Appendix B

Emissions Estimation Methodology for Commercial Harbor Craft Operating in California

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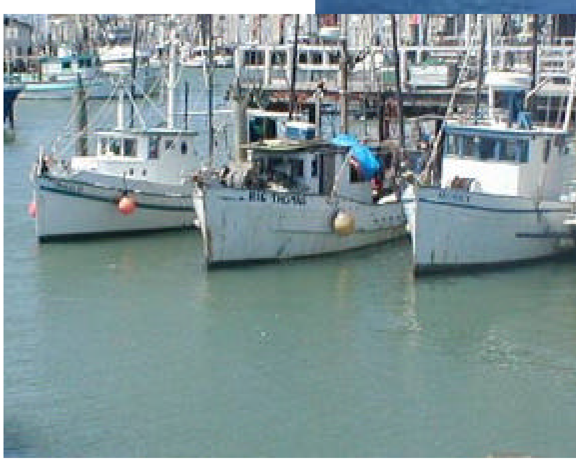

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EXECUTIVE SUMMARY

Air Resources Board (ARB) staff have developed a consistent methodology to estimate emissions from commercial harbor craft in California. This updated inventory will be used to support regulatory analysis of statewide regulations to reduce emissions from these marine engines. Other goals in undertaking this emissions inventory update were to:

- Update the inventory to reflect the most current harbor craft fleet;
- Accurately reflect adopted regulations and other regulatory programs in the baseline inventory and in any forecasts.
- Establish a structure that would allow allocation of the statewide emissions to individual air pollution control districts and air basins;

In the Proposed Regulation for Diesel Engines on Commercial Harbor Craft, "commercial harbor craft" means any private, commercial, government, or military marine vessels including, but not limited to, passenger ferries, tug boats, tow boats, push-boats, crew vessels, work boats, pilot vessels, supply boats, research vessels, United States Coast Guard vessels, hovercraft, emergency response harbor craft, and barge vessels that do not otherwise meet the definition of ocean-going vessels or recreational vessels.

This inventory covers commercial harbor craft that operate within California coastal waters and inland waterways, and have a home port located in California. Due to limited information currently available about the number of U.S. Navy and/or U.S. Coast Guard (USCG) vessels, vessel characteristics, and vessel activity, we decided not to include emissions from these vessel types into this inventory.

For this inventory purpose, we grouped commercial harbor craft into nine types of vessels, including commercial fishing vessels, charter fishing vessels, crew and supply boats, ferry and excursion vessels, pilot vessels, tow boats, tug boats, work boats, and "others", i.e. other type of vessels that do not fit into the above eight categories.

To estimate California statewide commercial harbor craft emissions, we first estimated vessel type and region specific emissions rates, i.e. average emissions per engine per year, using an activity-based approach based on engine information collected in the 2004 ARB's Commercial Harbor Craft Survey. We then estimated statewide emissions by multiplying number of engine in each engine category and in each region by average emissions per engine.

Using the proposed methodology, we estimate statewide emissions from commercial harbor craft diesel-fueled engines in 2004 were about 3.3 tons per day of diesel PM, about 73.2 tons per day of oxides of nitrogen (NO_x). Detailed emission estimates are presented in Table ES-1.

Table ES-1 Commercial Harbor Craft Emissions in California in 2004 (Tons/day)

Vessel Type	Vessel Population	Engine Population	NOx	PM	ROG	CO
Charter Fishing	563	1,419	12.7	0.6	0.9	3.3
Commercial Fishing	2,727	4,309	17.4	0.8	1.3	4.8
Crew and Supply	64	230	1.4	0.1	0.1	0.4
Ferry/Excursion	416	1,348	21.0	0.9	1.4	5.6
Pilot Vessels	27	50	0.4	0.0	0.0	0.1
Tow Boats	35	114	3.0	0.1	0.2	0.7
Tug Boats	128	449	15.3	0.6	1.0	3.8
Work Boats	89	158	0.5	0.0	0.0	0.1
Others	136	214	1.5	0.1	0.1	0.4
Total	4,185	8,291	73.2	3.3	5.0	19.2

Ferry/excursion vessels and tug/tow boats jointly account for about 14% of the statewide harbor craft population and 50% of the statewide harbor craft emissions. The engines of these vessels are relatively larger and operate more often than other vessel categories. Commercial fishing vessels account for 65% of the harbor craft population but only emit around 25% of the emissions.

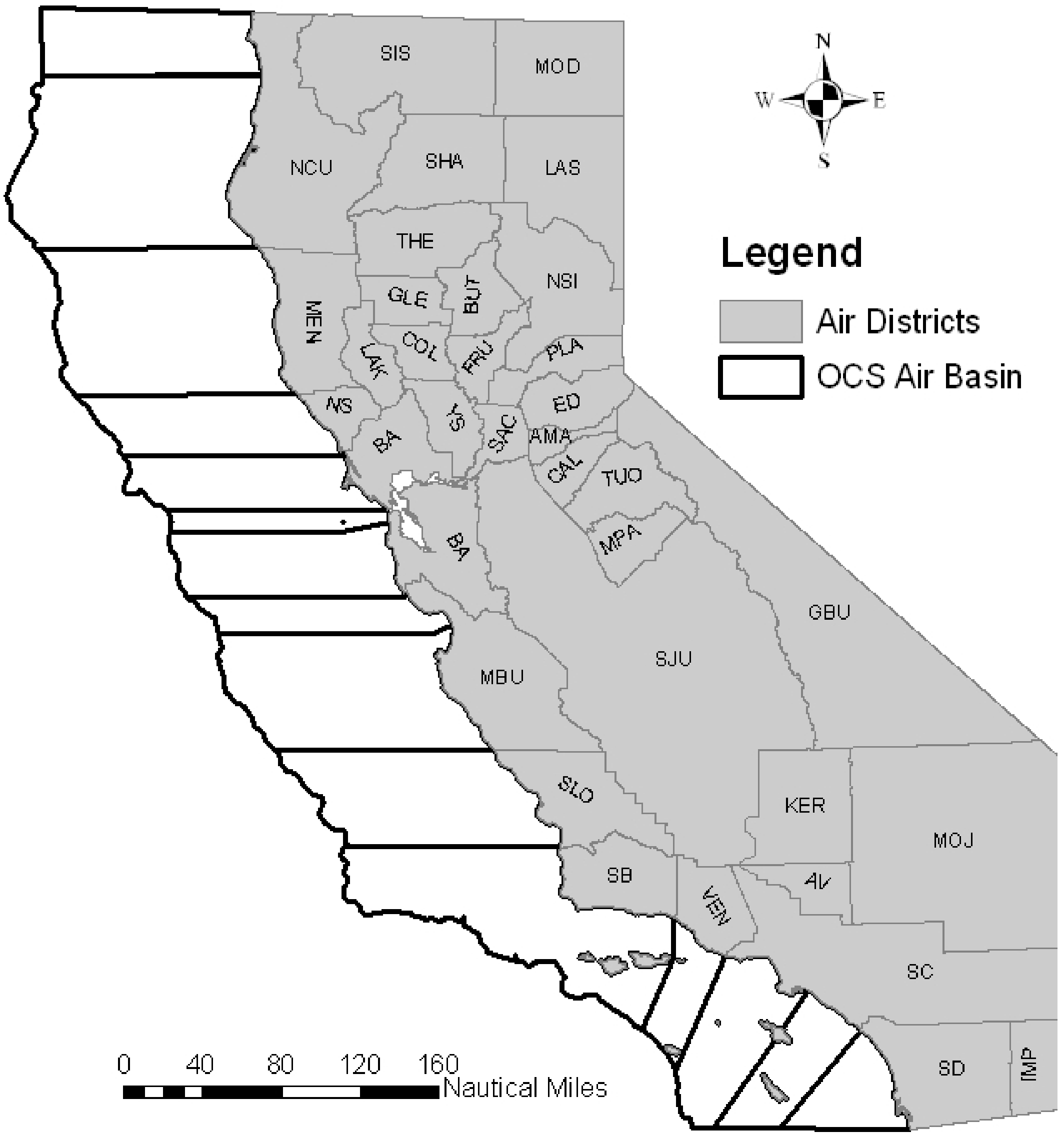
Table ES-2 provides NOx emissions by engine and vessel type. Propulsion engines account for 93% of NOx emissions from commercial harbor craft.

Table ES-2 NOx Emissions By Engine Type and Vessel Type in 2004

	Main Engine		Auxiliary Engine	
Vessel Type	Number of Engines	Tons/day NOx	Number of Engines	Tons/day NOx
Charter Fishing	997	12.1	422	0.6
Commercial Fishing	3,054	14.8	1,254	2.6
Crew and Supply	160	1.1	70	0.4
Ferry/Excursion	836	20.2	512	0.8
Pilot Vessels	46	0.4	4	0.0
Tow Boats	74	2.8	41	0.2
Tug Boats	246	14.9	204	0.4
Work Boats	130	0.5	28	0.0
Others	151	1.4	63	0.1
Total	5,693	68.1	2,598	5.1

Table ES-3 summarizes NOx and PM emissions by Air Quality Management District (AQMD) or Air Pollution Control District (APCD) and Outer Continental Shelf (OCS) air basin in calendar year 2004. The AQMDs and APCDs are commonly called air districts. OCS air basin covers 3-100 nautical miles from shore. Figure ES-1 illustrates these air districts and OCS air basins.

Figure ES-1 Illustration of California Air Districts and OCS Air Basins



About one third of the state harbor craft are in the Bay Area AQMD. These vessels account for about 37% of statewide NOx or PM emissions. South Coast AQMD has 18% of the statewide harbor craft and account for about 26% of the NOx or PM emissions. San Diego County APCD only has 7% of the statewide population but these vessels emitted about 12% of statewide harbor craft NOx or PM emissions. These three air districts jointly are home to 60% of the statewide harbor craft and these vessels are responsible for 75% of statewide NOx or PM emissions.

Table ES-3 NOx, PM Emissions By Air District and Air Basin in 2004

Air Districts		Number of Vessels	NOx Tons/year	NOx in OCS	PM Tons/day	PM in OCS
Bay Area AQMD	(BA)	1,468	26.9	10.2	1.2	0.5
El Dorado County APCD	(ED)	9	0.3	0.0	0.0	0.0
Mendocino County AQMD	(MEN)	169	1.3	1.1	0.1	0.0
Monterey Bay Unified APCD	(MBU)	379	3.6	2.7	0.2	0.1
North Coast Unified APCD	(NCU)	299	2.3	1.9	0.1	0.1
Northern Sonoma County APCD	(NS)	145	1.2	1.0	0.1	0.0
Placer County APCD	(PLA)	9	0.3	0.0	0.0	0.0
San Diego County APCD	(SD)	307	9.2	5.5	0.4	0.2
San Joaquin Valley Unified APCD	(SJU)	43	0.8	0.0	0.0	0.0
San Luis Obispo County APCD	(SLO)	145	1.4	1.1	0.1	0.1
Santa Barbara County APCD	(SB)	193	2.7	2.0	0.1	0.1
South Coast AQMD	(SC)	745	18.7	11.7	0.8	0.5
Ventura County APCD	(VEN)	194	2.5	1.8	0.1	0.1
Yolo/Solano AQMD	(YS)	81	1.9	0.0	0.1	0.0
Total		4,185	73.2	38.9	3.3	1.8

Statewide about 53% of the emissions occur in the Outer Continental Shelf air basin. Generally fishing vessels spend the most time in the Outer Continental Shelf, while ferries tend to spend the most time closer to shore.

Figure ES-2 Estimation of Commercial Harbor Craft NOx, PM Emissions 2004-2025

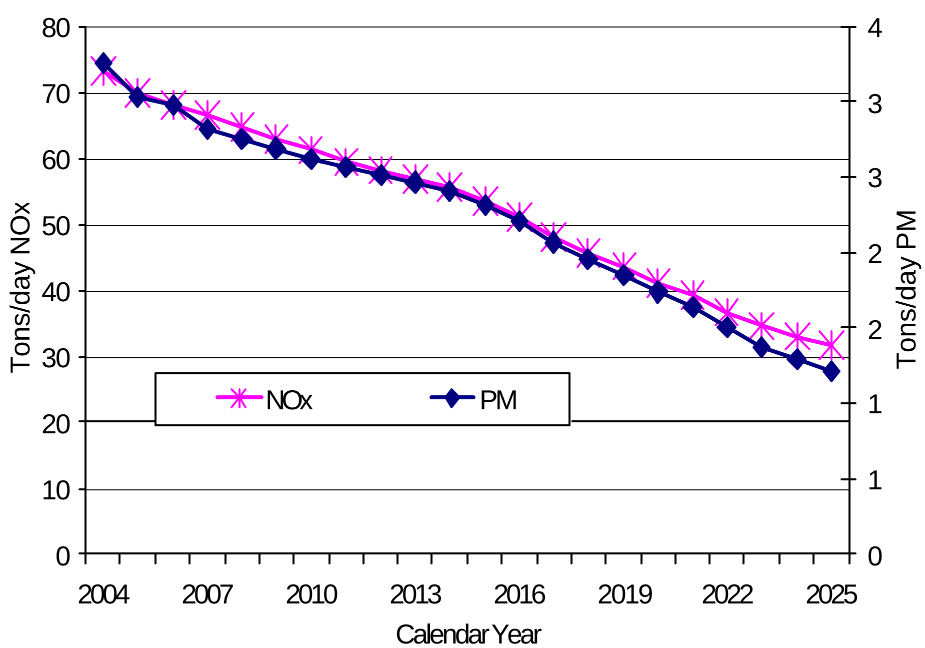


Figure ES-2 illustrates the change of commercial harbor craft NOx and PM emissions over time from 2004 to 2025. NOx emissions from harbor craft in California will decrease from 73 tons per day in 2004 to about 32 tons per day in 2025 and PM emissions will decrease from 3.3 tons per day to about 1.2 tons during the same period. The decline of emissions between 2004 and 2009 is partially caused by the decline of the fishing fleet from 2004 to 2009 as we project based on fish landing data, natural engine turnover, and the more stringent EPA marine engine emissions standards. New engines need to comply with EPA standards and are cleaner than the old engines which are replaced. The decrease in emissions after 2009 reflects the gradual phase in of new engines replacing old engines retired from the fleet.

I. INTRODUCTION

This section provides background on the commercial harbor craft emissions inventory, the purpose and goals in preparing this emissions inventory, and a general overview of the methodology used to estimate emissions from commercial harbor craft.

A. Background

In the Proposed Regulation for Diesel Engines on Commercial Harbor Craft, "commercial harbor craft" means any private, commercial, government, or military marine vessels including, but not limited to, passenger ferries, tug boats, tow boats, push-boats, crew vessels, work boats, pilot vessels, supply boats, research vessels, United States Coast Guard vessels, hovercraft, emergency response vessels, and barges that do not otherwise meet the definition of ocean-going vessels or recreational vessels. Except for commercial fishing vessels, commercial harbor craft spend most of their time within 100 nautical miles from shore.

Most commercial harbor craft are powered by marine diesel engines, including propulsion engines and auxiliary engines *(1)*. Propulsion engines are the primary engines that move vessels through the water. Auxiliary engines generally provide power to vessel electrical systems and may also provide additional power to unique, essential vessel equipment (i.e. refrigeration units) during the normal day-to-day operation of the vessel.

Marine diesel engines powering commercial harbor craft are usually larger than onroad and land based offroad diesel engines. These engines also last longer and have much longer operating lifetime. According to the 2004 ARB survey, the average age of commercial harbor craft propulsion engines in 2004 is about 18 years old with about 44% of the them older than twenty years, and about 20% of them older than thirty years *(1)*. In contrast, the average age of California in-state trucks is about 12 years old.[1] These marine engines are also among the least regulated sources of air pollutants in California. The first U.S. EPA rule regulating these engines, "Control of Emissions of Air Pollution from New CI Marine Engines at or above 37 kW", was published in 1999. The emission standard in this rule only applies to new engines and became mandatory in 2004. Marine engines are less controlled and tend to emit more air pollutants than land based engines. Even with a smaller population, commercial harbor craft are important sources of air emissions in California especially for coastal areas with heavy marine activities. It is estimated that emissions from commercial harbor craft in the Bay Area Air Quality Management District are equivalent to nearly 60% of the emissions from heavy heavy duty diesel trucks in this area.[2]

[1] Based on ARB's EMFAC2007 model, http://www.arb.ca.gov/msei/onroad/latest_version.htm
[2] Compared to emission estimates for heavy heavy duty diesel truck in the emissions inventory for Proposed State Strategy for California's State Implementation Plan (SIP) for the New Federal PM2.5 and 8-Hour Ozone Standard, http://www.arb.ca.gov/planning/sip/2007sip/2007sip.htm

B. Purpose and Overview

To avoid inconsistencies in the statewide emissions inventory, ARB staff developed a consistent methodology which can be used statewide to estimate emissions from harbor craft. This updated inventory will be used to support analysis of statewide regulations to reduce emissions from these marine engines. Other goals in undertaking this emissions inventory update were to:

- Update the inventory to reflect the most current harbor craft fleet;
- Accurately reflect adopted regulations and other regulatory programs in the baseline inventory and in any forecasts.
- Establish a structure that would allow allocation of the statewide emissions to individual air pollution control districts and air basins;

This inventory covers commercial harbor craft that operate within California coastal waters and inland waterways, and have a home port located in California. Due to limited information currently available about the number of U.S. Navy and/or U.S. Coast Guard (USCG) vessels, vessel characteristics, and vessel activity, we decided not to include emissions from these vessel types into this inventory.

For this inventory purpose, we grouped commercial harbor craft into nine types of vessels, including commercial fishing vessels, charter fishing vessels, crew and supply boats, ferry and excursion vessels, pilot vessels, tow boats, tug boats, work boats, and “others”, i.e. other type of vessels that do not fit into the above eight categories. The nine categories are described in Table I-1.

This inventory provides estimates of emissions of oxides of nitrogen (NOx), reactive organic gas (ROG), carbon monoxide (CO), particulate matter (PM), and sulfur oxides (SOx). We chose year 2004 as the base year of this inventory because that’s the end of the period when the population data were collected. We forecast emissions for the future years (2005-2025) based on projected fleet growth, turnover, engine deterioration, and the change of emission rates.

Table I-1 Categories of Commercial Harbor Craft Included in the Emissions Inventory

Vessel Type	Description
Commercial Fishing	Vessels used in the search and collection of fish for the purpose of sale at market.
Charter Fishing	Vessels available for hire by the general public and used for the search and collection of fish for the purpose of personal consumption.
Crew and Supply	Vessels used for carrying personnel and supplies to and from off-shore and in-harbor locations, including vessels at anchorage, construction sites, and off-shore platforms.
Ferry/Excursion	Vessels used for public use in the transportation of persons or property as a part of the public transport systems and commercial vessels used for sightseeing, whale watching, and dinner cruising, etc.
Pilot Vessel	Vessels used to carry pilots to and from ships to provide pilot service into and out of a port or harbor.
Towboat/Pushboat	Vessels used to push barges and pontoons. Towboats are characterized by a square bow with steel knees for pushing, a shallow draft, and powerful engines. They are most often seen on inland waterways since their hull designs (like little freeboard) would make open ocean operations dangerous.
Tug Boat	Vessels primarily used to assist other vessels maneuvering in harbors, over the open sea or through rivers and canals by pushing and towing. They are also used to tow barges, or other floating structures.
Work boat	Vessels used to perform duties such as fire/rescue, law enforcement, hydrographic surveys, spill/response research, training, and construction.
Other	Vessels used in various commercial operations that do not fit into any other category such as vessels used to dispose of cremated remains.

C. Public Process

Allowing stakeholders and the general public to review and comment on a product associated with a rulemaking process is a critical element of that rulemaking process. The following steps were taken to ensure interested parties could provide input.

Comments on impacts were solicited from the Commercial Harbor Craft Working Group. Members of the working group include representatives of the groups and agencies that would be impacted by any rulemaking undertaken by the ARB. Representatives include diesel-fueled compression ignition engine manufacturers, environmental groups, ferry operators, local air pollution control and air quality management districts, and control technology manufacturers.

We provided local air districts and the public the opportunity to review, comment on the methodology and the inventory by conducting working group meetings/teleconferences, and public workshops. The inventory was presented to six public workshops and several teleconferences with air districts. Comments obtained through these meetings, teleconferences and workshops were used to assess and modify the inventory.

II. EMISSION ESTIMATION METHODOLOGY

To estimate California statewide commercial harbor craft emissions, we first estimated vessel type and region specific emissions rates, i.e. average emissions per engine per year, using an activity-based approach based on engine information collected in the 2004 ARB's Commercial Harbor Craft Survey *(1)*. We then estimated statewide emissions by multiplying number of engine in each engine category and in each region by average emissions per engine.

A. Emission Inventory Inputs

Data needed for estimating harbor craft emissions include:

- Base year vessel and engine population
- Future fleet growth and engine turn over
- Engine hours of operation and engine load
- Zero-hour (new engine) emission factor
- Engine deterioration and other adjustments
- Spatial allocation surrogate

Engine population for a given year was estimated using base year vessel population, vessel profiles information collected from various sources, engine and vessel information collected in the ARB's Commercial Harbor Craft Survey *(1)*, fleet growth rates provided by air districts, and engine attrition rates based on the ARB's OFFROAD model.

1. Base Year Vessel Population and Vessel Profiles

Since there is no one available data set that covers all commercial harbor craft operating in California, vessel population data were collected from various sources, including the U.S. Coast Guard documentation data, the California Department of Fish and Game registration data, the ARB Harbor Craft Survey *(1)*, and information from recent emission inventory estimates generated for the Port of Los Angeles. Each of these sources of commercial harbor craft information is described in greater depth below. In addition, the specific steps taken to develop estimates of numbers of specific vessel types and spatially allocate those populations are also described below.[3] Based on available information, we estimate that there were approximately 4,185 harbor craft vessels operating in California in year 2004.

United States Coast Guard Vessel Data:

The United States Coast Guard (USCG) administers a vessel documentation program. The USCG vessel documentation program is a national form of registration. The ARB purchased the U.S. Coast Guard documentation data through the National Technical Information Service.

Types of vessels that are documented in the data set include:

- vessels that measure at least five net tons (a measure of the vessel's volume, most vessels more than 25 feet in length will measure five net tons or more)
- vessels wholly owned by a citizen of the United States (with the exception of certain oil spill response vessels)
- vessels of five net tons or more used in fishing activities on navigable waters of the United States or in the Exclusive Economic Zone (EEZ)
- vessels used in coastwise trade (transportation of merchandize or passengers between points in the United States)
- towboats operating between points and dredges operating in United States or the EEZ must be documented.

The information provided represents nation-wide vessel documentation information for the years 1985 through June 2001. ARB staff sorted the data by state and removed all non-California documented vessels. The majority of the vessels that are California documented vessels fall into one of five categories of vessels. Those categories are commercial boats, fishing, offshore supply, passenger, tow/tugboats, and unclassified.

California Department of Fish and Game Data:

The California Department of Fish and Game (DFG) registers all commercial fishing vessels, passenger fishing boats, and fish businesses in California. We obtained their file of the commercial fishing permits registrations issued for 2004. That information was used to augment the USCG documentation and ARB Survey data when evaluating the commercial and charter fishing categories of commercial harbor craft.

[3] In early 2004, ARB staff contacted approximately 60 of California's harbormasters and port and marina administrators. Using a brief two-page survey, ARB staff collected estimates of the current commercial harbor craft populations for the nine vessel types described earlier in this document. ARB staff was able to obtain numbers of commercial harbor craft at all but one of the harbors, ports, and marinas contacted. This information was used as a reality check of the estimates using the four population data sources listed above.

Port of Los Angeles Fishing Vessel Data:

During the course of the development of a port-wide emissions inventory, the Port of Los Angeles collected information about the commercial fishing vessels that operate out of the Port. The Port provided the ARB with vessel names and owner/operator contact information for approximately 250 commercial fishing vessels.

ARB's Commercial Harbor Craft Survey (March 2004):

In 2004, ARB staff conducted a survey of commercial harbor craft owner/operators in an effort to collect information about where the different types of harbor craft in the State operate, vessel activity, and engine-specific information (ARB's Statewide Commercial Harbor Craft Survey, or ARB Survey) *(1)*. Owners/operators of commercial fishing vessels, tugs, ferries and excursion vessels, work and tow boats, and crew and supply boats were sent a copy of the ARB's survey in late 2002. The survey requested information about the home port, the type of vessel, if the vessel was used for commercial fishing, the type of fishery targeted, annual fuel use, information about where the vessel generally operated, and engine information (make and model of the engine, is it a propulsion or auxiliary engine, horsepower, was it a repower, annual hours of use, etc.). The survey was sent to more than 5,000 owner/operators statewide and the ARB received more than 700 responses representing approximately 850 vessels.

Estimating Vessel Population:

To establish a data base from which to estimate the statewide commercial harbor craft vessel population, we first segregated the information from the USCG, the California Department of Fish and Game (DFG), the Port of Los Angeles (POLA), and the ARB commercial harbor craft survey into four major groups: Ferry/excursion vessels, fishing vessels, work boats, and other types of vessels. We chose these four groupings because they are the four primary groups the USGC uses to classify commercial harbor craft. We grouped the information from the DFG, the POLA and the USCG fishing with the information from the ARB's commercial harbor craft survey for commercial fishing and charter vessel data to develop the statewide population estimate for commercial fishing vessels. Ferry, crew and supply, and pilot vessel information from the ARB commercial harbor craft survey were grouped with the USCG ferry/excursion vessel data to develop statewide population estimates for ferry/excursion vessels. We added the ARB commercial harbor craft survey data for tugs, tow boats and work boats to the USCG work group data to develop statewide population estimates for work boats. Remaining vessels from the ARB commercial harbor craft survey were added to the USCG's "other" group data to develop statewide population estimates for other types of commercial harbor craft.

Table II-1 California Commercial Harbor Craft Population by Vessel type and by District in 2004

District	Charter Fishing	Commercial Fishing	Crew and Supply	Ferry/ Excursion	Others	Pilot Vessels	Tow Boats	Tug Boats	Work Boats	Total by District
Bay Area	164	972	9	140	64	4	23	57	34	1,468
El Dorado County	6	0	0	3	0	0	0	0	0	9
Mendocino County	5	158	0	3	1	0	0	0	1	169
Monterey Bay Unified	18	336	0	17	7	0	0	1	0	379
North Coast Unified	6	285	2		1	0	0	2	2	299
Northern Sonoma County	9	132	0	4	0	0	0	0	0	145
Placer County	5	0	0	4	0	0	0	0	0	9
San Diego County	84	106	0	76	15	0	8	16	2	307
San Joaquin Valley Unified	9	23	1	5	1	1	0	1	1	43
San Luis Obispo County	8	131	1	3	0	0	0	2	1	145
Santa Barbara County	31	119	23	11	4	0	0	1	3	193
South Coast	191	274	15	134	37	21	1	38	33	745
Ventura County	16	148	12	11	4	1	0	3	0	194
Yolo/Solano	11	43	0	3	2	0	3	8	11	81
Total by Vessel Type	563	2,727	64	416	136	27	35	128	89	4,185

Each population was then assigned to a county and a district based on their reported home port.[4] The distribution of vessels into the nine inventory categories was determined based on district-specific vessel distribution ratios developed using information from the ARB commercial harbor craft survey. As shown in Table II-1, fishing vessels account for the largest percentage of vessels at 77% of the total commercial harbor craft population. Table II-1 also shows the summary of the commercial harbor craft vessel population by AQMD or APCD.

2. Base Year Engine Population and Engine Profiles

As described previously, the ARB's Statewide Commercial Harbor Craft Survey collected information about the various commercial harbor craft and associated engines operating in California's coastal waters and inland waterways, harbors, and ports during 2002-2004. The vessel information included vessel home port, vessel use and age, annual fuel use, and percent of time operated at various distances off the California coast. In addition, the Survey collected information about the engines powering those vessels. The engine information included number of engines per vessel, engine make and model, engine age, engine horsepower, annual hours of operation, and other information. Detailed information for about 850 vessels with about 400 auxiliary engines and about 1000 propulsion engines were collected during the survey.

Based on the Survey, individual engine profiles were developed by combining specific information about an engine. That information includes engine use (propulsion or auxiliary), type of vessel the engine is associated with, model year of the engine, engine horsepower, annual hours of operation, etc. These data were used to estimate emissions from individual engines.

Table II-2 summarizes the statewide commercial harbor craft engine profiles developed using the vessel and engine data collected in the ARB Survey. Since most commercial harbor craft are doing routine work, the operation profile remains relatively stable. Because the information needed to project harbor craft engine profiles in the future was not available, we assumed the engine profiles developed from the ARB survey hold throughout the future years for which we estimated emissions. Number of engines per vessel by vessel type was used to estimate statewide engine population and engine useful life was used to account for engine attrition and engine deterioration described in the following sections. Total life is defined as the age when 90% of engines retire and useful life (UL) is defined as half of total life.

[4] Those vessels with home ports far from navigable waters were assigned to the closest ports. Those vessels that did not have a "home port" listed (11 percent of the vessels) were assigned one based on the address of the owner/operator. Those vessels that reported a "home port" outside of California (4 percent of the vessels) were assigned to the ports, harbors, and marinas in counties and districts where they "landed" their catch.

Table II-2 California Commercial Harbor Craft Engine Profile by Vessel Type

	Propulsion Engine			Auxiliary Engine		
Vessel Type	# of Engines per Vessel	Average Annual Operating Hrs	Useful Life	# of Engines per Vessel	Average Annual Operating Hrs	Useful Life
Commercial Fishing	1.12	1,250	21	0.46	1,633	15
Charter Fishing	1.77	1,622	16	0.75	2,077	15
Ferry/excursion Vessels	2.01	1,843	20	1.23	1,254	20
Crew and Supply	2.5	788	22	1.1	3,036	22
Pilot Vessels	1.7	1,031	19	0.14	994	25
Tug Boats	1.92	2,274	21	1.59	2,486	23
Tow Boats	2.1	1,993	26	1.17	2,965	25
Work Boats	1.46	675	17	0.32	750	23
Others	1.11	779	23	0.46	805	22

3. Future Year Vessel and Engine Population

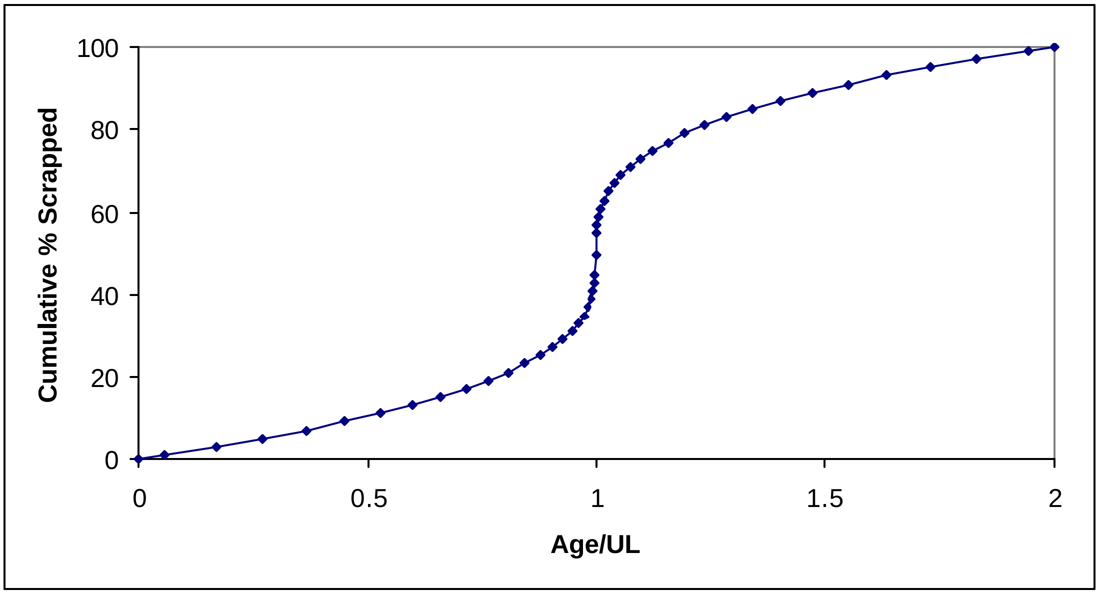
We estimated future year vessel and engine population based on fleet growth rates and engine turnover rates.

We used air districts' fleet growth rates to project commercial harbor craft population in the future years. We adjusted these growth rates based on available information. Since tug boats are generally over-powered and are capable of handling larger vessels, we assumed tug boats fleet growth is flat throughout the future years we projected. We adjusted growth rate for California's commercial fishing fleet to reflect the most recent fish landings (tons per year) data available. The data indicate that there has been a six percent per year decline in fish landings over the last decade. Since there is no way to accurately predict whether or not that trend continues indefinitely, an annual decline of six percent in the numbers of vessels in California's waters is continued through 2009. From 2010 on, the growth is flat.

We assumed vessels in the future years have the same number of engines and same engine profile as the vessels in the base year. Future year engine population was estimated using vessel population and number of engines by vessel type as shown in Table II-2.

We estimated engine turnover using attrition curve of ARB's OFFROAD model. Figure II-1 illustrates the engine attrition curve we applied to commercial harbor craft engines. Age/UL represents the ratio between engine age and useful life. The basic assumption of the attrition curve is that 50% of the engines of certain model year retire before they reach their useful life (when age/UL = 1), and 100% of the engines of certain model year retire when they reach their total life (when age/ UL = 2). Vessel and engine use specific useful life are presented in Table II-2.

Figure II-1 Illustration of Engine Attrition Curve



We estimated number of new engines in each future calendar year using the difference between the population estimated based on growth rates and the population estimated based on engine turnover. The calendar year was used as engine model year of the new engines. Vessel type and horsepower range specific average horsepower and average hours of operation were estimated using engine information collected in the 2004 ARB's Commercial Harbor Craft Survey *(1)* and were assigned to these new engines.

4. Engine Activity

Two of the key inputs of the emission estimation methodology include the engine's annual hours of operation and the typical engine load. Annual hours of operation for each individual engines collected in the ARB survey were used to estimate emissions from these engines.

We chose the marine engine load factor (43%) in the U.S. EPA's Nonroad model for commercial harbor craft auxiliary engines. We adjusted tug boats auxiliary engine load factor to 31% following the Port of Los Angeles' emission inventory developed by the Starcrest Consulting Group, LLC based on more detailed data.

We estimated main engine load factor based on fuel consumption data, engine horsepower, and annual hours of operation data collected in the ARB Survey. The ARB Survey provided engine-specific annual use values. We assumed that all of an engine's hours of operation occurred within the California Coastal Waters. Vessel type specific propulsion engine load factor was estimated using the following equation.

$$LF = BSFC * HP * Hr / TF$$

Where:

LF is the vessel type specific propulsion engine load factor;
BSFC is brake specific fuel consumption rate; we used 0.078 gal/kW-hr or 0.058 gal/hp-hr estimated from manufacturers' marine engine data;
HP is rated horsepower of the engine;
Hr is the number of annual operating hours of the engine;
TF is total fuel consumption per engine per year.

Table II-3 summarizes the engine load factors used to estimate commercial harbor craft emissions.

Table II-3 Engine Load Factor by Vessel Type and by Engine Use

Vessel Type	Propulsion Engine Load	Auxiliary Engine Load
Commercial Fishing	0.27	0.43
Charter Fishing	0.52	0.43
Ferry/Excursion	0.42	0.43
Crew and Supply	0.45	0.43
Pilot Vessels	0.51	0.43
Tug Boats	0.50	0.31
Tow Boats	0.68	0.43
Work Boats	0.45	0.43
Others	0.52	0.43

5. Zero-hour Emission Factor

ARB staff collected potential commercial harbor craft emission factors from a broad range of sources. Those sources included the U.S. EPA's Compilation of Air Pollutant Emission Factors (AP-42), Lloyd's Register of Ships, U.S. EPA Category 1 marine engine emission factors, U.S. EPA Marine Engine Certification data, ARB OFFROAD Model, and actual emission testing results from a variety of vessels.
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ARB staff reviewed the emission factors from all of these sources in an effort to select those that would be the most applicable to the development of a commercial harbor craft emission inventory. Applicability was based on a number key engine-related of factors to make that determination. Those factors included the horsepower of the engine, the model year, whether there were emission factors for the pollutants of interest (NOx, PM, HC, and CO), and the engine test cycle associated with the emission factor.

ARB's OFFROAD Model emission factors have been used in the past to estimate emissions from off-road equipment and those emission factors met the criteria set forth by the ARB's emission inventory staff, the balance of the potential emission factor sets were compared to those emission factors.

After evaluation of the available data, we chose the emission factors in the ARB's OFFROAD Model with the following adjustments:

- for 1996 through 1999 model year engines, use the Tier Zero (1996) emission factors;
- for 2000 and beyond model year engines, use the U.S. EPA emission standards for marine engines or the NOx limits of the IMO MARPOL Annex VI whichever is lower;[5] and
- adjust the OFFROAD Model emission factors to reflect an "E3" test cycle for propulsion engines and "D2" test cycle for auxiliary engines.[6]

No changes were made to the OFFROAD emission factors to differentiate between "wet" and "dry" exhaust from marine engines. This decision was made based on a lack of information definitively supporting any difference between the characteristics of the two methods of exhausting marine engine combustion gases.

No changes were made to the OFFROAD emission factors to differentiate between emissions from 2 stroke and 4 stroke engines. This decision was also based on a lack of information on the differences in emissions between the two types of engines that would allow ARB staff to make that distinction at this time.

The harbor craft emission factors are shown in Appendix A.

6. Fuel Correction Factor

ARB OFFROAD model's fuel correction factors are used to account for the benefits of cleaner diesel fuel *(2)*. Engines certified using federal on- and off-road diesel fuel receive NOx and PM benefit of 7% and 20% respectively, due to the lower aromatic content of California diesel fuel. Engines certified using federal off-road diesel fuel receive an additional 5% PM benefit due to the lower sulfur content of California diesel fuel. A fuel correction factor of 0.72 for hydrocarbon emissions will be applied to all diesel-powered engines beginning with the 1994 calendar year. Starting in 2007, California will requires the use of ultra low sulfur diesel fuel (ULSD -15 ppmw sulfur). An additional 4% PM benefit is assumed for all engines not certified on this fuel *(2)*. Table II-4 summarizes the fuel correction factors.

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[5] We compared OFFROAD emissions factors, U.S. EPA Tier I, II and proposed Tier III and Tier IV standards, and the NOx limits of the Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL). We chose the lowest of these emission factors.

[6] Because the OFFROAD Model emission factors are based on a "C1" engine test cycle, ARB staff compared emission results from similar engines testing for both the "C1" and "E3" test cycles. Based on this evaluation, we recommended that the OFFROAD Model emission factors be adjusted to better reflect the "E3" test cycle. The adjustment factors for propulsion engines are 1.19 for NOx, 0.73 for CO, and 0.94 for PM. The same evaluation was conducted to compare "C1" and "D2" testing cycles for auxiliary engines are 1.19 for HC, 1.03 for CO, and 0.84 for PM.

Table II-4 Fuel Correction Factor

Calendar Years	Horsepower Range	Model Years	NOx	PM
1994-2006	<25	Pre-1995	0.930	0.750
	25-50	Pre-1999		
	51-100	Pre-1998		
	101-175	Pre-1997		
	176+	Pre-1996		
	<25	1995+	0.948	0.822
	25-50	1999-2010		
	51-100	1998-2010		
	101-175	1997-2010		
	176+	1996-2010		
2007+	<25	Pre-1995	0.930	0.720
	25-50	Pre-1999		
	51-100	Pre-1998		
	101-175	Pre-1997		
	176+	Pre-1996		
	<25	1995+	0.948	0.800
	25-50	1999-2010		
	51-100	1998-2010		
	101-175	1997-2010		
	176+	1996-2010		
	All	2011+	0.948	0.852

Source: Off-road Exhaust Emissions Inventory Fuel Correction Factors *(2)*

7. Engine Deterioration

As an engine ages, the pollutant-specific emission factors slowly increase with age. This phenomenon is described as “deterioration” which is primarily due to the wear on the various parts of an engine associated with its day-to-day activities and is a result of malfunction of emissions related components. Deterioration occurs at different rates for each pollutant. When developing emission estimates, it is essential that deterioration be taken into account and factored in the emission estimation methodology.

We adopted engine deterioration factors from ARB’s OFFROAD model *(3)*. Table II-5 summarizes the deterioration factor we used for estimating emissions from commercial harbor craft operating in California. The values represent the increase of emission factors at the end of the useful life of engines. For example, for an engine larger than 250 horsepower, the NOx, PM, HC, and CO emission factors will increase 21%, 67%, 44% and 25%, respectively, at the end of its useful life.

Table II-5 Engine Deterioration Factor

Horsepower Range	NOx	PM	HC	CO
25-50	0.06	0.31	0.51	0.41
51-250	0.14	0.44	0.28	0.16
>251	0.21	0.67	0.44	0.25

B. Methodology

1. Overview

The basic equation for the estimating emissions from a commercial harbor craft engine is:

$$E = EF_0 \times F \times (1 + D \times \frac{A}{UL}) \times HP \times LF \times Hr$$

Where:

E is the amount of emissions of a pollutant (ROG, CO, NOx, or PM) emitted during one period; [7]
EF₀ is the model year, horsepower and engine use (propulsion or auxiliary) specific zero hour emission factor (when engine is new);
F is the fuel correction factor which accounts for emission reduction benefits from burning cleaner fuel;
D is the horsepower and pollutant specific engine deterioration factor, which is the percentage increase of emission factors at the end of the useful life of the engine;
A is the age of the engine when the emissions are estimated;
UL is the vessel type and engine use specific engine useful life;
HP is rated horsepower of the engine;
LF is the vessel type and engine use specific engine load factor;
Hr is the number of annual operating hours of the engine.

Total emissions from the California statewide commercial harbor craft fleet can be estimated by summing up the emissions from individual engines or by multiplying the emissions rates, average emissions per engine per year, with the engine population.

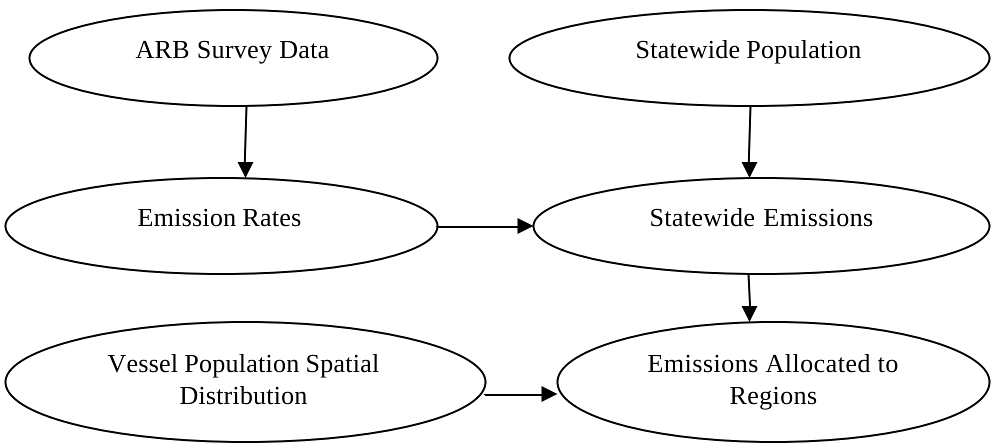
The data described in the previous section were feed into a database driven harbor craft emissions estimation model. The model estimates vessel type specific emission rates

[7] SO_2 will be estimated using the percent sulfur found in the different types of diesel fuel used statewide and estimated fuel consumption. This methodology is described in section B.2.

based on survey data and scales up to the statewide population. The model is able to project future year emissions by taking into account fleet growth, engine deterioration, the change of emission standards, and other factors.

Figure II-2 shows the relationship among the elements of the model. Emissions are estimated based on engine population and emission rates. Engine population is estimated based on vessel population and the average number of engines per vessel. Vessel population is estimated based on base year fleet population and growth rates.

Figure II-2 Illustration of the Commercial Harbor Emission Estimation Methodology



Future engine data are based on the base year engine data collected in the ARB survey, the growth rates, and attrition rates. The methodology also accounts for the impacts of regulations on engine emission factors and engine turnover rates. These projections reflect expected growth rates in the commercial harbor craft populations, changes in emission factors over time as the new engine standards are implemented, and the fleet turnover, and proposed regulations.

2. SOx Emission Estimation

We used a fuel-based methodology to estimate SOx emissions from commercial harbor craft. We first estimated annual fuel consumption of individual engines based on the following equation.

$$F_C = HP \times LF \times Hr \times BSFC$$

Where

Fc is fuel consumed per engine per year;
HP is rated horsepower of the engine;
Hr is the number of annual operating hours of the engine;

LF is the load factor;
LF is the vessel type specific engine load factor;
BSFC is brake specific fuel consumption rate; we used 0.078 gal/kW-hr or 184 g/hp-hr estimated from manufacturers' marine engine data.

We then converted fuel consumption to SOx emissions based on mass based sulfur content of fuels. We assumed that 1) fuel consumption rate is constant over time; 2) all (100%) sulfur is emitted as SO_2; 3) SO_2 emission rate is a function of fuel consumption and sulfur content only; and 4) SO_2 emission rate is not subject to engine deterioration.

Sulfur content will be vessel type and air district specific before calendar year 2007, when all California commercial harbor craft are required to use ultra low sulfur fuel with 15 ppm sulfur. We assumed all commercial craft use EPA on-road diesel with 330 ppm sulfur content before year 2007, except:

- In calendar years 2002-2007, ferries were required to use CARB diesel with 140 ppm sulfur. All commercial harbor craft fueling in the following districts receive CARB diesel: Mendocino, North Coast Unified, Northern Sonoma, and Tehama;
- From 2006, all south coast commercial harbor craft use ultra low sulfur fuel with 15 ppm sulfur.

3. Spatial Allocation

We allocated emissions to counties, air districts, and air basins based on where the home ports of the vessels are and/or where the activities occur using our best engineering judgment. We also split emissions between land side air basins and Outer Continental Shelf (OCS) air basins based on the ARB's Commercial Harbor Craft Survey which collected the percent of time vessels spend at varying distances from shore, including percent of time spent in harbor, within 0-25, 25-50, 50-75, 75-100, and beyond 100 nautical miles. The land side air basins cover the areas 3 nautical miles from shore and the Outer Continental Shelf air basin cover the areas 3-100 nautical miles from shore. Table II-6 summarizes the statewide average of percent of vessel activity at varying distances from shore by ship type.

Table II-6 Statewide Average of Percent of Vessel Activity at Varying Distances from Shore

Vessel Type	Harbor	0-25nm	25-50nm	50-75nm	75-100 nm	>100nm
Commercial Fishing	6%	37%	16%	11%	8%	22%
Charter Fishing	8%	40%	20%	19%	12%	0%
Ferries	51%	40%	6%	2%	1%	0%
Tow Boats	40%	22%	14%	9%	8%	7%
Tug Boats	34%	15%	12%	13%	20%	6%
Pilot Vessels	33%	30%	13%	10%	12%	1%
Work Boats	35%	32%	5%	10%	9%	8%
Crew and Supply	29%	27%	13%	11%	13%	8%
Others	30%	30%	12%	11%	10%	7%

Source: ARB Commercial Harbor Craft 2002 survey

Table II-7 summarizes the percent of time commercial harbor craft spend within land side air basins or the Outer Continental Shelf air basins based on the information collected in the ARB's Commercial Harbor Craft Survey.

Table II-7 Summary of Percent of Time Spent within Land Side Air Basins and Outer Continental Shelf Air Basins

Vessel Type	Land side Air Basin	Outer Continental Shelf Air Basin
Commercial Fishing	12%	88%
Charter Fishing	15%	85%
Ferries	59%	41%
Tow Boats	43%	57%
Tug Boats	36%	64%
Pilot Vessels	39%	61%
Work Boats	42%	58%
Crew and Supply	33%	67%
Others	35%	65%

We received several comments and suggestions to improve the spatial allocation. These comments reflected regional specific differences in vessel operations. According to Ventura County APCD, tug boats meet vessels one nautical mile from port and most emissions should be allocated to the land air basin. We believe there are tugs pushing barges transiting along the coast and these activities account for the emissions we allocated to the Outer Continental Shelf air basin. Ventura APCD suggests 36% of Crew & Supply vessel emissions occur within the South Central Coast air basin while 64% occur in the Outer Continental Shelf air basin. These numbers agree well with the statewide allocation in Table II-7.

Santa Barbara APCD suggests emissions from commercial boats are split evenly between the South Central Coast air basin and the Outer Continental Shelf air basin. We believe that this allocation sounds reasonable for commercial boats other than fishing vessels. This also agrees with the statewide allocation within acceptable range. Because we understand that most fishing activities occur beyond the 3 nautical mile zone, we assign more than 85% of fishing vessel emissions to the Outer Continental Shelf.

Considering the heavy marine traffic in the San Francisco air basin, we conducted additional analysis to allocate emissions within the Bay Area Air Quality Management District (BAAQMD). We allocate 84% of commercial fishing and charter fishing vessel emissions to the OCS air basin, and allocate the remaining 16% to the San Francisco air basin; we allocate tow boat emissions following the statewide default to reflect the inter-port long haul activity; we allocate 5% of emissions from all the other type of vessels to the OCS air basin, and allocate the remaining 95% to the San Francisco air basin.

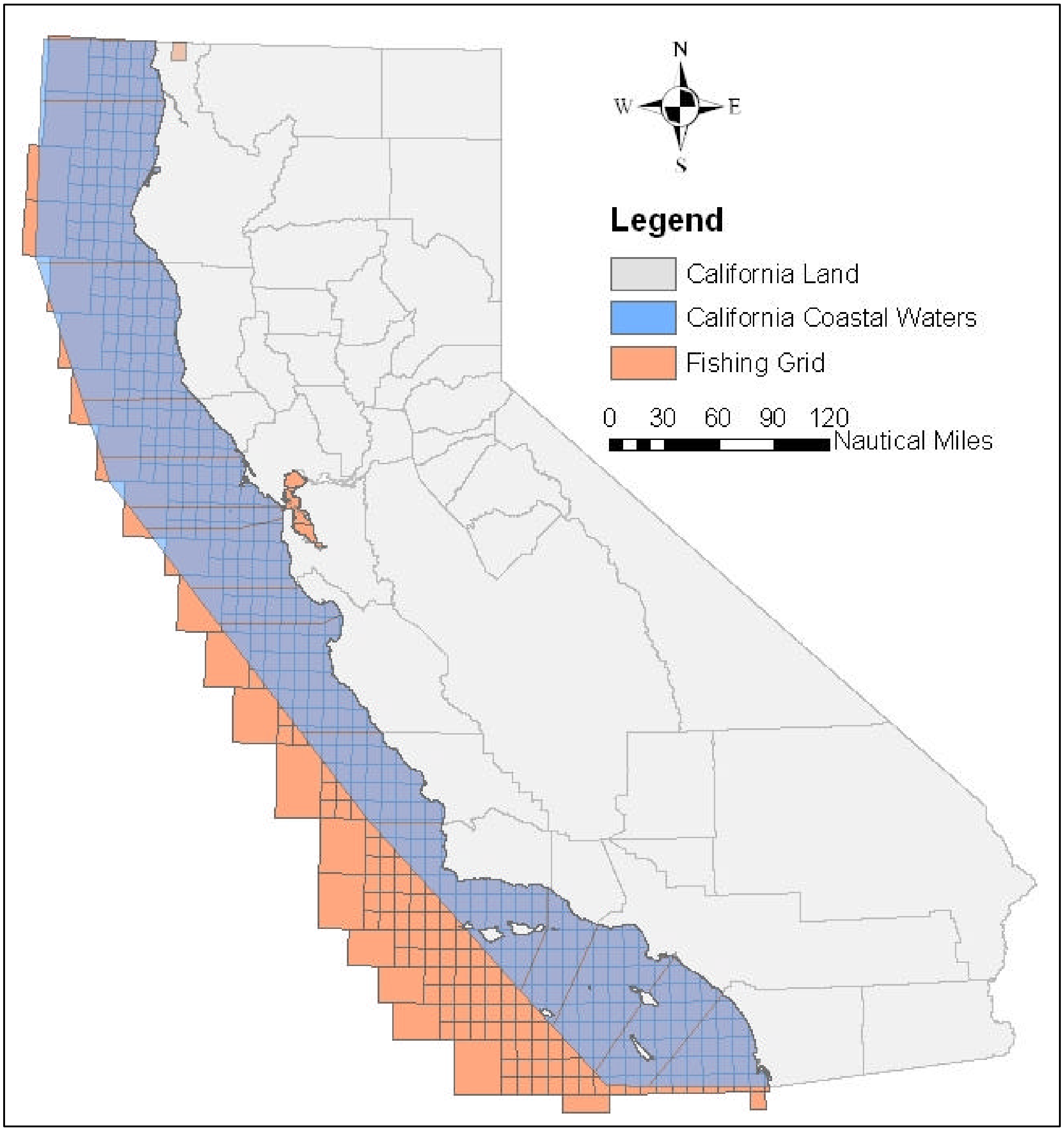
4. Additional Considerations and Assumptions

a. Operation in California Coastal Waters

The emission estimation methodology assumes all of the hours of operation occur within the boundaries defined by the California Coastal Waters. The two vessel types that might deviate from this assumption would be commercial fishing and charter fishing vessels. In an effort to address the issue as it pertains to those two types of commercial harbor craft, the ARB staff contacted the California Department of Fish and Game (DFG) and requested information about the region off California where fishing primarily occurs. The DFG segregates the waters off the coast of California into 10 minute by 10 minute grid system in an effort to track the types and quantities of marine resources taken off the California coast and landed at California's ports and harbors. Comparison of the DFG grid system with the ARB's definition of "California Coastal Waters" reveals that for the majority of the coastline, the DGF Fisheries Charts were within California Coastal Water boundaries. The results of that comparison are illustrated in Figure II-3.

We noticed an area of the DFG Fisheries Charts associated with the waters west of the Catalina Islands that lie outside California's Coastal Waters. ARB staff evaluated the DFG 2002 landings data and found that the resources caught in that area amounted to less than one percent of the total 2002 landings for the counties associated with those waters (Santa Cruz, Monterey, San Luis Obispo, Santa Barbara, Ventura, Los Angeles, Orange, and San Diego). With that being the case, the ARB determined that it would make little or no difference in the emission estimates to continue to include emissions from commercial fishing vessels and charter fishing vessels associated with that area.

Figure II-3 The Overlap Between the California Department of Fish and Game's Fish Landings Grid System and the ARB's "California Coastal Waters"



b. Fuel Type

The emission estimation methodology assumes all commercial harbor craft engines are powered by diesel fuel. During the course of reviewing and collating the responses to the ARB's Commercial Harbor Craft Survey, the ARB staff noticed that the percentage of vessel owner/operators that indicated they use gasoline as the primary fuel for their propulsion or auxiliary engines was less than five percent of all engines reported. When preparing the Survey data for use to typify commercial harbor craft engines, the ARB staff removed any engines that were clearly powered by gasoline.

c. Vessel Profile and Future Improvements

The ARB's Commercial Harbor Craft Survey collected information for about 850 vessels which represent about 20% of the statewide population. The emission methodology assumes the results of the Survey are representative of California's commercial harbor craft and used these profiles to scale up to statewide population.

ARB's proposed commercial harbor craft regulation will require vessel owners and operators to report more detailed information of the vessels and the engines. We will build a more complete and more reliable California commercial harbor craft data set which will provide a foundation for us to improve the emissions estimation in the future.

III. EMISSION ESTIMATES

Using the proposed methodology, we estimate statewide emissions from commercial harbor craft diesel-fueled engines in 2004 were about 3.3 tons per day of diesel PM, about 73.2 tons per day of oxides of nitrogen (NOx). Detailed emission estimates are presented in Table III-1.

Table III-1 Commercial Harbor Craft Emissions in California in 2004 (Tons/day)

Vessel Type	Vessel Population	NOx	PM	ROG	CO
Charter Fishing	563	12.7	0.6	0.9	3.3
Commercial Fishing	2,727	17.4	0.8	1.3	4.8
Crew and Supply	64	1.4	0.1	0.1	0.4
Ferry/Excursion	416	21.0	0.9	1.4	5.6
Pilot Vessels	27	0.4	0.0	0.0	0.1
Tow Boats	35	3.0	0.1	0.2	0.7
Tug Boats	128	15.3	0.6	1.0	3.8
Work Boats	89	0.5	0.0	0.0	0.1
Others	136	1.5	0.1	0.1	0.4
Total	4,185	73.2	3.3	5.0	19.2

Ferry/excursion vessels and tug/tow boats jointly account for about 14% of the statewide harbor craft population and 50% of the statewide harbor craft emissions. The engines of these vessels are relatively larger and operate more often than other vessel categories. Commercial fishing vessels account for 65% of the harbor craft population but only emit around 25% of the emissions.

Table III-2 provides NOx emissions by engine and vessel type. Propulsion engines account for 93% of NOx emissions from commercial harbor craft.

Table III-2 NOx Emissions By Engine Type and Vessel Type in 2004

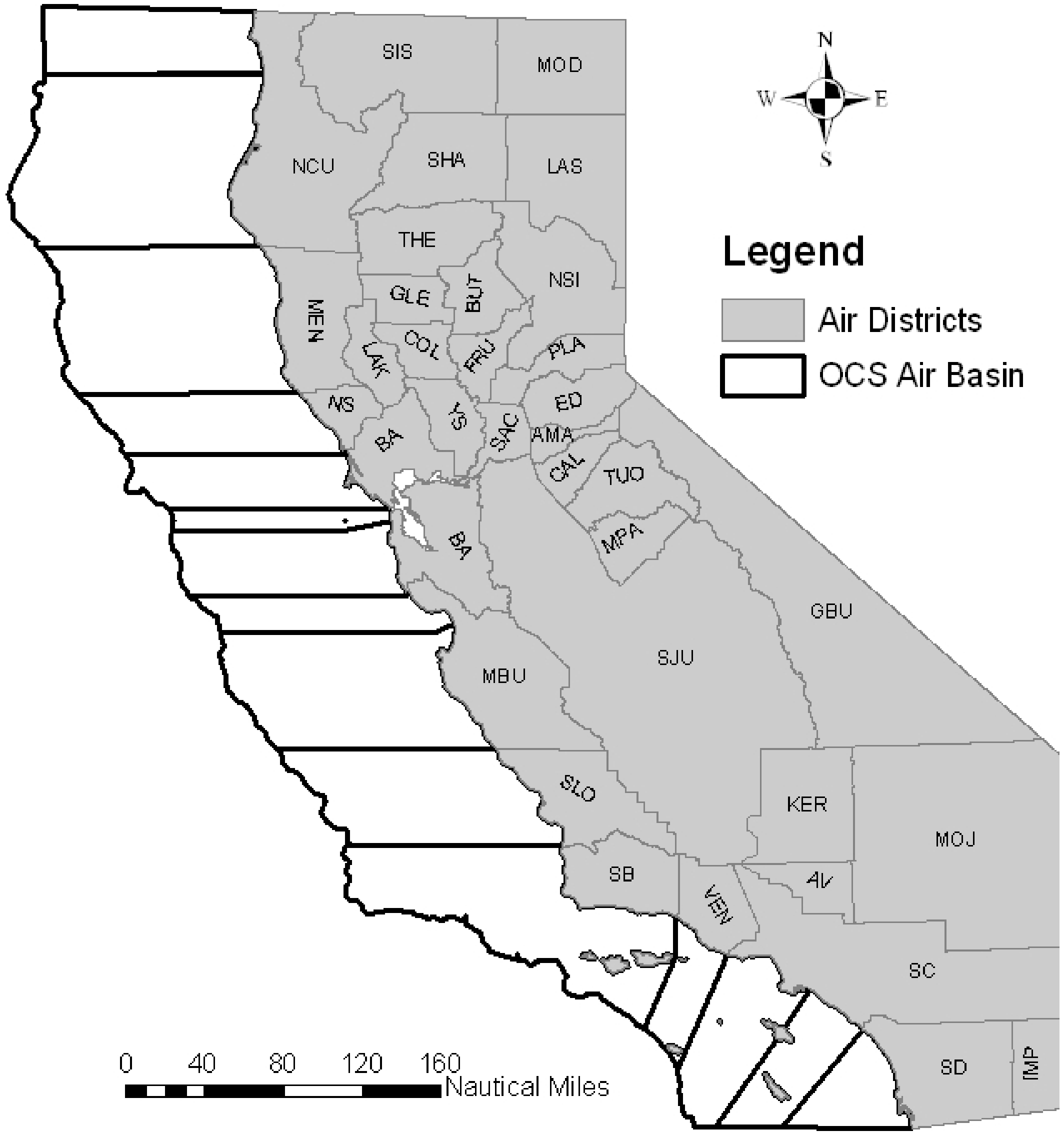
	Main Engine		Auxiliary Engine	
Vessel Type	Number of Engines	Tons/day NOx	Number of Engines	Tons/day NOx
Charter Fishing	997	12.1	422	0.6
Commercial Fishing	3,054	14.8	1,254	2.6
Crew and Supply	160	1.1	70	0.4
Ferry/Excursion	836	20.2	512	0.8
Pilot Vessels	46	0.4	4	0.0
Tow Boats	74	2.8	41	0.2
Tug Boats	246	14.9	204	0.4
Work Boats	130	0.5	28	0.0
Others	151	1.4	63	0.1
Total	5,693	68.1	2,598	5.1

Table III-3 summarizes NOx and PM emissions by Air Quality Management District (AQMD) or Air Pollution Control District (APCD) and Outer Continental Shelf (OCS) air basin in calendar year 2004. The AQMDs and APCDs are commonly called air districts. OCS air basin covers 3-100 nautical miles from shore. Figure III-1 illustrates these air districts and OCS air basins.

Table III-3 NOx, PM Emissions By Air District and Air Basin in 2004

Air Districts		Number of Vessels	NOx Tons/year	NOx in OCS	PM Tons/day	PM in OCS
Bay Area AQMD	(BA)	1,468	26.9	10.2	1.2	0.5
El Dorado County APCD	(ED)	9	0.3	0.0	0.0	0.0
Mendocino County AQMD	(MEN)	169	1.3	1.1	0.1	0.0
Monterey Bay Unified APCD	(MBU)	379	3.6	2.7	0.2	0.1
North Coast Unified APCD	(NCU)	299	2.3	1.9	0.1	0.1
Northern Sonoma County APCD	(NS)	145	1.2	1.0	0.1	0.0
Placer County APCD	(PLA)	9	0.3	0.0	0.0	0.0
San Diego County APCD	(SD)	307	9.2	5.5	0.4	0.2
San Joaquin Valley Unified APCD	(SJU)	43	0.8	0.0	0.0	0.0
San Luis Obispo County APCD	(SLO)	145	1.4	1.1	0.1	0.1
Santa Barbara County APCD	(SB)	193	2.7	2.0	0.1	0.1
South Coast AQMD	(SC)	745	18.7	11.7	0.8	0.5
Ventura County APCD	(VEN)	194	2.5	1.8	0.1	0.1
Yolo/Solano AQMD	(YS)	81	1.9	0.0	0.1	0.0
Total		4,185	73.2	38.9	3.3	1.8

Figure III-1 Illustration of California Air Districts and OCS Air Basins

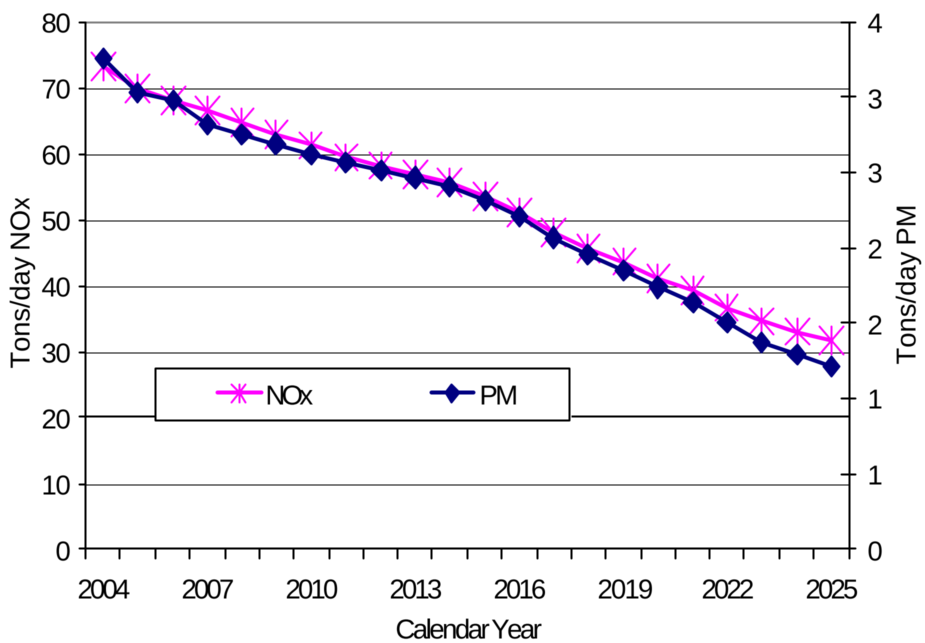


About one third of the state harbor craft are in the Bay Area AQMD. These vessels account for about 37% of statewide NOx or PM emissions. South Coast AQMD has 18% of the statewide harbor craft and account for about 26% of the NOx or PM emissions. San Diego County APCD only has 7% of the statewide population but these vessels emitted about 12% of statewide harbor craft NOx or PM emissions. These three air districts jointly are home to 60% of the statewide harbor craft and these vessels are responsible for 75% of statewide NOx or PM emissions.

Statewide about 53% of the emissions occur in the Outer Continental Shelf air basin. Generally fishing vessels spend the most time in the Outer Continental Shelf, while ferries tend to spend the most time closer to shore.

Figure III-2 illustrates the change of commercial harbor craft NOx and PM emissions over time from 2004 to 2025. NOx emissions from harbor craft in California will decrease from 73 tons per day in 2004 to about 32 tons per day in 2025 and PM emissions will decrease from 3.3 tons per day to about 1.2 tons during the same period. The decline of emissions between 2004 and 2009 is partially caused by the decline of the fishing fleet from 2004 to 2009 as we project based on fish landing data, natural engine turnover, and the more stringent EPA marine engine emissions standards. New engines need to comply with EPA standards and are cleaner than the old engines which are replaced. The decrease in emissions after 2009 reflects the gradual phase in of new engines replacing old engines retired from the fleet.

Figure III-2 Estimation of Commercial Harbor Craft NOx, PM Emissions 2004-2025



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APPENDIX A COMMERCIAL HARBOR CRAFT EMISSION FACTOR TABLE

HP Range	Model Year	ME NOx	ME PM	ME ROG	ME CO	AE NOx	AE PM	AE ROG	AE CO
25-50 hp	pre-1998	8.14	0.72	1.84	3.65	6.90	0.64	2.19	5.15
	1998-1999	8.14	0.72	1.80	3.65	6.90	0.64	2.14	5.15
	2000-2004	7.31	0.72	1.80	3.65	6.90	0.64	2.14	5.15
	2005-2008	5.32	0.30	1.80	3.73	5.32	0.30	2.14	3.73
	2009-2020	5.32	0.22	1.80	3.73	5.32	0.22	2.14	3.73
51-120 hp	pre-1997	15.34	0.80	1.44	3.50	13.00	0.71	1.71	4.94
	1997-1999	10.33	0.66	0.99	2.55	8.75	0.58	1.18	3.59
	2000-2004	7.31	0.66	0.99	2.55	7.31	0.58	1.18	3.59
	2005-2008	5.32	0.30	0.99	3.73	5.32	0.30	1.18	3.73
	2009-2020	5.32	0.22	0.99	3.73	5.32	0.22	1.18	3.73
121-175 hp	pre-1971	16.52	0.73	1.32	3.21	14.00	0.65	1.57	4.53
	1971-1978	15.34	0.63	1.10	3.21	13.00	0.55	1.31	4.53
	1979-1983	14.16	0.52	1.00	3.21	12.00	0.46	1.19	4.53
	1984-1986	12.98	0.52	0.94	3.14	11.00	0.46	1.12	4.43
	1987-1995	12.98	0.52	0.88	3.07	11.00	0.46	1.05	4.33
	1996-1999	9.64	0.36	0.68	1.97	8.17	0.32	0.81	2.78
	2000-2003	7.31	0.36	0.68	1.97	7.31	0.32	0.81	2.78
	2004-2012	5.10	0.22	0.68	3.73	5.10	0.22	0.81	3.73
	2013-2020	3.80	0.09	0.68	3.73	3.80	0.09	0.81	3.73
176-250 hp	pre-1971	16.52	0.73	1.32	3.21	14.00	0.65	1.57	4.53
	1971-1978	15.34	0.63	1.10	3.21	13.00	0.55	1.31	4.53
	1979-1983	14.16	0.52	1.00	3.21	12.00	0.46	1.19	4.53
	1984-1986	12.98	0.52	0.94	3.14	11.00	0.46	1.12	4.43
	1987-1994	12.98	0.52	0.88	3.07	11.00	0.46	1.05	4.33
	1995-1999	9.64	0.36	0.68	1.97	8.17	0.32	0.81	2.78
	2000-2003	7.31	0.36	0.68	1.97	7.31	0.32	0.81	2.78
	2004-2013	5.10	0.15	0.68	3.73	5.10	0.15	0.81	3.73
	2014-2020	3.99	0.08	0.68	3.73	3.99	0.08	0.81	3.73
251-500 hp	pre-1971	16.52	0.70	1.26	3.07	14.00	0.62	1.50	4.33
	1971-1978	15.34	0.60	1.05	3.07	13.00	0.53	1.25	4.33
	1979-1983	14.16	0.50	0.95	3.07	12.00	0.45	1.13	4.33
	1984-1986	12.98	0.50	0.90	3.07	11.00	0.45	1.07	4.33
	1987-1994	12.98	0.50	0.84	2.99	11.00	0.45	1.00	4.22
	1995-1999	9.64	0.36	0.68	1.97	8.17	0.32	0.81	2.78
	2000-2003	7.31	0.36	0.68	1.97	7.31	0.32	0.81	2.78
	2004-2013	5.10	0.15	0.68	3.73	5.10	0.15	0.81	3.73
	2014-2020	3.99	0.08	0.68	3.73	3.99	0.08	0.81	3.73

Continued from previous page

HP Range	Model Year	ME NOx	ME PM	ME ROG	ME CO	AE NOx	AE PM	AE ROG	AE CO
501-750 hp	pre-1971	16.52	0.70	1.26	3.07	14.00	0.62	1.50	4.33
	1971-1978	15.34	0.60	1.05	3.07	13.00	0.53	1.25	4.33
	1979-1983	14.16	0.50	0.95	3.07	12.00	0.45	1.13	4.33
	1984-1986	12.98	0.50	0.90	3.07	11.00	0.45	1.07	4.33
	1987-1994	12.98	0.50	0.84	2.99	11.00	0.45	1.00	4.22
	1995-1999	9.64	0.36	0.68	1.97	8.17	0.32	0.81	2.78
	2000-2006	7.31	0.36	0.68	1.97	7.31	0.32	0.81	2.78
	2007-2012	5.10	0.15	0.68	3.73	5.10	0.15	0.81	3.73
	2013-2020	3.99	0.08	0.68	3.73	3.99	0.08	0.81	3.73
751-1900 hp	pre-1971	16.52	0.70	1.26	3.07	14.00	0.62	1.50	4.33
	1971-1978	15.34	0.60	1.05	3.07	13.00	0.53	1.25	4.33
	1979-1983	14.16	0.50	0.95	3.07	12.00	0.45	1.13	4.33
	1984-1986	12.98	0.50	0.90	3.07	11.00	0.45	1.07	4.33
	1987-1998	12.98	0.50	0.84	2.99	11.00	0.45	1.00	4.22
	1999	9.64	0.36	0.68	1.97	8.17	0.32	0.81	2.78
	2000-2006	7.31	0.36	0.68	1.97	7.31	0.32	0.81	2.78
	2007-2011	5.53	0.20	0.68	3.73	5.53	0.20	0.81	3.73
	2012-2016	4.09	0.08	0.68	3.73	4.09	0.08	0.81	3.73
	2017-2020	1.30	0.03	0.18	3.73	1.30	0.03	0.18	3.73
1901-3300 hp	pre-1971	16.52	0.70	1.26	3.07	14.00	0.62	1.50	4.33
	1971-1978	15.34	0.60	1.05	3.07	13.00	0.53	1.25	4.33
	1979-1983	14.16	0.50	0.95	3.07	12.00	0.45	1.13	4.33
	1984-1986	12.98	0.50	0.90	3.07	11.00	0.45	1.07	4.33
	1987-1998	12.98	0.50	0.84	2.99	11.00	0.45	1.00	4.22
	1999	9.64	0.36	0.68	1.97	8.17	0.32	0.81	2.78
	2000-2006	7.31	0.36	0.68	1.97	7.31	0.32	0.81	2.78
	2007-2012	5.53	0.20	0.68	3.73	5.53	0.20	0.81	3.73
	2013-2015	4.37	0.10	0.68	3.73	4.37	0.10	0.81	3.73
	2016-2020	1.30	0.03	0.18	3.73	1.30	0.03	0.18	3.73
3301-5000 hp	pre-1971	16.52	0.70	1.26	3.07	14.00	0.62	1.50	4.33
	1971-1978	15.34	0.60	1.05	3.07	13.00	0.53	1.25	4.33
	1979-1983	14.16	0.50	0.95	3.07	12.00	0.45	1.13	4.33
	1984-1986	12.98	0.50	0.90	3.07	11.00	0.45	1.07	4.33
	1987-1998	12.98	0.50	0.84	2.99	11.00	0.45	1.00	4.22
	1999	9.64	0.36	0.68	1.97	8.17	0.32	0.81	2.78
	2000-2006	7.31	0.36	0.68	1.97	7.31	0.32	0.81	2.78
	2007-2013	5.53	0.20	0.68	3.73	5.53	0.20	0.81	3.73
	2014-2015	4.94	0.25	0.68	3.73	4.94	0.25	0.81	3.75
	2016-2020	1.30	0.03	0.18	3.73	1.30	0.03	0.18	3.75