many of the trucks serving the Port of Los Angeles are older than 13 years. For instance, at the Port of Los Angeles, the 90th percentile of truck age is 17 years compared to 12 years for the Port of Oakland. The EMFAC/BURDEN distribution for the Bay Area (population and the VMT-weighted population) is as expected least applicable, because there are more newer and older model year trucks. The VMT-weighted age distribution is the distribution typically used to reflect area emissions, and accounts for the fact that newer trucks drive more miles than older trucks.

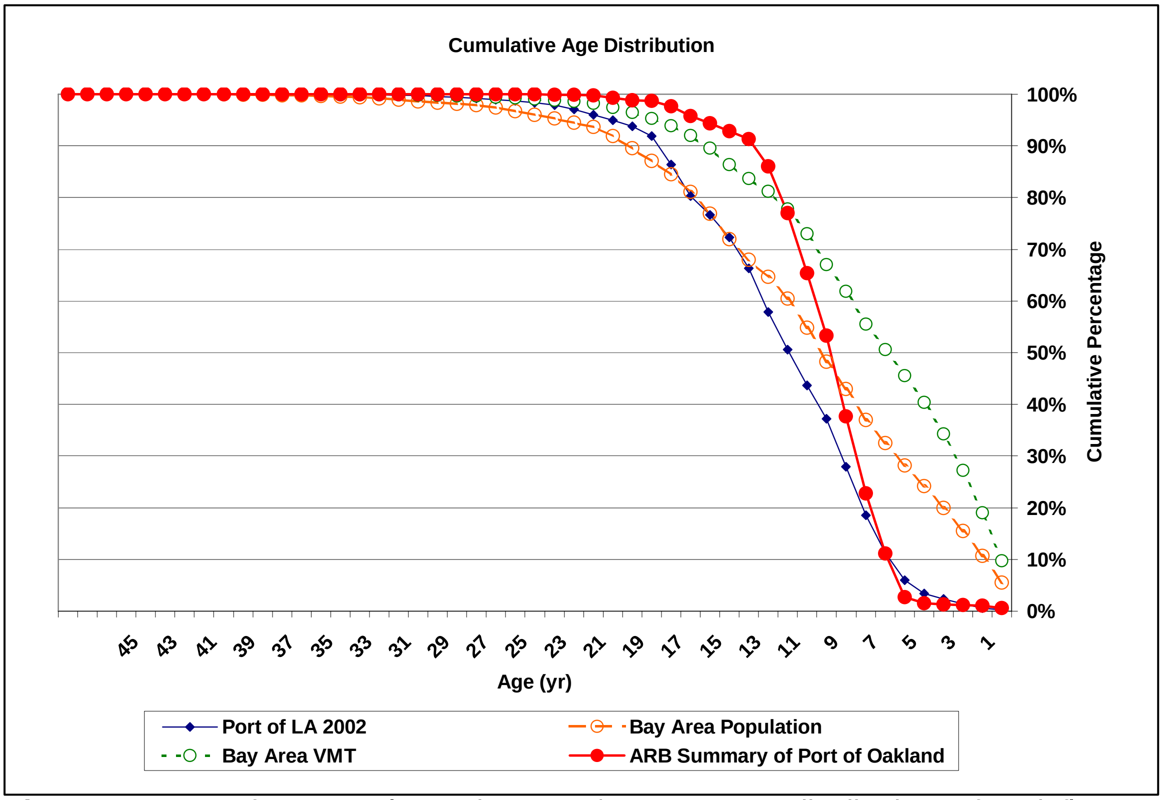

Figure 5-5. Port of Los Angeles and EMFAC/BURDEN age distributions of truck fleets.

ENVIRON derived emission factors for heavy heavy-duty diesel (Federal Highways Administration Class 8a and 8b having a gross vehicle weight rating above 33,000 lbs.) trucks using the EMFAC2007 beta version that ARB provided to ENVIRON in August 2006. ARB requested that the beta version be used to maintain consistency with the rail yard emission modeling conducted for UP Railport. ENVIRON also estimated the emissions with the most current (as of January 2007) publicly available version of EMFAC2007, version 2.3, as the model input. Both emission factor estimates are provided in Table 5-4.

ENVIRON used ROG, CO, NOx, PM, and SO2 emissions factors calculated in grams per mile (or grams per hour for idling) for vehicles speeds of 0 (idling), 10, 15, 20, 25, 30, 35, 40, and 45 mph. ENVIRON determined emission factors by model year by running the model in the "burden mode". The burden mode generates the total BAAQMD emissions inventory, population, and VMT; and back calculates the emissions factors using the area-wide totals. These emission factors were calculated using the average of all conditions over the year. The emission factor results used were for calendar year 2005 and included all model years from 1965 – 2005. Table 5-5 shows the average emission factors for trucks serving the Port of Oakland in 2005.

Table 5-5. On-road Trucking – Port of Oakland specific average heavy heavy-duty (HHDT) on-road truck emission factors – 2005.

EMFAC2007 Pre-release Beta Version Emission Factors						
Speed	**ROG**	**CO**	**NO_x**	**PM**	**SO2**	**Unit**
Idle	13.1	52.6	108.0	2.12	0.6	g/hr
5 mile/hour	14.7	22.3	55.0	4.27	0.3	g/mile
10 mile/hour	11.2	19.5	44.6	3.49	0.3	g/mile
15 mile/hour	5.8	14.8	29.7	2.22	0.2	g/mile
20 mile/hour	2.6	11.0	22.9	1.36	0.2	g/mile
25 mile/hour	1.8	8.8	22.1	1.01	0.2	g/mile
30 mile/hour	1.4	7.3	21.8	0.81	0.2	g/mile
35 mile/hour	1.1	6.1	21.6	0.67	0.2	g/mile
40 mile/hour	0.9	5.0	21.6	0.58	0.2	g/mile
45 mile/hour	0.8	4.3	21.7	0.55	0.2	g/mile
EMFAC2007 Version 2.3 (January 2007) Emission Factors						
Speed	**ROG**	**CO**	**NO_x**	**PM**	**SO2**	**Unit**
Idle	13.1	52.6	108.0	2.12	0.6	g/hr
5 mile/hour	15.8	23.9	55.9	4.52	0.3	g/mile
10 mile/hour	12.0	20.9	45.3	3.69	0.3	g/mile
15 mile/hour	6.20	15.8	30.3	2.35	0.2	g/mile
20 mile/hour	2.78	11.8	23.3	1.43	0.2	g/mile
25 mile/hour	1.92	9.47	22.3	1.08	0.2	g/mile
30 mile/hour	1.51	7.84	22.1	0.87	0.2	g/mile
35 mile/hour	1.20	6.46	21.9	0.71	0.2	g/mile
40 mile/hour	0.99	5.36	21.9	0.61	0.2	g/mile
45 mile/hour	0.89	4.51	22.0	0.57	0.2	g/mile

5.5 On-Road Truck Emissions Results

ENVIRON identified the street segments and terminal locations for truck travel on road ways, detailed terminal traffic data including truck gate counts and ship lifts, and tabulated survey estimates of terminal queuing and other idle time and travel distances on site.

One positive trend over the past years has been the reduction of trips per ship lift due to better container management. Many ocean carriers and their subsidiaries offer full logistics services and aim to reduce the empty container returns to the terminals by dispatching them directly on route to be re-loaded (NYK, 2003). While it is difficult to precisely estimate the effect of those programs with limited available data, the number of empty containers stored has declined. Compared to 1997, today's empty container storage amounts to approximately 21% (Figure 5-1), down from the 25 – 35 % assumed during the analysis for the Berths 55 – 58 EIR (Port of Oakland, 1997). Reducing the number of empty containers returned to the Port continues to be a measure that reduces the overall emission burden in the Port area by reducing the number of lifts and truck trips to and within the terminals.

On-road trucks that provided service to the Port of Oakland terminals and rail yards emitted approximately 335 tons of NO_x and 16 tons of PM within the Port area.[2] The in-terminal emissions for all pollutants are more significant than the over-the-road emissions. However, there are differences in the importance of each source area for different pollutants, e.g., idling and slow speed "creep" modes (such as found at terminals) produce higher emission rates for some pollutants than for others. For particulate (PM) emissions, idling plays a minor role. PM emissions over the road are more pronounced but represent only about 30% of the total truck PM emissions. The largest portion of PM emissions occurs during in terminal driving at slower speeds with frequent stops in what is referred to as the creep mode. For NO_x emissions, idling is an important contributor, contributing about 34-38% to the overall emissions. Over-the-road NOx emissions are about 25-33% of the total. The emission results by operating mode are shown in Table 5-6.

[2] The emission figures do not include the emissions from trucks within the Union Pacific rail yards. In accordance with the Railroad MOU with ARB, UP will provide those emissions separately. The emissions from trucks on the road to and from the UP rail yard are included in this analysis.

Table 5-6. On-road Trucking – Port on-road truck emissions for 2005 by truck activity categories for different versions of EMFAC.

Emission Category	Beta	Version 2.3	Beta	Version 2.3	Beta	Version 2.3	Beta	Version 2.3	Beta	Version 2.3
	ROG (tons/yr)	ROG (tons/yr)	CO (tons/yr)	CO (tons/yr)	NO_x (tons/yr)	NO_x (tons/yr)	PM (tons/yr)	PM (tons/yr)	SO2 (tons/yr)	SO2 (tons/yr)
Surface roads	10	11	39	42	107	108	4.89	5.19	0.8	0.8
Gate idling in queue	4	4	16	16	32	32	0.63	0.63	0.2	0.2
In terminal driving	25	27	54	57	114	117	8.75	9.26	0.8	0.8
In terminal idling	10	10	40	40	81	81	1.59	1.59	0.4	0.4
Total	**49**	**52**	**149**	**155**	**334**	**338**	**15.86**	**16.67**	**2.2**	**2.2**

Table 5-6, above, indicates that in-terminal emissions contribute significantly to the overall emissions. Emissions from truck movements, whether on the surface road or within the terminal, were more significant than emission from truck idling. The lower mileage within the terminal sites was offset by higher emission rates from slow moving stop and go driving on site. The idling at the gates in queue was the lowest emissions mode for all pollutants.

For use for future analysis, ENVIRON calculated the emissions with the version of EMFAC2007, Version 2.3, available at the time of this study, January 2007. ENVIRON used the later version to provide the Port a more appropriate basis for future year assessments.

As a sensitivity analysis, ENVIRON calculated truck emissions using the San Pedro Bay Ports' truck age distribution. This analysis is useful to illustrate the importance of the age distribution on the emissions. Table 5-7 provides the emissions using the San Pedro Bay ports' age distribution to compare with the emission estimates using the Port of Oakland sampled truck age distribution. The primary effect of the older San Pedro Bay truck age distribution is on PM emissions increasing the emission totals by 30%.

Table 5-7. On-road Trucking – Sensitive Analysis of Port on-road truck emissions for 2005 by truck activity categories using the San Pedro Bay Truck Age Distributions.

EMFAC2007 Prerelease Beta Version Emissions					
Emission Category	**ROG (tons/yr)**	**CO (tons/yr)**	**NO_x [tons/yr)**	**PM (tons/yr)**	**SO2 (tons/yr)**
Surface roads	12	52	106	7.09	0.8
Gate idling in queue	5	17	30	0.83	0.2
In terminal driving	28	66	112	10.85	0.8
In terminal idling	12	42	75	2.09	0.4
Total	**57**	**177**	**323**	**20.86**	**2.2**

6.0 LOCOMOTIVE EMISSIONS

This section describes the data and methods used in estimating emissions from locomotives at the Oakland International Gateway (OIG) rail yard. OIG is a Port of Oakland terminal operated under a lease by the Burlington Northern Santa Fe (BNSF) railway. The Union Pacific (UP) rail yard, also known as UP Railport – Oakland and sits adjacent to the Port terminals and serves as an intermodal yard for freight movements through the port, is not considered in this evaluation because UP is privately owned. UP provided ARB an independent analysis of the emissions in their Oakland facility.

Locomotives are used for line-haul (long haul trains into and out of California) and switching (moving rail cars to make up trains). Line-haul locomotives move into and out of the rail yard with idle periods just after arrival and prior to departure. Switching engines work in the yard with idle periods interspersed throughout the day. Often, both line-haul and switching locomotives undergo maintenance, engine load testing, and refueling while in a rail yard,. However, maintenance and load testing of locomotives is not performed at the OIG. Only refueling of locomotives occurs at the OIG. Locomotives operate using a series of load modes called "notches". These notches and the locomotive idle periods constitute the operating modes for locomotives. ENVIRON's methodology for estimating emissions from locomotives followed ARB guidance for rail yard emission modeling that requires per engine per mode emission rates to be used with time in mode estimates calculated by the number of engines visiting the rail yard multiplied by the average time in mode profile for each visit.

6.1 Summary of Locomotive Emission Factors by Engine Model

Emission factors used in this study were based primarily on the emission factors used in the California Air Resources Board (ARB, 2004b) risk assessment study for the Union Pacific Roseville facility, and the Southwest Research Institute (SwRI, 2000) study sponsored by ARB, entitled "Diesel Fuel Effects on Locomotive Exhaust Emissions". Since the publication date of the Roseville report, ARB provided ENVIRON with additional emission factors for criteria pollutants, and made some adjustments to the original Roseville data (ARB, 2006c). ENVIRON also received permission from the engine owners to use additional emission factor data from the Exhaust Plume Study performed by SwRI (2005).

The PM emission factors relevant to all locomotives in the OIG facility are summarized in Tables 6-1a and 6-1b for several different locomotive model groups and certification tiers. Specific locomotives and engines in each locomotive model group can be inferred from the fleet characterization described for the OIG facility. The two tables represent the emission rates at two different fuel sulfur content levels and are included to demonstrate the PM emission rates adjusted for fuel sulfur content. Based on conversations with the principal researcher on all the locomotive studies (SwRI, 2006), ENVIRON learned that the fuel sulfur content of 0.3% was used on all emissions test results and certification data produced with locomotives to date. The emission rates using this 0.3% sulfur fuel are reflected in Table 6-1a. The factors affecting the emission rates include the engine's rated power and the certification standard to which the engine was defined including precontrolled (before emission standards), Tier 0, Tier 1, or Tier 2 levels.

Table 6-1a. Locomotive – Diesel PM emission factors for locomotives used in the study, assuming default fuel sulfur content (0.3%).

Locomotive Model Group	Cert Tier[a]	PM Emission Factors (g/hr) by Throttle Notch									
		Idle	DB[b]	1	2	3	4	5	6	7	8
Switchers[1]	Precntl	31.0	56.0	23.0	76.0	138.0	159.0	201.0	308.0	345.0	448.0
GP-3x[1]	Precntl	38.0	72.0	31.0	110.0	186.0	212.0	267.0	417.0	463.0	608.0
GP-4x[1]	Precntl	47.9	80.0	35.7	134.3	226.4	258.5	336.0	551.9	638.6	821.3
GP-50[1]	Precntl	26.0	64.1	51.3	142.5	301.5	311.2	394.0	663.8	725.3	927.8
GP-60[1]	Precntl	48.6	98.5	48.7	131.7	284.5	299.4	375.3	645.7	743.6	941.6
SD-7x[1]	Precntl	24.0	4.8	41.0	65.7	156.8	243.1	321.1	374.8	475.2	589.2
Dash-7[1]	Precntl	65.0	180.5	108.2	121.2	359.5	327.7	331.5	299.4	336.7	420.0
Dash-9[2]	Precntl	32.1	53.9	54.2	108.1	219.9	289.1	370.6	437.7	486.1	705.7
GP-60[3]	0	21.1	25.4	37.6	75.5	239.4	352.2	517.8	724.8	1,125.9	1,319.8
SD-7x[1]	0	14.8	15.1	36.8	61.1	230.4	379.8	450.8	866.2	1,019.1	1,105.7
Dash-8[1]	0	37.0	147.5	86.0	133.1	291.4	293.2	327.7	373.5	469.4	615.2
Dash-9[4]	0	33.8	50.7	56.1	117.4	229.2	263.8	615.9	573.9	608.0	566.6
Dash-9[3]	1	16.9	88.4	62.1	140.2	304.0	383.5	423.9	520.2	544.6	778.1
ES44/Dash-9[3]	2	7.7	42.0	69.3	145.8	304.3	365.0	405.2	418.4	513.5	607.5

[1] Final locomotive emission factors (an update to the Roseville study emission factors Table B-1) received via email from Dan Donohue of ARB, May 9, 2006. (ARB, 2006c)
[2] "Diesel Fuel Effects on Locomotive Exhaust Emissions", Southwest Research Institute, October 2000. (SwRI, 2000)
[3] Confidential data from SwRI, 2005.
[4] Average of ARB and confidential source.
[a] Precntl: Precontrolled
[b] DB: Dynamic Braking

Table 6-1b provides emission factors adjusted for fuel sulfur content of 0.105% because BNSF estimated this as the average fuel sulfur level used in its locomotives in 2005. This adjustment was performed according to documented ARB procedures from the OFFROAD Modeling Change Technical Memo (ARB, 2005d). All locomotive diesel particulate emissions presented in this document used the emission factors from Table 6-1b.

Table 6-1b. Locomotive – Diesel PM Emission Factors for locomotives used in the study, adjusted for reduced fuel sulfur content (0.105%).

Locomotive Model Group	Cert Tier[a]	PM Emission Factors (g/hr) by Throttle Notch									
		Idle	DB[b]	1	2	3	4	5	6	7	8
Switchers[1]	Precntl	31.0	56.0	23.0	76.0	131.8	146.1	181.5	283.2	324.4	420.7
GP-3x[1]	Precntl	38.0	72.0	31.0	110.0	177.7	194.8	241.2	383.4	435.3	570.9
GP-4x[1]	Precntl	47.9	80.0	35.7	134.3	216.2	237.5	303.5	507.4	600.4	771.2
GP-50[1]	Precntl	26.0	64.1	51.3	142.5	288.0	285.9	355.8	610.4	681.9	871.2
GP-60[1]	Precntl	48.6	98.5	48.7	131.7	271.7	275.1	338.9	593.7	699.1	884.2
SD-7x[1]	Precntl	24.0	4.8	41.0	65.7	149.8	223.4	290.0	344.6	446.8	553.3
Dash-7[1]	Precntl	65.0	180.5	108.2	121.2	322.6	302.9	307.7	268.4	275.2	341.2
Dash-9[2]	Precntl	32.1	53.9	54.2	108.1	197.3	267.3	343.9	392.4	397.3	573.3
GP-60[4]	0	21.1	25.4	37.6	75.5	228.7	323.6	467.7	666.4	1,058.5	1,239.3
SD-7x[1]	0	14.8	15.1	36.8	61.1	220.1	349.0	407.1	796.5	958.1	1,038.3
Dash-8[1]	0	37.0	147.5	86.0	133.1	261.5	271.0	304.1	334.9	383.6	499.7
Dash-9[5]	0	33.8	50.7	56.1	117.4	205.7	243.9	571.5	514.6	496.9	460.3
Dash-9[4]	1	16.9	88.4	62.1	140.2	272.8	354.5	393.4	466.4	445.1	632.1
ES44/Dash-9[4]	2	7.7	42.0	69.3	145.8	273.0	337.4	376.0	375.1	419.6	493.5

[1] Final locomotive emission factors (an update to the Roseville study emission factors Table B-1) received via email from Dan Donohue of ARB, May 9, 2006. (ARB, 2006c)
[2] "Diesel Fuel Effects on Locomotive Exhaust Emissions", Southwest Research Institute, October 2000. (SwRI, 2000)
[3] Confidential data from SwRI, 2005.
[4] Average of ARB and confidential source.
[a] Precntl: Precontrolled
[b] DB: Dynamic Braking

BNSF determined the average sulfur content value of 0.105% by averaging sulfur levels for diesel fuel dispensed in 2005 at all BNSF locomotive refueling facilities in California, and those near California, as shown in Table 6-2. For fuel dispensed at sites outside of California, ENVIRON assumed that half of that fuel would be used in California, because trains moving in either direction may be fueled at this out-of-state facility. In reality, it is likely that less than half of the out-of-state fuel dispensed will be used in California, because many of those fueling facilities are a significant distance from the state border.

Table 6-2. Locomotive – BNSF fuel sulfur and total annual 2005 fueling rates at locomotive refueling locations.

Location	State	Total Gallons	% Sulfur
Holbrook	AZ	21,935	0.192
Phoenix	AZ	3,542,292	0.034
Flagstaff	AZ	2,019	0.192
Kingman	AZ	334,309	0.034
Vacaville	CA	33,074	0.034
Redding	CA	1,004	0.192
Summit	CA	1,750	0.192
San Diego	CA	530	0.192
Bakersfield	CA	240,976	0.034
Barstow	CA	1,946,092	0.015
Oakland	CA	1,762,993	0.034
Needles	CA	770,667	0.192
Bakersfield	CA	131,075	0.034
Bakersfield	CA	11,070	0.034
Corona	CA	103,982	0.034
Fresno	CA	2,669,884	0.034
Kaiser	CA	460,390	0.034
Kings Park	CA	61,900	0.034
Pittsburg	CA	12,695	0.034
Riverbank	CA	2,070,244	0.034
San Bernardino	CA	9,940,295	0.034
San Diego	CA	111,369	0.192
Stockton	CA	1,018,965	0.034
Stuart Mesa	CA	41,509	0.192
Terminal Island	CA	14,816,643	0.192
Victorville	CA	66,042	0.034
Watson	CA	1,152,454	0.192
Bakersfield	CA	11,236	0.192
Winslow	AZ	3,496,072	0.170
Belen	NM	202,462,278	0.192
Barstow	CA	52,439,321	0.015
Commerce	CA	31,573,289	0.015
Richmond	CA	22,255,177	0.034
Klamath Falls	OR	3,070,865	0.381

The fuel sulfur correction methodology described by ARB (2005d) was used to adjust PM emission rates from an average fuel sulfur level of 0.3% to 0.105% using the fuel sulfur – PM relationship equation, A + B * (fuel sulfur, ppm). The emission reductions calculated for GE and EMD engines shown in Table 6-3 were applied to the base emission rates to calculate the emission rates at the in-use fuel sulfur levels.

Table 6-3. Locomotive - Fuel sulfur emission reductions by notch and engine type.

Notch	B	A	Fuel Sulfur 0.3% EF (g/hp-hr)	Fuel Sulfur 0.105% EF (g/hp-hr)	Reduction
GE 4-stroke Engine					
8	0.00001308	0.0967	0.13594	0.110434	18.76%
7	0.00001102	0.0845	0.11756	0.096071	18.28%
6	0.00000654	0.1037	0.12332	0.110567	10.34%
5	0.00000548	0.132	0.14844	0.137754	7.20%
4	0.00000663	0.1513	0.17119	0.1582615	7.55%
3	0.00000979	0.1565	0.18587	0.1667795	10.27%
EMD 2-stroke engine					
8	0.0000123	0.3563	0.3932	0.369215	6.10%
7	0.0000096	0.284	0.3128	0.29408	5.98%
6	0.0000134	0.2843	0.3245	0.29837	8.05%
5	0.000015	0.2572	0.3022	0.27295	9.68%
4	0.0000125	0.2629	0.3004	0.276025	8.11%
3	0.0000065	0.2635	0.283	0.270325	4.48%

Source: ARB (2005d)

Emissions for other criteria pollutants were calculated in a similar manner, by engine model and by notch setting. Emission factors for these other pollutants are shown in Tables 6-4, 6-5, and 6-6. ENVIRON made no correction to the NOx emission rates with the partial use of California diesel because the fuel used in specific engines at specific facilities is not known and the impact of low sulfur ARB diesel fuel on NOx is small.

Table 6-4. Locomotive – HC Emission Factors for locomotives used in the study.

Locomotive Model Group	Cert Tier[a]	HC Emission Factors (g/hr) by Throttle Notch									
		Idle	DB[b]	1	2	3	4	5	6	7	8
Switchers[1]	Precntl	99	145	93	117	145	194	274	377	521	666
GP-3x[1]	Precntl	124	269	122	150	188	261	372	469	652	807
GP-4x[1]	Precntl	185	295	155	201	247	321	424	611	878	1,169
GP-50[1]	Precntl	76	279	39	209	312	352	488	664	933	1,082
GP-60[1]	Precntl	113	158	12	176	304	408	500	646	1,062	1,351
SD-7x[1]	Precntl	118	174	117	167	265	319	421	605	804	1,052
Dash-7[1]	Precntl	259	422	125	99	276	287	347	499	697	750
Dash-9[2]	Precntl	184	240	138	201	403	390	572	741	908	1,063
GP-60[3]	0	120	163	114	154	240	287	366	476	749	902
SD-7x[1]	0	62	65	91	139	298	393	501	894	1,230	1,433
Dash-8[1]	0	269	627	331	358	395	419	655	614	738	861
Dash-9[4]	0	109	160	141	227	584	492	726	870	999	1,239
Dash-9[3]	1	55	309	210	298	606	714	789	931	978	1,094
ES44/Dash-9[3]	2	24	65	62	120	220	224	311	408	488	619

[1] Final locomotive emission factors (an update to the Roseville study emission factors Table B-1) received via email from Dan Donohue of ARB, May 9, 2006. (ARB, 2006c)
[2] "Diesel Fuel Effects on Locomotive Exhaust Emissions", Southwest Research Institute, October 2000. (SwRI, 2000)
[3] Confidential data from SwRI, 2005.
[4] Average of ARB and confidential source.
[a] Precntl: Precontrolled
[b] DB: Dynamic Braking

Table 6-5. Locomotive – CO Emission Factors for locomotives used in the study, adjusted for reduced fuel sulfur content (0.105%).

Locomotive Model Group	Cert Tier[a]	CO Emission Factors (g/hr) by Throttle Notch									
		Idle	DB[b]	1	2	3	4	5	6	7	8
Switchers[1]	Precntl	181	350	183	294	339	354	416	676	2,085	5,710
GP-3x[1]	Precntl	283	699	240	429	430	479	604	926	1,773	3,973
GP-4x[1]	Precntl	564	660	267	292	329	434	760	1,912	5,029	5,907
GP-50[1]	Precntl	99	408	59	228	744	1,083	1,932	1,743	1,520	1,817
GP-60[1]	Precntl	144	192	106	132	314	517	1,108	2,213	1,700	1,597
SD-7x[1]	Precntl	237	344	243	263	290	598	1,210	2,005	1,733	2,470
Dash-7[1]	Precntl	354	485	199	338	1,489	2,949	5,516	4,551	3,295	3,000
Dash-9[2]	Precntl	276	394	143	332	1,486	4,647	8,055	10,143	9,511	10,644
GP-60[3]	0	118	233	147	186	248	347	945	2,678	2,443	1,989
SD-7x[1]	0	84	90	186	293	336	407	434	3,046	1,441	1,515
Dash-8[1]	0	367	1,113	688	874	1,974	2,373	1,843	1,868	2,012	2,871
Dash-9[4]	0	95	197	139	310	831	2,136	2,801	2,502	2,932	3,250
Dash-9[3]	1	49	461	244	368	896	1,505	1,788	2,014	2,714	3,356
ES44/Dash-9[3]	2	30	120	142	239	607	806	479	537	790	1,034

[1] Final locomotive emission factors (an update to the Roseville study emission factors Table B-1) received via email from Dan Donohue of ARB, May 9, 2006. ARB, 2006c)
[2] "Diesel Fuel Effects on Locomotive Exhaust Emissions", Southwest Research Institute, October 2000. (SwRI, 2000)
[3] Confidential data from SwRI, 2005.
[4] Average of ARB and confidential source.
[a] Precntl: Precontrolled
[b] DB: Dynamic Braking

Table 6-6. Locomotive – NOx Emission Factors for locomotives used in the study.

Locomotive Model Group	Cert Tier[a]	Emission Factors (g/hr) by Throttle Notch									
		Idle	DB[b]	1	2	3	4	5	6	7	8
Switchers[1]	Precntl	987	3,415	1,240	2,775	5,716	9,794	14,135	17,999	21,891	24,028
GP-3x[1]	Precntl	1,247	2,803	1,825	4,336	8,137	12,410	16,974	23,232	29,605	34,755
GP-4x[1]	Precntl	1,635	4,134	2,808	6,040	10,180	15,407	20,892	25,564	31,187	36,929
GP-50[1]	Precntl	999	2,847	1,104	7,819	14,060	18,769	24,388	42,575	54,573	57,021
GP-60[1]	Precntl	999	2,847	1,104	7,819	14,060	18,769	24,388	42,575	54,573	57,021
SD-7x[1]	Precntl	1,475	1,728	2,533	5,520	13,367	21,349	27,710	43,213	57,587	56,252
Dash-7[1]	Precntl	306	493	830	1,416	5,367	9,738	16,321	22,974	25,108	33,000
Dash-9[2]	Precntl	595	940	2,121	5,495	14,999	22,069	31,372	36,876	42,905	46,971
GP-60[3]	0	731	967	2,267	4,696	8,501	11,090	12,850	13,831	25,626	27,621
SD-7x[1]	0	934	1,066	2,882	5,382	9,984	13,308	14,892	23,612	31,134	33,418
Dash-8[1]	0	746	2,063	3,403	4,618	7,426	9,912	14,746	18,676	22,800	29,527
Dash-9[4]	0	928	1,010	2,511	4,806	13,851	18,663	13,663	21,113	25,089	31,154
Dash-9[3]	1	376	2,036	1,538	4,672	14,369	16,071	13,855	18,020	20,886	23,913
ES44/Dash-9[3]	2	329	657	1,135	2,730	5,310	7,246	9,612	13,455	16,005	18,566

[1] Final locomotive emission factors (an update to the Roseville study emission factors Table B-1) received via email from Dan Donohue of ARB, May 9, 2006. (ARB, 2006c)
[2] "Diesel Fuel Effects on Locomotive Exhaust Emissions", Southwest Research Institute, October 2000. (SwRI, 2000)
[3] Confidential data from SwRI, 2005.
[4] Average of ARB and confidential source.
[a] Precntl: Precontrolled
[b] DB: Dynamic Braking

Table 6-7. Locomotive – Fuel consumption factors for locomotives used in the study.

Locomotive Model Group	Cert Tier[a]	Fuel Consumption Factors (lb/hr) by Throttle Notch									
		Idle	DB[b]	1	2	3	4	5	6	7	8
Switchers[1]	Precntl	26	80	41	95	167	249	332	419	529	630
GP-3x[1]	Precntl	32	103	55	137	226	331	442	567	710	854
GP-4x[1]	Precntl	40	114	64	167	275	404	556	740	994	1,177
GP-50[1]	Precntl	22	91	92	179	363	480	652	919	1,136	1,281
GP-60[1]	Precntl	26	107	91	171	354	479	623	799	1,190	1,383
SD-7x[1]	Precntl	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dash-7[1]	Precntl	18	98	60	121	236	368	523	679	802	991
Dash-9[2]	Precntl	26	42	81	189	395	572	798	1,014	1,240	1,539
GP-60[3]	0	26	39	87	164	354	483	628	790	1,194	1,385
SD-7x[1]	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dash-8[1]	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dash-9[4]	0	27	43	81	186	388	562	812	1,018	1,254	1,564
Dash-9[3]	1	20	54	86	184	371	510	720	938	1,161	1,461
ES44/Dash-9[3]	2	20	44	102	209	447	612	825	1,060	1,310	1,598

[1] Final locomotive emission factors (an update to the Roseville study emission factors Table B-1) received via email from Dan Donohue of ARB, May 9, 2006. (ARB, 2006c)
[2] "Diesel Fuel Effects on Locomotive Exhaust Emissions", Southwest Research Institute, October 2000. (SwRI, 2000)
[3] Confidential data from SwRI, 2005.
[4] Average of ARB and confidential source.
[a] Precntl: Precontrolled
[b] DB: Dynamic Braking

6.2 Overview of the OIG Yard

BNSF uses the OIG as a near dock transfer point for Port of Oakland maritime cargo containers. Only Port containers are handled at this yard.

The site is situated generally northwest-southeast. Entrance and exit tracks curve north and east of the main yard. Locomotives and trains enter the general port area from the north via the Union Pacific (UP) main line, and leave in the same direction via tracks going north through Richmond and onto BNSF lines out of the Bay Area.

6.3 Locomotive Facility Operations

The OIG locomotive operations include several activities including locomotive refueling, switching locomotive movements, and line-haul locomotive movements via train arrival and departure. Even though locomotive load testing and maintenance are routine services often conducted in rail yards, they do not occur at the OIG.

Because different locomotive and engine models have different emission characteristics, it was important to characterize the types and models of the locomotives that are operated at OIG. Using BNSF data, ENVIRON estimated the locomotive fleet, which is composed of different locomotive types and models, for each of the railyard activity described below.

A. Basic Locomotive Refueling

According to BNSF records, 1,762,003 gallons of fuel were used in 2005 at the OIG with an average of 1,139 gallons per locomotive, so an estimated 1,548 locomotives were refueled at OIG. Based on discussions with BNSF staff, total idle time during refueling is estimated to be 1.5 hours and it includes the idling before refueling when the engine is maneuvered into the refueling area, and the idling after the refueling event. The idle time during refueling was subtracted from the total idle time estimated for line-haul locomotives arriving and departing the yard because the total idle time determine from engine downloads for line-haul locomotives could not distinguish idling during refueling from other idling.

Because refueling can be performed on any locomotive arriving and departing the facility, ENVIRON assumed that the fleet characteristics for this activity group are equivalent to the average fleet characteristics of the locomotive arrivals to the yard. Data provided by BNSF detailed the fleet of locomotives arriving and departing the OIG facility between November 1, 2005 and October 31, 2006. ENVIRON classified the annual locomotive counts by unique engine model description for all BNSF owned and operated engines. Some of engine model types could not be identified because some engines were originally, or are currently, owned by other railroads (such as CSX or Norfolk Southern) and are leased by BNSF. The portion of unidentified engines (16.8 % of the total fleet) was reallocated proportionally across the rest of the fleet. The final fleet characterization is shown in Table 6-8. For the purpose of estimating emissions, an engine surrogate and its associated emission factors were assigned for each locomotive model. This was done when emission factors for a specific engine model was not available.

The location of the refueling activity is defined specifically as an area dedicated for refueling locomotives at the OIG. The annual Diesel PM emissions for Basic Service by individual activities are presented in Table 6-9. ROG, CO, NOx, and SOx emissions were calculated in a similar manner and are summarized in Table 6-10.

Table 6-8. Locomotive – Fleet characterization for locomotive mainline activity at the OIG facility and for basic services in the OIG facility in 2005.

Locomotive Model	Certification Tier	Fleet %	Engine Surrogate	Surrogate Tier
C44-9W	0	34.7	Dash-9	0
Unknown	Unknown	16.8	Redistributed	Redistributed[1]
C44-9W	1	16.2	Dash-9	1
SD40-2	Precontrolled	7.4	GP-4x	Precontrolled[2]
C44-9W	Precontrolled	6.6	Dash-9	Precontrolled
C40-8W	0	5.5	Dash-8	0
ES44DC	2	5.5	ES44/Dash-9	2
SD40-2	0	1.4	GP-4x	Precontrolled
B40-8W	Precontrolled	1.2	Dash-8	0
GP60B	0	0.5	GP-60	0
GP35	Precontrolled	0.4	GP-3x	Precontrolled
GP60M	0	0.4	GP-60	0
SD50	Precontrolled	0.4	GP-50	Precontrolled
SD60	Precontrolled	0.4	GP-60	Precontrolled
B40-8W	0	0.3	Dash-8	0
GP60	Precontrolled	0.3	GP-60	Precontrolled
GP60	0	0.3	GP-60	0
B40-8	Precontrolled	0.2	Dash-8	0
GP30	Precontrolled	0.2	GP-3x	Precontrolled
GP39M	Precontrolled	0.2	GP-3x	Precontrolled
SD45-2	Precontrolled	0.2	GP-4x	Precontrolled
SD40-2T	Precontrolled	0.1	GP-4x	Precontrolled
GP38-2	Precontrolled	0.1	GP-3x	Precontrolled
GP40M	Precontrolled	0.1	GP-4x	Precontrolled
SD40	Precontrolled	0.1	GP-4x	Precontrolled
SD70MAC	0	0.1	SD-7x	0
GP38	Precontrolled	0.0	GP-3x	Precontrolled
GP9	Precontrolled	0.0	Switchers	Precontrolled
SD40-2B	Precontrolled	0.0	GP-4x	Precontrolled
SD45	Precontrolled	0.0	GP-4x	Precontrolled
SD45-2T	Precontrolled	0.0	GP-4x	Precontrolled
SD60M	Precontrolled	0.0	GP-60	Precontrolled
SD70MAC	Precontrolled	0.0	SD-7x	Precontrolled
SD75M	0	0.0	SD-7x	0

[1] – Redistributed means that the unknown engine models were redistributed in the same proportion as the known engine models.
[2] – Precontrolled means that the engines predate emission regulations or have yet to be rebuilt to any emission standard.

Table 6-9. Locomotive – Estimated annual Diesel PM emissions associated with refueling in the OIG facility in 2005.

Locomotive Model Group	Certification Tier	# of Loco	Annual Total (grams)
Switchers	Precontrolled	1	38
GP-3x	Precontrolled	17	988
GP-4x	Precontrolled	176	12,638
GP-50	Precontrolled	7	290
GP-60	Precontrolled	14	1,023
SD-7x	Precontrolled	1	30
Dash-7	Precontrolled	0	0
Dash-9	Precontrolled	122	5,882
GP-60	0	21	679
SD-7x	0	2	55
Dash-8	0	136	7,546
Dash-9	0	646	32,789
Dash-9	1	301	7,634
ES44/Dash-9	2	102	1,182
Total		**1,548**	**70,772**

Table 6-10. Locomotive – Total Estimated annual emissions (grams per year) associated with locomotives idling in the refueling area at the OIG facility in 2005.

HC Emissions (grams/year)	CO Emissions (grams/year)	NOx Emissions (grams/year)	Diesel PM Emissions (grams/year)	SO2 Emissions (grams/year)
282,006	409,604	1,906,445	70,772	58,180

B. Switching Engine Movements

Switching engine fleet characteristics in the OIG area were determined from a sample of engines operating at OIG in early 2006 and made available by BNSF. Switching engines assigned to OIG rotate in and out of service, but were all of similar power and type to that shown in Table 6-11.

Table 6-11. Locomotive – Switching engine characterization for the OIG facility in 2005.

Locomotive Model	Certification Tier	HP	Number of Engines	Engine Surrogate
SD-40-2	Precontrolled or Tier 0	3000	1	GP-4x precontrolled

The time in mode for switching engine activity, Table 6-12, was determined from event recorder downloads of a sample of three engines operating in the OIG yard. Four downloads of the three engines were conducted in a period of 4-5 days. The time in mode from the event recorder downloads could not distinguish engine idling and engine off periods, so the idle mode was fixed at the EPA switching engine cycle estimate of 59.8% and the remaining notch settings were renormalized so that the full cycle would sum to 100% of the time. This adjustment has the effect of increasing the emissions estimate by placing more of the activity into the higher notch settings, but may overestimate switching engine activity.

Table 6-12. Locomotive – Switching engine relative time in mode at the OIG facility in 2005.

Throttle Notch	Adjusted Time in Mode	Raw Event Recorder Data
DB	1.4%	0.4%
Idle	59.8%	88.3%
1	6.6%	1.9%
2	15.0%	4.4%
3	9.5%	2.8%
4	4.4%	1.3%
5	1.9%	0.6%
6	0.3%	0.1%
7	0.0%	0.0%
8	1.0%	0.3%

The total switching engine activity was estimated as one engine operating at all times each day of the year (i.e., 24 hours of switching engine use per day, or 8,760 hours per year). Estimated annual TOG, CO, NOx, and diesel PM emissions for switching activities at the OIG facility are presented in Table 6-13.

Table 6-13. Locomotive - Estimated annual emissions associated with switching engine movements at the OIG facility in 2005.

ROG Emissions (grams/year)	CO Emissions (grams/year)	NOx Emissions (grams/year)	Diesel PM Emissions (grams/year)	SO2 Emissions (grams/year)
1,883,730	4,731,058	40,684,974	865,585	1,035,553

C. Train Arrival and Departures in the Yard

The primary locomotive activity at OIG was from arriving and departing line-haul locomotives and their operation throughout the yard. Activities of line-haul engines in the OIG yard include: arriving with a train, separating from the train, moving to the refueling area, moving to the ready area where the engines are assigned a train, and leaving the yard. Because the refueling is done at a specific location, that activity was separated out from the overall engine activity in the yard and is described under section A above.

The number of engines moving through the yard was determined from a BNSF-supplied train arrival and departure database. The train arrival and departure raw data included 2,254 arrivals and 2,221 departures, so 2,254 engines were used as the total activity at OIG. However, the database showed 64 arrivals occurred within one minute of each other, and so were considered to be duplicate entries. These duplicates were subtracted from the total, and the emissions calculation was based on an estimated 2,190 engines arriving and departing from the yard. BNSF provided duty cycle information for three separate locomotives arriving and departing from OIG. ENVIRON calculated the average time in mode for freight movement activity along the mainline using event recorder data for four representative locomotives and the complete duty cycle data for the three representative locomotives from BNSF. The average time in mode data are summarized in Table 6-14.

Table 6-14. Locomotive – Time in mode for arriving and departing locomotives at the OIG facility in 2005.

Throttle Notch	Average Operation Time (hours)
DB	0.020
Idle	12.148
1	0.413
2	0.174
3	0.052
4	0.008
5	0.008
6	0.002
7	0.001
8	0.008

The fleet characterization for locomotives along the mainline, provided in Table 6-8, was derived from all engines entering the site.

The diesel PM emission estimates for BNSF freight movements during the one-year period are presented in Table 6-15. These emissions occur anywhere on the rail lines within the facility.

Table 6-15. Locomotive – Diesel PM emissions from Arriving/Departing locomotives at the OIG in 2005.

Tier	Model Group	# of Engines	Engine Mode Diesel PM Emissions (grams/year)										Total
			Idle	DB	1	2	3	4	5	6	7	8	
X	Switcher	1	401	1	11	15	8	1	2	1	0	4	**445**
X	GP-3x	25	10,329	35	313	468	227	39	47	18	6	111	**11,594**
X	GP-4x	249	132,168	394	3,662	5,798	2,798	481	601	245	83	1,527	**147,757**
X	GP-50	11	3,030	13	222	260	157	24	30	12	4	73	**3,826**
X	GP-60	20	10,694	39	399	454	281	44	54	23	8	140	**12,134**
X	SD-7x	1	311	0	20	13	9	2	3	1	0	5	**364**
X	Dash-7	0	0	0	0	0	0	0	0	0	0	0	**0**
X	Dash-9	173	61,513	184	3,864	3,243	1,774	376	473	132	38	789	**72,386**
0	GP-60	30	7,101	15	471	398	361	80	113	39	18	300	**8,896**
0	SD-7x	4	574	1	53	37	40	10	11	5	2	29	**763**
0	Dash-8	193	78,917	563	6,836	4,452	2,621	425	466	125	41	766	**95,213**
0	Dash-9	914	342,917	918	21,149	18,624	9,783	1,817	4,160	915	252	3,350	**403,884**
1	Dash-9	426	79,841	746	10,915	10,371	6,048	1,231	1,335	386	105	2,145	**113,124**
2	ES44/ Dash-9	145	12,358	120	4,138	3,664	2,057	398	433	106	34	569	**23,877**
Total		2,190	740,155	3,031	52,053	47,797	26,163	4,930	7,728	2,009	591	9,808	**894,264**

D. Freight Movements on Adjacent Mainline

All freight trains enter and leave through the UP rail yard and those movements should be captured as part of the UP assessment of rail yard emissions estimates for its yard.

E. Commuter Rail Operations on the Adjacent Mainline

No such activity occurs within the OIG facility.

6.4 Summary Locomotive Emission Estimates for OIG

The locomotive emissions for the OIG facility are summarized in Table 6-16.

Table 6-16. Locomotive – Estimated annual locomotive emissions at the OIG facility - 2005.

Source Type	THC Emissions (grams/year)[1]	CO Emissions (grams/year)	NOx Emissions (grams/year)	Diesel PM Emissions (grams/year)	SO2 Emissions (gram/year)
Refueling Area	282,006	409,604	1,906,445	70,772	58,180
Switching Engines	1,883,730	4,731,058	40,684,974	865,585	1,035,553
Train Arrival/ Departure	3,297,705	4,905,485	26,560,789	894,264	839,557
Total – grams	**5,463,441**	**10,046,147**	**69,152,208**	**1,830,621**	**1,933,290**
Total (short tons)	**6.0**	**11.1**	**76.2**	**2.0**	**2.1**

[1] – ROG to THC ratio for diesel engines is 1.21 from Walter Wong, ARB on May 29, 2007.

7.0 SUMMARY AND RECOMMENDATIONS

The Port of Oakland and ENVIRON characterized maritime activity and emissions in detail for 2005 in this study. ENVIRON provided the specific activity and emission estimates by individual operating modes and vessel, equipment, truck, and locomotive types for use in air quality planning. The emission results are presented in Table 7-1 by source category. ENVIRON presents emissions for most categories as a range rather than a single value. The lower and upper ends of the range can differ significantly, reflecting ENVIRON's understanding of the technical uncertainty inherent in making emissions estimates of complex activities and sources and the sensitivity of the estimate to site-specific versus general or state-wide inputs. For a more detailed explanation of the range values and uncertainties, see the Section for each source category.

Table 7-1. Port of Oakland emissions summary by emission source category, comparing ARB emission estimates and Environ emission estimates – tons in 2005.

Emission Source Category	ROG		CO		NOx		PM		SO2	
	ARB Estimates	*ENVIRON Estimates*[1]	ARB Estimates	*ENVIRON Estimates*[1]	ARB Estimates	*ENVIRON Estimates*[1]	ARB Estimates	*ENVIRON Estimates*[1]	ARB Estimates	*ENVIRON Estimates*[1]
Ocean-going vessels (OGV)	117	*Same as ARB*	235	*Same as ARB*	2,484	*Same as ARB*	219.5[2]	*Same as ARB*	1,413	*Same as ARB*
Harbor Craft	22	*18*	83	*68*	345	*282*	13.4	*10.8*	3	*2*
CHE	53	*33*	408	*241*	766	*422*	21.7[2]	*12.3*[2]	7	*4*
Truck	49	*52*	149	*155*	334	*338*	15.9	*16.7*	2	*2*
Locomotive	7	*Same as ARB*	11	*Same as ARB*	76	*Same as ARB*	2.0	*Same as ARB*	2	*Same as ARB*
Total	**248**		**886**		**4,005**		**272.5**		**1,427**	
ENVIRON Alternative Total		***220***		***710***		***3,602***		***261.3***		***1,424***

[1] Differences between ARB's estimates and ENVIRON's estimates are due to:

Harbor Craft - ARB's calculation use statewide default load factor for tug main engines during the assist operation and ENVIRON's calculations use a load factor from the literature appropriate to Port operations.

CHE - ARB's calculation use default load factor used in previous studies and ENVIRON's calculation use the results of a CHE fuel consumption survey conducted at the Port in 2006 to estimate the average load factor for the Port CHE operations.

Truck - ARB calculated emissions using a pre-release beta version of EMFAC model and ENVIRON's calculations use the most recent (January 2007) version of the EMFAC2007 model

[2] A small portion of the particulate in these categories includes boiler or LPG engine emissions; most of the emissions are from diesel exhaust.\

Ocean going vessels are the largest source category for all pollutants, producing 75-80% of estimated particulate matter emissions and the major portion of other pollutants. Table 7-2 shows a more detailed assessment of ocean going vessel emissions by mode of operation. Trucks, harbor craft, and cargo handling equipment each produced 5-10% of the estimated Port-related particulate matter emissions. Locomotives from the one rail yard included in this study produced a small fraction of the total emissions.

It is important to keep in mind that location of emissions is often as significant as the total quantity because emissions generated close to community receptors will have a greater effect on human health risk on a per ton basis. The impact of the various source categories on air quality in West Oakland will not necessarily be directly proportional to the magnitude of their emissions because proximity to the community is not addressed in this emissions inventory. For example, the particulate matter emissions from ocean going vessels in cruising mode, which occurs outside the Golden Gate, will have less impact on sensitive receptors in Oakland than emissions that occur closer to shore during the maneuvering or hoteling modes.

Table 7-2. OGV emissions summary by mode, using ARB-specified activity emission factors – tons in 2005.

Emission Mode	ROG	CO	NOx	PM[1]	SO2
OGV – Cruise	16	46	588	52.4	383
OGV – RSZ	27	63	647	60.2	395
OGV – Maneuver	53	58	458	43.6	157
OGV – Berth	21	65	767	61.3	464
OGV – Anchorage	1	2	24	2.0	15
OGV subtotal	**117**	**235**	**2,484**	**219.5**	**1,413**

[1] A small portion of the particulate in these categories was from boilers; most of the emissions are from diesel exhaust.

In the course of preparing this emissions inventory, it was apparent that additional studies would help in better estimating the Port's maritime-related emissions. Due to cost and schedule considerations, these studies were not performed. However, recommended future studies that could contribute to reducing some of the uncertainties in seaport emissions inventory would address:

- Revisit the load factors or specific duty cycle evaluation of different types of cargo handling equipment under site-specific operating conditions
- Truck trip modeling and engine age distribution
- Activity and emissions of auxiliary boilers on OGVs
- Auxiliary engine OGV emission rates during all maneuvering activity
- Port-specific tug propulsion engine load factors during vessel assist operations

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APPENDIX A

Steps for Determining Port of Oakland Vessel Calls
(Combining Wharfinger and Lands Commission Data)

Steps for Determining Port of Oakland Vessel Calls
(Combining Wharfinger and Land Commission Data)

Wharfinger Data: Received in electronic format from Port of Oakland for January 2005 through November 2005. December 2005 data were received on hard copy and manually entered into a spreadsheet with the electronic data. The data contains pertinent information related to ship calls, terminal and berth visited, and berthing time. The data set was missing IMO numbers making it difficult to match the data with the individual vessels. The data set was also missing next and last port of call information.

California State Lands Commission (SLC) Data: Received in electronic format from the Port of Oakland for 2005. The SLC data contained pertinent information related to ship calls and the last and next Port of Call to determine the vessel direction outside of the Pilot Buoy. Duplicate calls were evident and the Lands Commission report did not include many calls listed in the Wharfinger data. This is likely due to a lag in the end of year calls reporting.

Dataset fields:

Wharfinger data field names: Berth Name, berth code, terminal, shipper code, vessel code, voyage, arr date, arr time, shipping line, vessel name, dep date, dep time, arr draft, dep draft, elapsed time.

California State Land Commission data field names: IMONumber, VesselName, ArrivalDate, ArrivalPort, VesselType, LastPort, CountryLastPort, LastIncomingDirection*, NextPort, CountryNextPort, *NextPortDirection (*Field added by Chris Lindhjem)

Steps in combining followed the premise that the Wharfinger data was accurate and that the Lands Commission had data quality concerns and could include duplicate calls or be missing calls because of delayed reporting:

Wharfinger dataset pre-processing:

1. Added IMO Number to Wharfinger data:
   a. Searched the ship name in the Lands Commission dataset (with excel function) to find corresponding IMO Number.
   b. If the Wharfinger ship name did not match a ship name in the Lands Commission dataset (~5-10% of calls), then manually looked at the Land Commission dataset for a ship of similar name within a day or two of the date of the ship visit in question. Always able to find the ship, albeit with a slightly different name or spelling.
   c. Changed the Wharfinger dataset ship name and set it equal to the Lands Commission ship name and excel was able to find the needed IMO Number.
2. Used pivot table to sort data by IMO Number and Date.
3. For each IMO Number assigned a time series based rank to each ship visit (IMO+rank = unique identifier for each POAK ship visit).
4. Flagged vessels that included 2 berthing times in less than four days and combined these into one IMO+rank.
5. Used pivot table to determine elapsed time for each IMO+rank.
6. Summarized all information for each IMO+rank.

Lands Commission pre-processing:

1. Used pivot table to sort data by IMO Number and Data.
2. Assigned time series based rank for each call by IMO Number (IMO+rank = unique identifier for each POAK ship visit)
3. Summarized all information for each IMO+rank.

Combining Data Sets:

1. Matched IMO+rank between data sets.
2. From each dataset, pulled two fields (IMO+rank and IMO+date) into one file, side by side for comparison.
3. Matched IMO+ranks between datsets with EXCEL macro.
   a. Data were flagged as follows:

Table A-1. Schematic of the procedure.

<table>
<tr><th colspan="3">Description</th><th>Flag</th><th>Action</th><th>Total Number</th><th>Percent</th></tr>
<tr><td colspan="3">Ship visited more than one berth in one day</td><td>L</td><td>Lumped elapsed time together into one ship call.</td><td>19</td><td>0.9%</td></tr>
<tr><td colspan="3">IMO No. in Land Commission data, but not Wharfinger data.[1]</td><td>M</td><td>Ship omitted</td><td>23</td><td>1.1%</td></tr>
<tr><td rowspan="4">IMO No. present in both datasets, but date not present in Wharfinger</td><td rowspan="3">Date of previous or next ship visit occurs within 4 days</td><td>Quick trip to LA</td><td>N1</td><td>Ship omitted</td><td>0</td><td>0.1%</td></tr>
<tr><td>POAK origination indicated, unable to understand</td><td>N2</td><td>Ship omitted</td><td>3</td><td>0.1%</td></tr>
<tr><td>Duplicate trip data shown unable to understand</td><td>N3</td><td>Ship omitted</td><td>13</td><td>0.6%</td></tr>
<tr><td colspan="2">Date of previous or next ship visit does not occur within 4 days</td><td>O</td><td>Ship omitted</td><td>43</td><td>2.1%</td></tr>
<tr><td colspan="3">IMO No. present in both datasets, but date not present in Land Commission data</td><td>P</td><td>Add next and last port directions to Wharfingers date based on other trips for this ship</td><td>16</td><td>0.8%</td></tr>
<tr><td colspan="3">Manually omitted</td><td>D</td><td>Ship omitted due to maintenance issue, one time delivery or other Schnitzer call</td><td>3</td><td>0.1%</td></tr>
<tr><td colspan="5">No flag</td><td>1879</td><td>93.9%</td></tr>
<tr><td colspan="5">Total in both datasets</td><td>2001</td><td>100.0%</td></tr>
<tr><td colspan="5">Total Calls in 2005</td><td>1914</td><td></td></tr>
</table>

[1] In most or all cases, a call to the Schnitzer private berth.

4. Combined datasets by creating a pivot table for each flag of side-by-side IMO+rank for each database.
5. Based on IMO+rank, obtained needed data from each dataset.
6. Output data for inclusion in ENVIRON vessel call database used to estimate emissions.

.

Fields from Wharfinger and Land Commission data included in the ENVIRON vessel emission estimation database.

IMO No.
Ship Name
Arrival Date
Arrival Time
Departure Date
Departure Time
Berthing Time
Berth Code
Terminal
Last Port
Last Port Direction
Next Port
Next Port Direction
Shifts

APPENDIX B

Processing Steps to Generate Port of Oakland (POAK) Vessel Data

Processing Steps to Generate Port of Oakland (POAK) Vessel Data

1. Searched for ship information by IMO in the Lloyds Ship Register database[1]. Used IMO Numbers from the Lands Commission dataset, which included all POAK ship call IMO numbers.
2. Lloyds Ship Register did not export IMOs from database; therefore, Lloyd's database names output was matched with IMO numbers in the Lands Commission dataset.
3. 377/393 ship names corresponded to IMO numbers in Lands Commission database. For ships that did not match, due to a change of ship name, IMO numbers were determined individually in the Lloyd's database with online screens.
4. Output selected fields for inclusion in the ENVIRON emission estimation database.

Fields from Lloyd's Database included in ENVIRON vessel emission estimation database:

- IMO No.
- Ship Name
- Flag
- Length
- Speed
- Propulsion Type
- 1st Engine: Power (kW)
- 1st Aux Engine (LR): Max Power (KW)
- Engine: Power (KW)
- Aux Generator: Total Power*

* Used as estimate of Auxiliary Engine Power, described below.

- Much of the auxiliary engine data was missing from Lloyd's database; only 43 of 392 POAK ships had values for both main and auxiliary engines. However, because an estimate of the auxiliary power was required for this study, auxiliary generators were used to estimate auxiliary engine power. On average, auxiliary generator power underestimates auxiliary engine power by 208kW for all POAK ships that had both values. Auxiliary generator power was used and not adjusted upward to account for this (relatively small) discrepancy. See Appendix C for a discussion of this issue.
- Auxiliary generator power was generally found with Lloyd's database. However, when it was not in Lloyd's CD-ROM, a text version of Lloyd's data was used in some instances. When auxiliary generator power was not in the CD-ROM or text versions of Lloyd's database, California ARB[2] TEU vs. auxiliary engine power relationship for container ships was used to estimate auxiliary generator/engine power. 6 ships, 2 bulk carriers and 4 general cargo ships had no data in The Lloyd's CD-ROM or text version and were not considered container ships. The average auxiliary generator power was estimated for these ships using similar ship types in the POAK data table and Lloyd's database. These latter vessels may include calls to the Schnitzer private berth within the spatial area of this study but are not included in this emissions inventory.

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[1] Fairplay, Limited, 2006. "Register of Ships on CD-ROM, January 2006, Version 2.21",
[2] ARB, 2006. "Evaluation of Cold-Ironing Vessels at California Port", February, 2006. ARB Cold-Ironing, DRAFT document. http://www.arb.ca.gov/msprog/offroad/marinevess/documents/coldironing0306/appf.pdf

Special cases were made for certain NYK ships as flagged in the data. The Lloyds text look-up for all NYK ships of same characteristics were used to account for likely within-fleet consistency not shown in the CD-Rom version of Lloyd's database.

APPENDIX C

Auxiliary Power Estimations

Vessels have auxiliary engines that drive on-board electrical generators to provide electric power on board. Lloyds (2006) vessel data often does not have complete information on auxiliary engine installed power, but it does often report generator capacity. The maximum auxiliary power available for a vessel was derived from the auxiliary generator capacity. The auxiliary generator capacity was derived from the Lloyds online/electronic database (83% of vessels), supplemented with Lloyds (2006) hard copy Vessel Registry (4% of vessels) and ENVIRON (2004) (2 vessels only), and with the remaining entries (12%) using the California ARB (2005a,b) correlation of generator capacity and TEUs capacity or general cargo estimates. In addition, 4 vessels did not have generation capacity or TEU reported, but based on the manufacturer, size, gross tonnage, and other similarities, were deemed identical to other vessels for which such information was available.

Auxiliary generator capacity was typically found to be lower than the auxiliary engine rated power. This is shown in Figure C-1 for the 43 vessels calling at Oakland where both engine power and generator capacity were available. Figure C-1 shows that primarily vessels with higher engine power ratings had higher engine power than generator capacity. ERG/Starcrest (2003) also found and reported engine rated power to be 6% higher on average than the generator capacity. This study used generator capacity and so may underestimate power demand for larger auxiliary engines. Engine load factors, however, are not well understood, and the actual engine load is more important than the rated power. The uncertainty between the engine power and load factors has not been precisely characterized at this time.

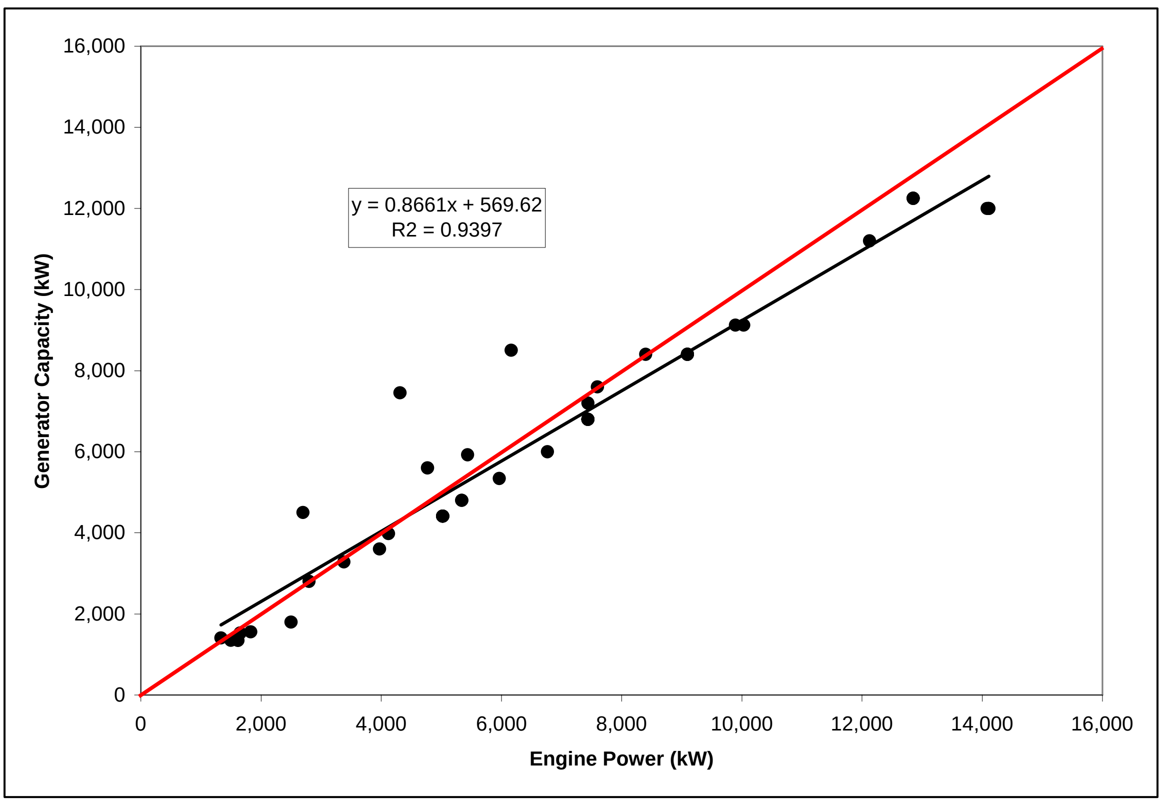

Figure C-1. Auxiliary generator capacity and auxiliary engine rated power.

Because there is uncertainty about the relationship between rated engine power and load factors, ENVIRON elected to report the auxiliary generator power as equivalent to auxiliary engine power.

APPENDIX D

Cargo Handling Equipment (CHE) Survey

Equipment Use Survey for the Port of Oakland Emission Inventory

Please provide us with more specific information about each vehicle or piece of off-road equipment operating on a regular basis at your terminal. Enter as much information as possible into table below. Please make copies of this page if you will need additional space.

1) Company Name ______________________________
2) Terminal ______________________________
3) Berths Served ______________________________
4) Contact Name ______________________________
5) Contact Phone Number______________________________
6) Fax Number ______________________________

What is your terminal's total yearly off-road equipment fuel consumption by fuel type? (Useful for determining load factors)

Diesel – Highway (undyed gallons): ______________
Diesel – Off-road (red dyed gallons): ______________
Gasoline (gallons used in nonroad equipment): ________
Compressed Natural Gas (CNG): ______________
Liquid Natural Gas (LNG): ______________
Propane: ______________

On-road Vehicle Profiles

Vehicle Make	Vehicle Model	Fuel Type: Gasoline (G) or Diesel (D) or LNG, or CNG or Propane	Vehicle Age/ Model Year	Annual Mileage	Cumulative Mileage
Ford	F-350	D	1988	8,000	140,000

Additional comments

Examples of cargo handling equipment are provided in the list below.

Yard trucks	Top Picks	Forklifts	
RTG cranes	Side Picks	Sweepers/Scrubbers	
Cranes (not RTG)	Reach Stackers		

Other Off-road Equipment types (if used)

Generator Sets	Welders	Rubber-Tire Loaders	Tractors/Loaders/Backhoes
Pumps	Pressure Washers	Skid Steer Loaders	Crawler Tractor/Dozers
Air Compressors	Aerial Lifts	Excavators	Graders
Gas Compressors	AC\Refrigeration	Dozers	Signal Boards/Light Plants

Offroad Equipment Profiles (or use ARB survey form)

	Equipment Type	# of Equip.	Chassis Make & Model	Chass Model Year	Engine Model	Engine Retrofit or Repower? (Y/N)	Engine Model Year and (Service Start Date *)	Gasoline (G) or Diesel (D) or LNG or CNG or Propane	Engine Rated HP	Estimated or Measured Hours of Use per Week or Year	Estimated or Measured Weeks of Us per Year	Cumulative Hours on Engine (Estimated Life)	Typical Fuel Use in Gallons (optional) **
EX.	Top Handl	2	Taylor 950	1989	Cummins LT10C5.9		1989 (June '89)	D	250	1800 hours/yr	Annual	28,800 (40,000)	150 Gal. for 35 Hr

* Especially important if the engine is newer than the equipment

** If available please indicate the gallons by one of the following: hourly, daily, weekly, monthly or annually

Additional comments ______________________________

Please return the survey to:

APPENDIX E

Truck Speeds in the Port of Oakland Memorandum

180 Grand Avenue, Suite 250
Oakland, CA 94612
www.dowlinginc.com

510.839.1742
510.839.0871 fax
traffic@dowlinginc.com

Dowling Associates, Inc.

Date: February 6, 2006

Memorandum

To: Chris Lindhjem

cc: Mark Bowman

From: Steve Colman

Reference #: P06-013

Subject: Port of Oakland Truck Speeds

The spreadsheet included with this transmittal gives our best estimate of observed average running speeds on the 33 road segments you selected in the Port of Oakland. They are based on observations made today, when the Port was very active.

There are obviously many factors that influence the average truck speeds, including vehicle, operator, and roadway characteristics. Posted speed limits are shown in the attachment, if there was a speed limit sign posted on the link (in one case, the UP terminal, a speed limit sign was posted on private property).

We have also noted in the comments field any important characteristics of the link, usually having to do with traffic control or the roadway. AWSC is an abbreviation for a link that has an All-Way Stop Control intersection at its beginning, end, or in between. Obviously, this will tend to slow average speed, and if travel demand is heavy, may result in some queuing (although the queues at AWSC intersections observed seemed fairly short).

On the short sections between Port/public streets and gates, the speeds are influenced by the short distances involved and the fact that in some cases queuing (idling) occurs for inbound trucks. Generally, it appeared these short sections had average speeds of 15 to 18 mph, but there was a fair amount of variation.

Although not rigorously studied, a few observations of idling characteristics can be noted. Gates varied considerably in their activity level and queuing; some gates had (apparently) no activity; many had one or two trucks queuing at the gate; and a few were very busy. One location was observed to have 10 trucks queuing what appeared to be at least 10 minutes each to get into a gate. The only significant traffic congestion not associated with gates was on 5th Street near Broadway, which historically has been a problematic intersection for the City of Oakland (it is in downtown, and is a major portal to the Webster Street tube to Alameda).

The greatest number of queuing/idling vehicles was observed at Middle Harbor Road and Maritime Street about 11:15 AM. An unladen trailer train moved forward, backed up, and moved forward again, blocking the crossing for at least 15 minutes, and probably more (I gave up waiting and found a longer route around the blockage). Meanwhile, many trucks were stacked in the left and right turn lanes on Middle Harbor Road, and also on the Maritime Road approaches (I would guess as many as 30, possibly more, but that is a very rough estimate).

A more in-depth examination of idling would require some thought, because in most places there is no easy place for an observer to safely stand or sit in a car. Shoulder areas on major roadways are frequently used for truck parking and queuing, and medians are not suitable for observation purposes. Most trucks seemed to have their engines on, as they were waiting short periods to creep forward when the truck in front of them did. Shutting down the engine probably isn't reasonable under such circumstances.

One possibility might be some form of aerial photography, if the economics work out. That would not tell you how many vehicles are idling, however.

On one section (#28), I found the speeds to be potentially different on the north and south parts of this relatively long (~1,100 ft.) link. Speeds on the south section are likely to be fairly high (35-40 mph), but at the north, there are several closely spaced traffic signals near the I-880/Bay Bridge connectors, which would tend to slow the average speed down. However, at the times I was there, traffic in this location was fairly light, and therefore the signal-related delays small.

Please let me know if you have any questions or comments.

Truck Speeds in the Port of Oakland Memorandum

February 6, 2006

Link ID	Location	Length (feet)	Running Speed (mph)	Posted Speed (mph)*	Comments
0	20-22, gate to Maritime St.	217.2	15		
1	23, gate to Maritime St.	377.5	18		
2	24, gate to Maritime St.	710.8	18		
3	Maritime St., 20-22 to 23	190.5	40	35	
4	Maritime St., 23 to 24	338.6	40	35	
5	Maritime St. 24 to Petroleum St.	81.8	35		
6	25-26, gate to 7th	317.0	18		
7	30, gate to 7th	287.0	15		
8	35-38, gate to 32-34	739.6	40	30	AWSC at end of link
9	7th, 32-34 to Middle Harbor Rd.	636.6	35-40	45	signal
10	55-56, gate to Middle Harbor Rd.	376.9	15		
11	Middle Harbor Rd., 7th to 55-56	520.8	40		signal at 7th St.
12	7th, Middle Harbor Rd. to 30	194.0	27		
13	7th, 30 to 25-26	402.8	27		AWSC
14	7th, 25-26 to Petroleum St.	149.6	27		
15	7th, Maritime St. to 880	699.9	30		
16	Maritime St., 7th to BNSF	794.5	30	35	slight grade
17	BNSF, gate to Maritime St.	369.9	15		
18	57-59, gate to Middle Harbor Rd.	368.3	15		
19	Middle Harbor Rd., 57-59 to UP	1,023.9	30	30	AWSC
20	Middle Harbor Rd., 55-56 to Maritime St.	1,191.0	40	45	
21	Maritime St., BNSF to Middle Harbor Rd.	500.8	35		signal @ Middle Harbor
22	60-63, gate to Middle Harbor Rd.	187.0	15		
23	UP, gate to Middle Harbor Rd.	370.0	15-20	15	
24	Middle Harbor Rd. UP to 3rd	732.2	30-35		grade sep slows veh on upgrade
25	Market St. 3rd to 5th; 5th, Market St. to Broadway	1,011.2	20	25	closely spaced signals; congestion near Broadway
26	Market St. Embarcadero to 3rd	196.4	20-25		
27	67-68, gate to Embarcadero	109.4	15		
28	Maritime St. 20-22 to 880	1,081.1	35		North end has signals nr. 880
29	Petroleum St.	296.2	20		
30	7th, Petroleum St. to Maritime St.	264.1	30	30	signal @ 7th/Maritime
31	Maritime St., Petroleum St. to 7th	258.2	25	35	signal
32	3rd, Market to Adeline	466.6	25-30		level; AWSC @ 3rd/Adeline
33	Adeline St, 3rd to 880	157.4	25		

APPENDIX F

Truck Age Distribution Survey for Port of Oakland Traffic
Dowling, Inc.

Truck License Plate Survey—Data Collection Description

A randomized truck survey was undertaken to determine the fleet characteristics for trucks serving the Port of Oakland terminals. The age distribution could be important in determining the base emissions levels. Later model year trucks were subject to more stringent emission regulations and so were designed for lower emissions. .

This survey was conducted to meet two of the Port's needs:

1) To provide information on the age distribution of truck tractor units in order to improve the estimates of truck emissions related to the Port's operations.

2) To provide a registered owner and mailing address list so that the Port can communicate (via mail) with selected truck owners.

Truck license plate data were collected manually via dictation where an observer read the license plate into a recorder and later entered them into a computer file. This methodology was chosen after conducting a pre-test on the Adeline Street Bridge (referred to as location 1, as explained below) on September 11, 2006. Writing down plate numbers (and associated information) was found to be too slow and cumbersome, but dictation equipment worked well, despite the relatively high background noise levels caused by accelerating trucks.

Surveyors were temporary workers hired through Kelly Services in downtown Oakland, and trained at Dowling Associates offices in Oakland. Two of the three surveyors were Oakland residents. After the office training, the survey supervisor went with the crew to a field location to practice data collection. Surveyors were provided with a digital recorder, a yellow safety vest, and a chair to sit on (due to long shift durations). The digital recorders had a 'time stamp' device that provided a running clock with the dictation; as a backup, surveyors were also requested to read the clock hour when it occurred (e.g., "It's now 9 AM".). Dowling Associates provided field supervision, including filling in during breaks in the morning and afternoon periods.

The survey fieldwork began on Wednesday, October 4, 2006. The location codes were as follows in Table F-1 and used as shorthand for the data entry.

Table F-1. Location code cross reference

Location Number	Physical Location
1	Trucks exiting Port on Adeline St. Bridge, near 3rd St.
2	On 7th Street, exiting Port toward underpass (eastbound)
3	On Maritime Street, exiting Port, south of W. Grand Avenue
4	Middle Harbor Rd. @ UP Yard entrance, in eastbound/northbound direction
5	Maritime St. @ BNSF Yard (OIG) in southbound (counterclockwise) direction
11	Howard Terminal October 4-5 (provided by Port)
12	OICT October 4-5 (provided by Port)

These locations were selected to cover both external (locations 1-3) and internal (4-5) trips. They were also selected because:

- They were safe for survey workers (i.e., no traffic hazards)
- Have legal parking nearby for the surveyor's vehicle
- Have good sightlines to observe truck plates, which are only on the front of tractor units

Two terminals also supplied truck license information marked as sites 11 and 12. The survey for locations 1-5 was conducted from 7 AM to 4 PM, with a one hour break (Noon-1) for lunch, corresponding to the usual closing times of most shipper gates.

Originally, work was to be completed on October 6, but due to some unseasonable rains, work had to be temporarily suspended, and was completed on October 9.

Information was also collected on the type of unit, tractor only (bobtail), tractor and empty chassis, or tractor with container. Because of the high noise levels associated with the locations chosen, surveyors used the phonetic alphabet for alphabetic letters in a plate, e.g., 7B12345 would be read "seven-bravo-one-two…". This method avoids office transcription problems with letters that can sound alike, e.g., B, P, and V.

Approximately 3,380 plates in total were collected, with 2,344 unduplicated (unique) plates. The number of out-of-state plates was generally about 2% of the total. Out-of-state license plates were recorded by the surveyors, along with the name of the state. Unfortunately, because there are at least 50 distinct plate types, it sometimes was difficult to ascertain the name of the state when traffic was busy. By far, the largest number of out-of state plates from a single state was from Nevada.

Recordings were transcribed in Dowling's office by one of the fieldworkers, checked, and then the data emailed to the CARB. Transcription was done in two steps, the first to enter the data, and the second to verify (check) it was entered correctly.

Video Capture of License Plates

At the suggestion of CARB, Dowling also tested video data collection of license plate numbers for a brief period using an in-house camcorder. Unfortunately, this proved to be not as successful because of limitations on battery and recording tape time, and because the low angle of the late-fall sun (early and late in the day) often obscured the legibility of license plates. 'Amateur' (consumer, rather than professional) video cams often have a lower shutter speed, which may not provide a sharp image of the license plate when a truck is moving and/or the camera is not on a fixed mounting.

On the other hand, video recording technology does have advantages: it provides a permanent record, thus cutting down on transcription errors and increasing the percentage of truck license plates that can be recorded. The seven-character format of most

California truck plates (e.g., 9A12345) can be mentally difficult to parse when there is a very high volume of trucks to be recorded. Dowling recommends that if the Port wishes to conduct this survey again, that a professional video firm be considered to do the field data collection. This is likely to be more expensive than the collection of data via the manual technique employed in this study, and also means it is unlikely that Oakland residents would be employed to do this work.