Appendix C

Emission Inventory Methodology

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Appendix C

Updates on the Emissions Inventory for Commercial Harbor Craft Operating in California

1. INTRODUCTION

This section provides background on ARB's commercial harbor craft (CHC) emissions inventory, the purposes and goals in updating the emissions inventory, and a general overview of the updates made to the emissions inventory.

In 2007, ARB staff developed an updated CHC emissions inventory (2007 emissions inventory) using a consistent statewide methodology. This emissions inventory was used to support the regulatory analysis of the *Regulations to Reduce Emissions from Diesel Engines on Commercial Harbor Craft Operated Within California Waters and 24 Nautical Miles of the California Baseline* (harbor craft regulation), which was adopted on November 15, 2007 by the Air Resources Board. CHC are grouped into nine vessel types, including ferry and excursion vessels, tow boats, tug boats, pilot vessels, work boats, crew and supply vessels, commercial fishing vessels, charter fishing vessels, and other types of vessels that do not fit into the above eight categories.

The 2007 emissions inventory was based on the best information and best methodology available to ARB staff at the time the inventory was developed. Since there was no single data set that covered all CHC 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, and information from recent emission inventory estimates generated for the Port of Los Angeles. Staff estimated that there were about 4,200 CHC vessels operating in California in year 2004. Vessel and engine profiles, including vessel and engine type, age, size, annual hours of operation, annual fuel use etc., were developed based on ARB's survey that collected information for about 850 vessels, about 20 percent of the statewide CHC population. Future year emissions were forecasted based on estimated vessel/engine activity growth and estimated future engine age profiles. Emissions factors accounted for fuel sulfur content and increasing emission rates with engine age and use.

The proposed amendments to ARB's CHC regulation focus on crew and supply vessels; and barge and dredge vessels operating in California. To support the regulatory analysis of the amendments, staff updated the crew and supply vessel emissions inventory using 2009 initial reporting data and developed the barge and dredge vessel emissions inventory using 2009 survey information.

Vessel and engine data were reported to ARB in 2009 in compliance with ARB's 2007 CHC regulation. Many more engines and much more information were included in the reporting database than the information collected in the 2004 ARB survey. The reporting database virtually covers all crew and supply vessels operated in California. This offers ARB staff an opportunity to update crew and supply vessel emissions inventory with better and more complete data. The updated inventory has been used to support the regulatory analysis of the amendments to the ARB's CHC regulation. While the fundamental emissions estimation methodology is largely unchanged from the methodology used for the 2007 emissions inventory, the reporting data were used to update vessel and engine population, activity, engine useful life, and engine load.

Currently, barge and dredge vessels are not regulated under the ARB's CHC regulation. In 2009, ARB staff conducted a survey to collect information on barges and dredges operated in California. A preliminary emissions inventory was developed to support the inclusion of barge and dredge vessels in the CHC regulation.

2. METHODOLGY

The fundamental methodology remains unchanged from the methodology used for the 2007 emissions inventory except for the changes described in this section. The methodology documentation for the 2007 emissions inventory can be downloaded at: http://www.arb.ca.gov/regact/2007/chc07/appb.pdf.

The basic equation for the estimating PM and NOx 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 (PM and NOx) emitted during one period;
EF_0 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.

DATA SOURCE OVERVIEW

Statewide, about 21 vessel owner/operators reported information for about 70 crew and supply vessels with 163 propulsion engines and 73 auxiliary engines. Staff believes nearly 100 percent of crew and supply vessels operating in California waters are included in the reporting data set. Reporting data were generally consistent with estimates derived from the 2004 survey.

ARB's reporting data set includes vessel and engine information like vessel name, vessel owner, operator, home port, vessel use, engine model year, engine use, engine model, engine horsepower, engine annual fuel use, engine annual hours of operation. The information is complete for most vessels and engines. Staff believes that ARB's CHC reporting data set is the best currently available single data source for estimating emissions from crew and supply vessels operating in California. Staff decided to use the reporting data set to update ARB's crew and supply vessel emissions inventory. ARB staff made follow-up phone calls to clarify information not in the reporting data. Staff also obtained additional information on where vessels operate.

Staff also conducted a survey in 2009 to collect information on barge and dredge vessels operating in California waters. Information for about 400 auxiliary engines, and less than 10 propulsion engines was collected, representing nearly 100 percent of the statewide population of the equipment. Most barge and dredge vessels are not self-propelled and most of the engines are off-road engines for auxiliary purposes such as generating electricity, powering pumps, winches, cranes, etc. Information collected in the barge and dredge vessel survey is similar to the crew and supply vessel information reported to ARB, such as vessel name, vessel use, engine model year, engine horse power, engine annual hours of operation, and engine annual fuel use, etc. Staff developed a statewide barge and dredge vessel emissions inventory based on the information collected from the survey.

CREW AND SUPPLY VESSEL EMISSIONS ESTIMATION

Crew and Supply Vessel Population

There are about 70 crew and supply vessels with 163 propulsion engines and 73 auxiliary engines in the reporting data set with valid data. Based on the information ARB staff had, it was assumed 100 percent of crew and supply vessels operated in California in 2008 reported to ARB in compliance with the ARB's CHC regulation.

Because the reporting data are complete, staff was able to estimate emissions for each individual engine and each individual vessel operating in California and to aggregate the emissions to generate a statewide emissions inventory.

Crew and Supply Vessel Engine Hours of Operation and Engine Load

Analysis of the reporting data indicates that crew and supply vessel engines operate at a lower load with longer hours for propulsion engine than previously estimated. Table 1 and Table 2 compare average hours of operation and engine load for the ARB 2004 survey and 2009 reporting data set.

Table1: Crew and Supply Vessel Engine Hours of Operation

	2004 Survey Data	2009 Reporting Data	% Changed
Propulsion Engine	752	1,796	139%
Auxiliary Engine	3,321	2,265	-32%

Table 2: Crew and Supply Vessel Engine Load

	2004 Survey Data	2009 Reporting Data	% Changed
Propulsion Engine	0.45	0.38	-15%
Auxiliary Engine	0.43	0.32	-27%

The 2009 reporting data load factors are estimated as the average engine load weighted by engine horsepower and annual hours of operation. Large engines operating longer hours have more weight on the load factor. The new load factors are about15 percent and 27 percent lower than the load factors derived from the 2004 survey data for propulsion and auxiliary engines, respectively.

Crew and Supply Vessel Useful Life

Staff defines engine useful life as the age when 50 percent of engines retire from the fleet and 100 percent of engines are assumed to retire at the age of two useful lives. Based on comments from vessel owner/operators that marine engines are maintained very well because of the high capital costs, ARB staff assumed a 28 year of useful life for crew and supply vessel engines. Extending useful life from 22 as previously assumed to 28 years has a minor impact on emissions estimates.

Adjusting Crew and Supply Vessel Emission Rates Using Source Testing Data

The Santa Barbara County Air Pollution Control District (APCD) maintains a permitting program to reduce emissions from crew and supply vessels visiting offshore oil platforms in Santa Barbara County. Based on the requirements in the sample permits provided by the Santa Barbara County APCD, crew and supply vessels serving the oil platforms are required to achieve a NOx emissions rate of 8.4 g/bhp-hr for main engines using a combination of turbo-charging, enhanced inter-cooling, and 4 degrees timing retard and to achieve 5.99 g/bhp-hr for other vessels with newer engines. Most vessels

serving oil platforms in Santa Barbara County, including those vessels transiting in Ventura County APCD, have some degree of NOx control for main engines to achieve the target emission rates required by the permits.

Under the permits, at least one crew and one supply vessel must be tested per year per platform. The tests are performed at cruise load. Most of the crew and supply vessels that operate in Santa Barbara County waters have been tested at some time. Emission source testing data were used by the districts to estimate emissions from crew and supply vessels.

Staff obtained source test data from Santa Barbara County APCD. The average NOx emission rates of the 287 valid engine testing records is about 239 lb/1000 gallon fuel or about 6.3 grams/hp-hr. Staff used this number to adjust emission rates of engines that have emission control technology information in ARB's reporting data set and the emission rates of engines operating in Santa Barbara County APCD.

PM is not tested in the source tests. Therefore, based on engineering judgement, staff estimated a 10 percent PM emissions disbenefit due to NOx reduction strategies.

Crew and Supply Vessel Emissions Spatial Allocation

Based on phone conversations with vessel owner/operators, staff understands most vessels operate close to where their home ports are while several vessels operate in areas away from their home ports. For example, some vessels home-ported in Huntington Beach operate most of their time in Santa Barbara County or Ventura County. Supply vessels serving oil platforms in Santa Barbara County are too big to be home-ported in Santa Barbara County and these vessels have to transit from Port Hueneme in Ventura County to oil platforms in Santa Barbara County. Staff developed spatial allocation factors for each engine based on vessel home port and the percentage of time spent in each air district.

BARGE AND DREDGE EMISSIONS ESTIMATION

ARB staff collected information for about 400 auxiliary engines and less than ten propulsion engines used on barge and dredge vessels operating in California waters. Information collected in the barge and dredge vessel survey includes vessel name, vessel use, engine model year, engine horse power, engine annual hours of operation, and engine annual fuel use, etc. In cases when data fields in the survey are missing, staff filled missing information using average of available information by engine use.

Since most barges and dredges are non-self-propelled and most of the engines are off-road engines for auxiliary purposes such as generating electricity, powering pumps, winches, cranes, etc, staff used emission factors from OFFROAD model as the zero-hour emission factors and used OFFROAD fuel consumption rate to estimate barge and dredge fuel use. The OFFROAD is a model used to generate emissions inventory data for off-road mobile sources. The major categories of engines and vehicles included in

OFFROAD2007 are agricultural, construction, lawn and garden and off-road recreation, and equipment from hedge trimmers to cranes. More information about the OFFORAD model can be found at http://www.arb.ca.gov/msei/offroad/offroad.htm.

Staff estimated barge and dredge vessel engine load factors using engine horsepower, engine annual fuel use and annual hours of operation for each engine use category. Staff defined engine useful life as half of the age of the oldest engine by engine use. When the information is not available or there are too few data points to perform a valid analysis for certain engine use categories, staff used engine load or useful life of the same engine use in the OFFROAD model. Table 3 shows barge and dredge vessel engine load, useful life and data sources for this inventory.

Table 3: Barge and Dredge Vessel Engine Load, Useful Life

Engine Use	Engine Load	Data Source	Engine Useful Life	Data Source
Compressor	0.54	Survey	19.5	Survey
Crane	0.42	Survey	9.0	OFFROAD
Deck door engine	0.89	Survey	16.0	OFFROAD
Dredger	0.51	OFFROAD	16.0	OFFROAD
Generator	0.75	Survey	22.5	Survey
Hoist swing winch	0.31	Survey	27.0	Survey
Other	0.80	Survey	16.0	OFFROAD
Pump	0.71	Survey	21.0	Survey
propulsion	0.45	Survey	17.0	Survey

EMISSION FORECASTING

Based on discussions with vessel owner/operators, staff believes that both crew and supply vessel activity; and barge and dredge vessel activity will remain relatively constant in the future. As a result, staff assumed no growth for crew and supply vessel or barge and dredge vessel activity through 2025.

ESTIMATION OF BENEFITS OF THE PROPOSED AMENDMENTS

The proposed amendments of ARB's harbor craft regulation require existing engines onboard crew and supply vessels; and barges and dredges to be repowered with the current model year engines if the engines meet the model year and hours of operation criteria prescribed in Table 16 and Table 17 of the Staff report of the amendments. Staff assumed that new engines used to replace the existing engines have the same horsepower and the same operation pattern, i.e. hours of operation and location, as the existing engines. The new engines are cleaner than the old engines being replaced because of the more stringent emissions standards and less engine deterioration which increases as engines age.

Staff estimated emissions from these new engines using the same methodology described above. Staff estimated the emissions reduction benefits by subtracting the new model year emissions from the engines being replaced. Staff noticed there are more emission reductions in some years than others. The amount of emission reduction at a given calendar year is a function of the age distribution, horsepower, hours of operation of the fleet, and the compliance schedule.

2. EMISSION ESTIMATES

This section summarizes the updated crew and supply vessel emission estimates, barge and dredge vessel emissions estimates. This section also provides a summary of the comparison with previous crew and supply vessel emissions inventory and the comparison with independent emissions estimates by the Santa Barbara County APCD, the Ventura County APCD, and the Port of Los Angeles and the Port of Long Beach.

CREW AND SUPPLY VESSEL EMISSIONS

Crew and Supply Vessel Emission Estimates and Comparison with Previous Emissions Inventory

Figure 1 and Figure 2 compare the updated crew and supply vessel NOx and PM emissions estimates for years 2008 through 2025 using ARB's reporting data and the previous 2007 emissions inventory based on ARB's 2004 survey. The comparison shows that the 2010 crew and supply vessel emissions inventory (2008 as base year) are significantly higher than the 2007 emissions inventory (2004 as base year).

Figure 1: NOx Emissions from Crew and Supply Vessels in California

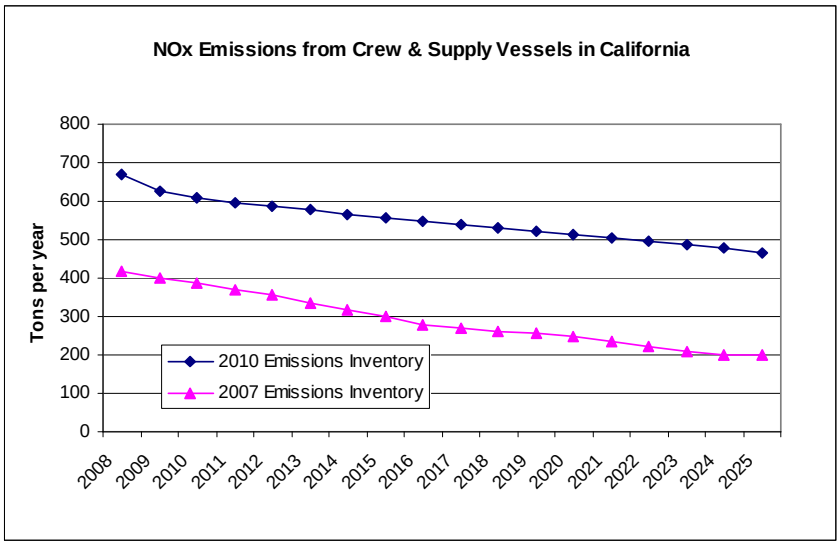
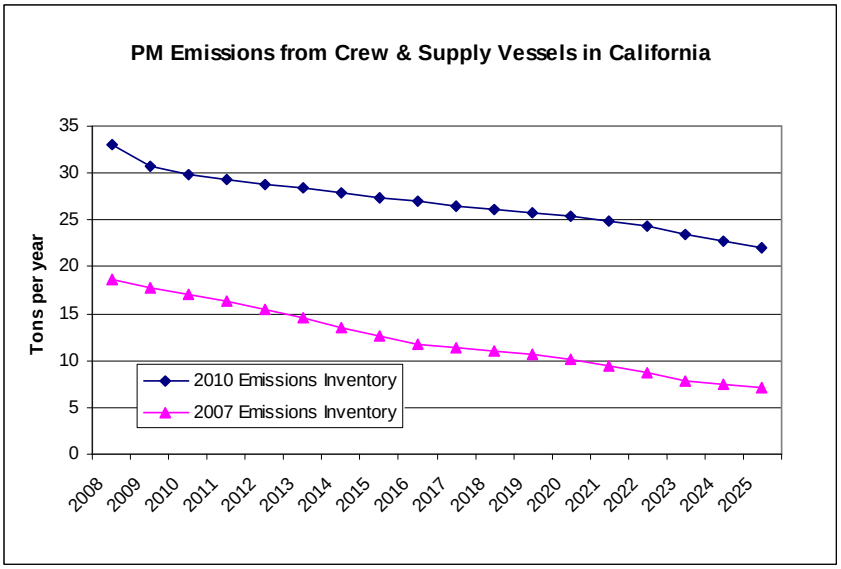


Figure 2: Diesel PM Emissions from Crew and Supply Vessels in California



Crew and Supply Vessel Emission Estimates by the Districts

Table 4 summarizes crew and supply vessels emissions estimates by the districts. More than 90 percent of statewide crew and supply vessel emissions occurred in the South Coast AQMD, Santa Barbara County, and Ventura County districts in 2008 where most of the oil platforms are. Vessels in Santa Barbara County account for a larger percentage of PM emissions than NOx emissions because NOx emission control required by the permits.

Table 4: Crew and Supply Vessel Emission Estimates by Air Districts for Year 2008 (tons/year)

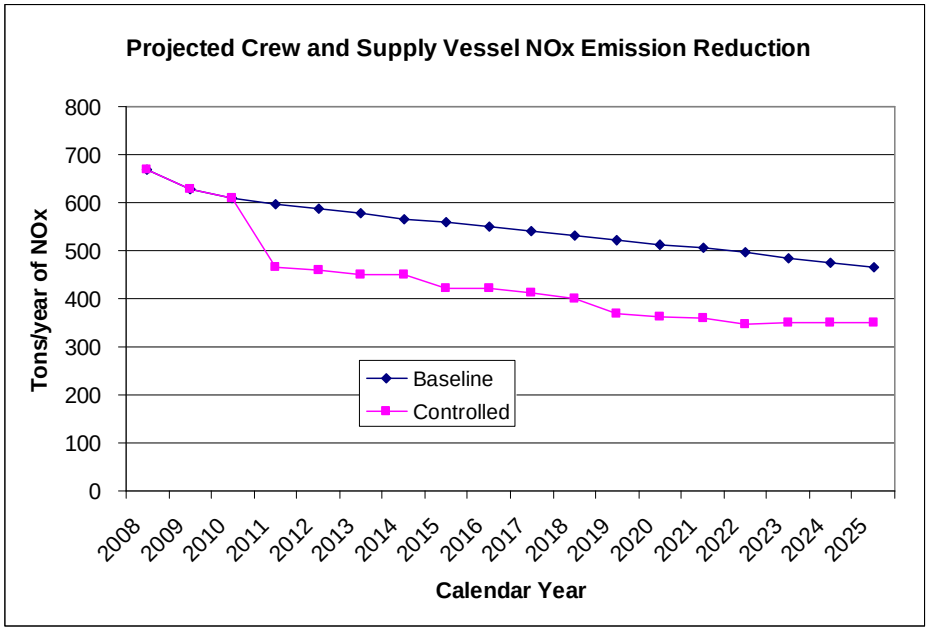
Air District	NOx	Percent of Total	PM	Percent of Total
BA	42.0	6%	1.4	4%
SB	138.2	21%	10.2	31%
SC	336.9	50%	14.4	44%
SD	11.3	2%	0.4	1%
VEN	140.8	21%	6.5	20%
Total	669.3	100%	33.0	100%

Crew and Supply Vessel Emission Reduction

The projected statewide annual emission reduction for crew and supply vessels is presented in Figures 3 and 4. Figure 3 shows that the projected statewide NOx emissions from and supply vessels are estimated to be about 670 tpy in 2008, dropping to about 466 tpy in 2025 without the proposed amendments. The reduction in uncontrolled emissions over this period is due to the anticipated or planned replacement

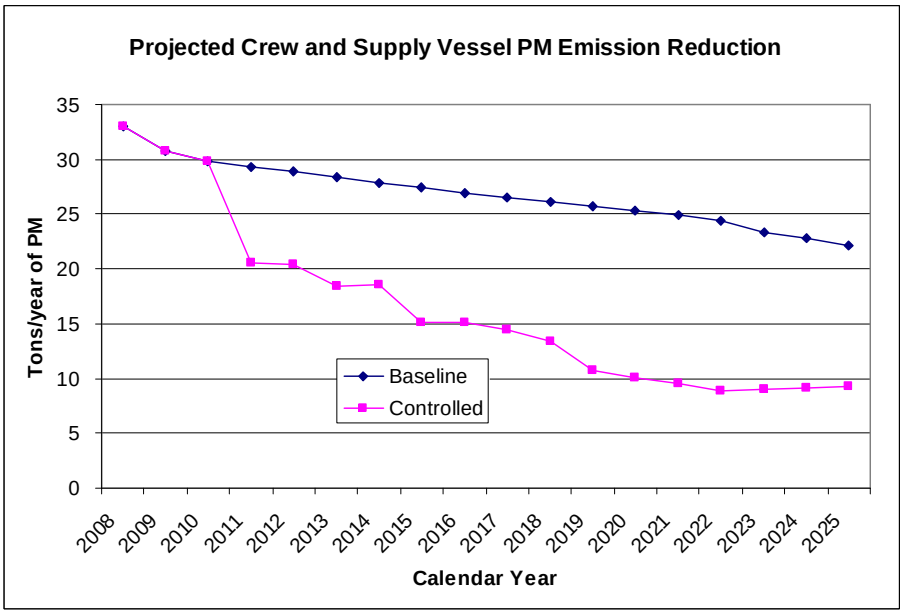
of older engines. With the proposed amendments in place, the NOx emissions would be further reduced from 466 tpy to about 350 tpy in 2025.

Figure 3: Projected Crew and Supply Vessel NOx Emission Reduction



Statewide, the baseline uncontrolled diesel PM emissions from crew and supply vessels are estimated to be about 33 tpy in 2008, dropping to about 22 tpy in 2025. With the proposed amendments in place accelerating engine turnover, would reduce diesel PM emissions in 2025 from 22 tpy to less than 10 tpy.

Figure 4: Projected Crew and Cupply Vessel PM Emission Reduction



BARGE AND DREDGE VESSEL EMISSIONS

Figure 5 shows that the projected statewide NOx emissions from barge and dredge vessels in California are estimated to be about 760 tpy in 2008, dropping to about 340 tpy in 2025 without the proposed amendments. The reduction in uncontrolled emissions over this period is due to the anticipated or planned replacement of older engines. With the proposed amendments in place, the NOx emissions would be further reduced from 340 tpy to about 255 tpy in 2025.

Figure 5: Projected Barges and Dredges NOx emission reduction

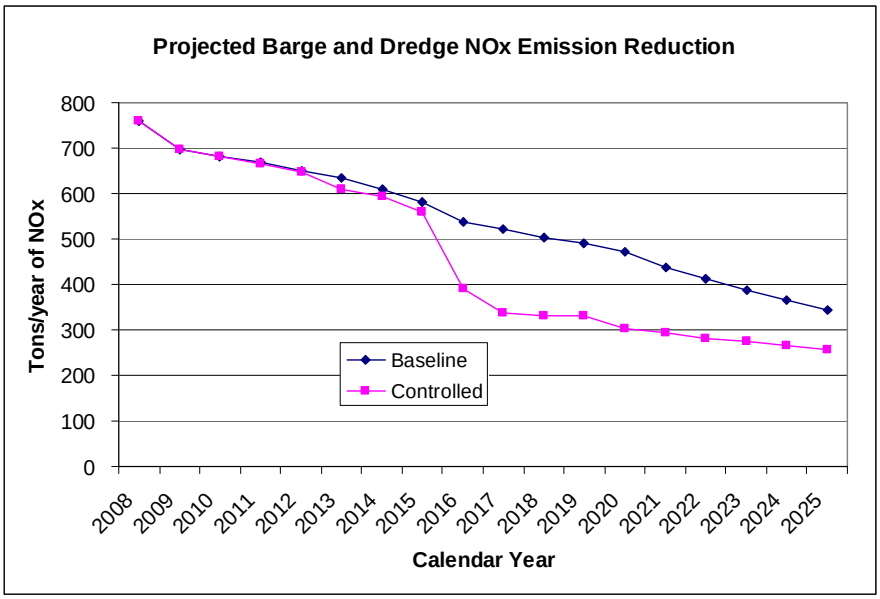


Figure 6 illustrates the statewide barge and dredge vessel engine diesel PM emissions with and without the proposed amendments. Statewide, the baseline uncontrolled diesel PM emissions from barges and dredges are estimated to be about 33 tpy in 2008, dropping to about 12 tpy in 2025. With the proposed amendments in place accelerating engine turnover, diesel PM emissions would be reduced in 2025 from 12 tpy to less than 7 tpy.

Figure 6: Projected Barges and Dredges PM emission reduction

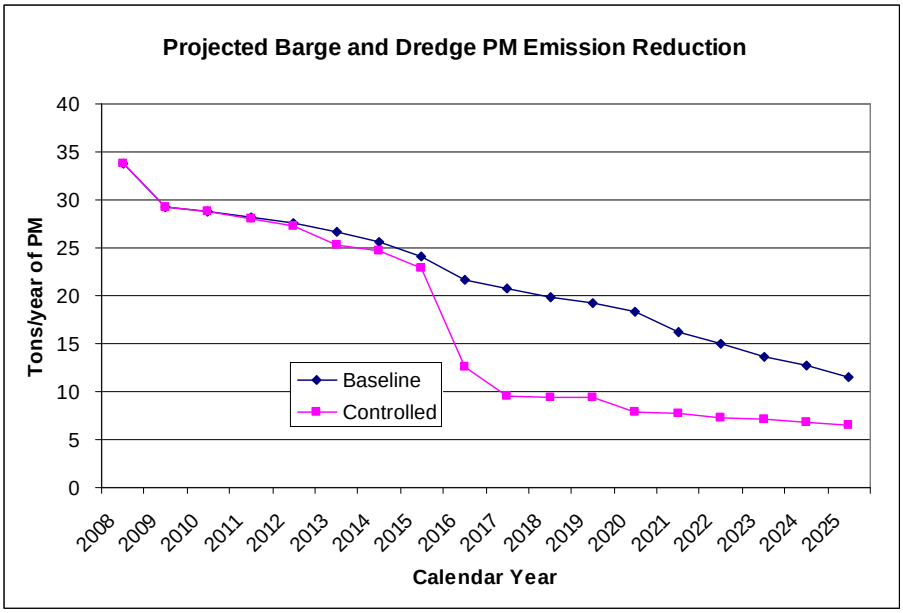


Table 5 shows emissions from barge and dredge vessels by air district. The Bay Area AQMD and the San Diego County APCD account for more than 50 percent of the statewide emissions from barge and dredge vessels.

Table 5: Barge and Dredge Emission Estimates by Air Districts for Year 2008 (tons/year)

Air District	NOx	% of Total	PM	% of Total
BA	206.5	27%	9.2	27%
IMP	6.8	1%	0.3	1%
MBU	28.8	4%	1.3	4%
NCU	62.9	8%	2.8	8%
SAC	10.3	1%	0.5	1%
SB	10.3	1%	0.5	1%
SC	129.9	17%	5.8	17%
SD	180.2	24%	8.0	24%
SJU	23.2	3%	1.0	3%
VEN	92.9	12%	4.1	12%
YS	7.7	1%	0.3	1%
Total	759.6	100%	33.4	100%

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