DELAWARE RIVER

Main Channel Deepening Project

General Conformity Analysis and Mitigation Report

August 7, 2009

Prepared for
U.S. Army Corps of Engineers
Philadelphia District
100 Penn Square East
Philadelphia, PA 19107-3390

Prepared by
Moffatt & Nichol

TABLE OF CONTENTS

List of Tables

List of Figures

List of Acronyms

CARB – California Air Resources Board

CEDEP – Corps of Engineers Dredge Estimating Program

EPA – U.S. Environmental Protection Agency

EF – Emission Factor

ER – Emission Rate

ERC – Emission Reduction Credit

USACE – U.S. Army Corps of Engineers

LAER – Lowest Achievable Emission Rate

LF – Load Factor

M&N – Moffatt & Nichol

MLW – Mean Low Water

NAAQS – National Ambient Air Quality Standards

NMHC – Non-Methane Hydrocarbons

NMOG – Non-Methane Organic Gases

NSR – New Source Review

OMET – Open Market Emissions Trading

OTC – Ozone Transport Commission

PAMT – Packer Avenue Marine Terminal

PANYNJ – Port Authority of New York and New Jersey

PRPA – Philadelphia Regional Port Authority

SCR – Selective Catalytic Reduction

SIP – State Implementation Plan

TEU – Twenty-foot Equivalent Unit

THC – Total Hydrocarbons

TOG – Total Organic Gases

VOC – Volatile Organic Compounds

EXECUTIVE SUMMARY

In February 2004, Moffatt & Nichol (M&N) prepared a study for the Philadelphia district of the U.S. Army Corps of Engineers (USACE) titled "Delaware River Main Channel Deepening Project, General Conformity Analysis and Mitigation Report." Since completing that report, several important factors have changed. Some of the significant changes include revisions to the scope of the project (most notably lower dredging quantities), changes to the air quality attainment status of the area, and new emission factor guidance from the regulatory agencies. Additionally, some of the emission mitigation strategies have evolved and new potential strategies have been identified.

In response to these changes, the USCACE retained M&N in 2009 to update the emissions estimates and mitigation strategies, including the evaluation of several new potential mitigation strategies. This report serves as an update to the 2004 General Conformity Analysis and Mitigation report.

The Delaware River Main Channel Deepening Project (project) proposes to deepen the main channel from -40 feet to -45 feet mean low water (MLW). The project extends from the Ports of Camden, New Jersey and Philadelphia, Pennsylvania south to the mouth of Delaware Bay, and follows the alignment of the existing federally authorized channel. Several berths at various oil refineries and port facilities along the Delaware River will also be deepened in addition to the channel deepening. The majority of the oil refineries and port terminals are located in the upstream reaches of the river near the Philadelphia/Camden area.

The purpose of the study was to estimate the air emissions generated by the equipment that will be used to construct the project and to evaluate the applicability of, and potential methods for complying with, the General Conformity requirements of the Clean Air Act. Detailed emission estimates were developed based on the latest USACE construction estimates. These estimates included equipment types, installed horsepower and work durations for dredging as well as land based disposal area equipment. Emission factors and load factors were developed based on the latest guidance as well as M&N's understanding of typical engine types in the existing industry fleet. A variety of potential mitigation alternatives were evaluated for feasibility and cost-effectiveness. These included both on-site measures as well as off-site air emission reduction projects that could be used to offset the project emissions on an annual basis.

Emission Estimate Results

The first step in the conformity analysis was to compare the annual project emissions of criteria pollutants to the de minimis threshold for each pollutant. In the case where the emissions are below the de minimis threshold, the project is exempt from General Conformity. The resulting annual emissions are shown in Table 1. Because the entire area is in attainment of the PM10 and CO standards, General Conformity does not apply to those pollutants and there is no need to compare them to a de minimis threshold. The project area is in non-attainment of ozone, however. The de minimis levels for ozone precursors, NOx and VOCs, are 100 and 50 tons per year respectively. The area is also in non-attainment for the fine particulate standard (PM2.5). The de minimis level for PM2.5 is 100 tons per year. The de minimis level for each of its precursors, NOx, VOCs, and SOx, is 100 tons per year.

Table 1: Summary of Annual Emissions for Each Criteria Pollutant

Calendar Year Emissions - tons						
De Minimis Level (tpy)	100	50	100			100
	NOx	VOCs	PM2.5	PM10	CO	SO2
2009	387.1	13.9	5.4	5.7	52.1	2.26
2010	711.5	26.6	11.1	11.8	83.5	2.19
2011	368.3	14.7	6.7	7.2	40.2	0.59
2012	539.8	22.3	10.3	11.1	61.9	1.08
2013	902.5	33.5	13.6	14.5	111.5	0.88
2014	128.5	4.6	2.2	2.3	18.1	0.40
Total Project	3037.72	115.61	49.15	52.52	367.37	7.41

The only criteria pollutant for which the project exceeds the de minimis level is NOx (as a precursor to ozone). Hence, General Conformity applies in regard to the emission of NOx. Annual NOx emissions range from a low of roughly 130 tons to a high of roughly 905 tons. Every calendar year is higher than the de minimis level of 100 tons per year.

Comparison of Emission Estimate Results to 2004 Report

The total project NOx emissions per the current analysis are only slightly less than the total project NOx emissions estimated in 2004 (3,038 tons in current study vs. 3,290 in 2004). The marine equipment emissions for the channel deepening only (not including berth deepenings or landside emissions), is 2,859 tons of NOx. In 2004, the marine emissions associated with the channel deepening were 3,083 tons of NOx. This 7% decrease in marine NOx emissions from 2004 to the current study is surprising given that the quantities to be dredged for the channel deepening were reduced from the 2004 project by nearly 40%. The emission rate per 10,000 cubic yards of dredging increased from 1.2 tons per 10,000 cubic yards of dredging in 2004 to nearly 1.8 tons per 10,000 cubic yards of dredging in the current study.

The 50% increase in NOx emissions per volume of dredging is due to a combination of factors. The largest reason for the difference is that the NOx emission factors used in the current study are 24% to 56% higher than those used in 2004. The 2004 study did not make distinctions among the types of engines that are used in the different kinds of dredges; all dredge types used the same emission factor. According to the latest literature, hopper dredge engines are most similar to medium speed ocean-going vessel auxiliary engines and cutter suction and booster pump engines are generally older locomotive style engines. The emission factors were adjusted accordingly.

In addition, the scope of work changed, shifting the work toward higher horsepower dredging. For example, the volume of work to be performed by a cutter suction dredge using two booster pumps increased by nearly 60%. This increased the emissions per volume of dredging because boosters are a significant source of emissions. The overall production rate per dredge working month also dropped in the current project. In 2004, the overall production rate of the dredging was roughly 435,000 cubic yards per dredge-month. The current project has an overall production rate of approximately 375,000 cubic yards per dredge-month. This 15% decrease in production increases the emissions per volume of material dredged.

Offsetting some of these increases are decreases in the clamshell dredge emission rates and changes to the assumed load factors. The net result is a 50% increase in the rate of emissions per volume of dredging. After factoring in the reduced volume, the net result is a slight reduction in total tons of NOx generated by the project as compared to the 2004 study. Other pollutants also varied from the 2004 study. Most notably, SOx emissions dropped dramatically with the advent of much lower sulfur level standards in fuel.

Mitigation Alternatives Analysis

Various strategies for offsetting the project NOx emissions were identified for this study. The goal was to calculate a value for the cost-effectiveness (in dollars per ton of NOx reduced per year) of each proposed strategy as well as to evaluate the capacity of each strategy to offset the project emissions in total tons per year.

The following mitigation strategies, as outlined in the scope of work, were studied:

On-site Mitigation:

1. Electrify dredge equipment
2. Install selective catalytic reduction (SCR) units on dredge equipment
3. Repower dredge equipment

Off-site Mitigation:

4. USACE Hopper Dredge McFarland
    a. Installing SCRs
    b. Repowering
    c. Repowering *and* installing SCRs
5. Cape May-Lewes ferries
    a. Installing SCRs
    b. Repowering
    c. Repowering *and* installing SCRs
6. Repowering local tug boats
7. Cold ironing (providing electric power to ships at berth, allowing auxiliary engines to be shut down)
    a. Packer Ave
    b. Pier 82
8. Electrifying diesel container cranes at Philadelphia Regional Port Authority (PRPA) facilities
9. Purchasing Emission Reduction Credits (ERCs)

For each strategy, M&N calculated the unmitigated and mitigated annual NOx emissions. Subtracting those values yields the tons of NOx reduced per year. The NOx emissions for the off-site strategies are simple because they are the same every year. However, for on-site measures (#1 – 3 above), the NOx emissions and reductions are different from year to year. For these strategies, the annual NOx reduction used to calculate cost effectiveness was the reduction in *project peak annual emissions*.

This is best explained by example. Electrification of dredges is used here for illustration. The peak NOx emissions for the unmitigated project occurs in Year 5 (902 tons), but the peak NOx emissions after electrification occurs in Year 4 (455 tons). The Year 5 NOx emissions after electrification were only 248 tons. The “Maximum Annual Reduction” for this strategy is (902 – 248) = 654 tons and occurs in Year 5. However, the “Peak Annual NOx Reduction” for this strategy is (902 – 455) = 447 tons. The lower of the two values is used to address the fact that electrification does not achieve a 654 ton reduction every year. This method only gives NOx reduction credit for the reduction in the project’s peak year emissions.

Each of the mitigations strategies studied was determined to be technically feasible. Cost estimates for each strategy were developed. The cost for the purchase of emission reduction credits was based on discussion with ERC brokers regarding recent market prices.

Dividing the cost for the strategy by the NOx reductions for a single year (or reduction of peak emissions in the case of the on-site measures) gives a cost-effectiveness value that can be used to compare all of the emission reduction strategies under consideration. Figure 1 shows the cost-effectiveness of each strategy graphically.

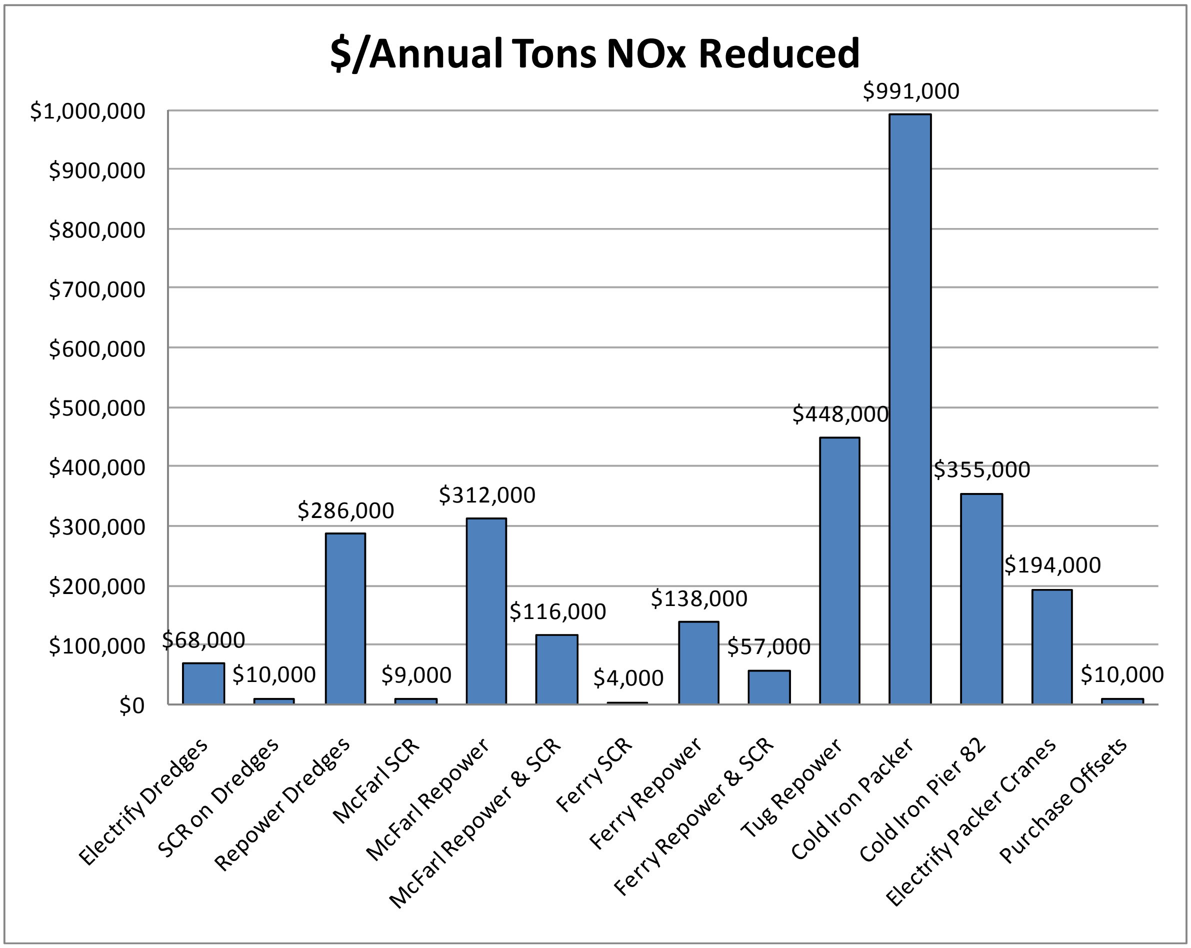


Figure 1: Cost Effectiveness of Each Strategy

Conclusions

The total direct (channel deepening) and indirect (berth deepening) NOx emissions were estimated to be 3,040 tons over the life of the project with a peak year of 905 tons in 2013. Based on a detailed evaluation of the emissions, a conformity determination is required for NOx emissions. Therefore, one of the following options must be applied:

a. The project emissions must be specifically included in the applicable SIPs, or

b. A written statement must be obtained from the state agencies responsible for the SIPs documenting that the total direct and indirect emissions from the action along with all other emissions in the area will not exceed the SIPs' emission budget, or

c. A written commitment must be obtained from the states to revise their SIPs to include the emissions from the action, or

d. The project emissions must be fully offset by reducing NOx emissions within the same non-attainment area.

A variety of on-site and off-site mitigation measures are possible to comply with option d (fully offsetting the NOx emissions). The most cost effective strategies are installing SCR systems on the dredges or ferries.

Based on the current schedule, the lead time necessary for many of these strategies studied is longer than the time available before dredging begins. It is anticipated that emission reduction credits will be purchased to offset work in the first contract because that is the only strategy that can meet the project schedule.

General Conformity Strategy

Project NOx emissions must be offset to zero to demonstrate General Conformity. Given the project schedule, the purchase of emission reduction credits is the only feasible strategy for the first of the seven expected construction contracts. Subsequent contracts can be offset using a mix of the identified reduction measures. As the project schedule and the development of the mitigation projects evolve, various mitigation measures can be implemented and managed to offset the project emissions on an annual basis.

1. INTRODUCTION

In February 2004, Moffatt & Nichol (M&N) prepared a study for the Philadelphia district of the U.S. Army Corps of Engineers (USACE) titled "Delaware River Main Channel Deepening Project, General Conformity Analysis and Mitigation Report." Since completing that report, several important factors have changed. Some of the significant changes include revisions to the scope of the project (most notably lower dredging quantities), changes to the air quality attainment status of the area, and new emission factor guidance from the regulatory agencies. Additionally, some of the emission mitigation strategies have evolved and new potential strategies have been identified.

In response to these changes, the USCACE retained M&N to update the emissions estimates and mitigation strategies, including the evaluation of several new potential mitigation strategies. This report serves as an update to the 2004 General Conformity Analysis and Mitigation report.

1.1 Background

The Delaware River Main Channel Deepening Project (project) proposes to deepen the main channel from -40 feet to -45 feet mean low water (MLW). The project extends from the Ports of Camden, New Jersey and Philadelphia, Pennsylvania south to the mouth of Delaware Bay, and follows the alignment of the existing federally authorized channel. Several berths at various oil refineries and port facilities along the Delaware River will also be deepened in addition to the channel deepening. The majority of the oil refineries and port terminals are located in the upstream reaches of the river near the Philadelphia/Camden area.

The costs of the berth deepenings will be borne by the facility owners and are not part of the project costs. However, based on recommendation from the Environmental Protection Agency (EPA) the emissions from the berth deepenings were included as part of the General Conformity analysis as "indirect" emissions. Subsequent maintenance dredging of the channel and berths is not included in the General Conformity Analysis because maintenance dredging is specifically exempt[1] from General Conformity.

1.2 Purpose

The purpose of the study was to estimate the air emissions generated by the equipment that will be used to construct the project and to evaluate the applicability of, and potential methods for complying with, the General Conformity requirements of the Clean Air Act. Detailed emission estimates were developed based on the latest USACE construction estimates. These estimates included equipment types, installed horsepower and work durations for dredging as well as land based disposal area equipment. Emission factors and load factors were developed based on the latest guidance as well as M&N's understanding of typical engine types in the existing industry fleet. A variety of potential mitigation alternatives were evaluated for feasibility and cost-effectiveness. These included both on-site measures as well as off-site emission reduction projects that could be used to offset the project emissions on an annual basis.

[1] 40 CFR Part 93, 93.153 c (2) ix

1.3 Federal Clean Air Act

As part of the Clean Air Act, the Code of Federal Regulations Title 40, Part 50 (40 CFR 50) establishes the overall regulations that specify the allowable concentrations of certain pollutants in the atmosphere. These standards are known as the National Ambient Air Quality Standards (NAAQS)[2].

The EPA's Office of Air Quality Planning and Standards has set, and periodically revises, NAAQS for six principal pollutants. These are called "criteria" pollutants. They are carbon monoxide (CO), nitrogen dioxide (NOx), ozone, lead (Pb), particulates (PM2.5 and PM10), and sulfur dioxide (SOx). The standards are maximum allowable pollutant concentration levels in the air based on different averaging schemes for each specific pollutant.

Under section 107 of the Clean Air Act, areas are designated as being in attainment or non-attainment of these standards. Those designations are subject to revision whenever sufficient data become available to warrant a change. States with areas in non-attainment are required to develop "State Implementation Plans" (SIPs) that demonstrate how the state intends to achieve attainment status.

1.4 General Conformity[3]

Section 176 (c) (42 U.S.C. 7506) of the Clean Air Act requires federal agencies to ensure that their actions conform to the applicable SIP for attaining and maintaining the NAAQS. The 1990 amendments to the Clean Air Act clarified and strengthened the provisions in section 176 (c). EPA published two sets of regulations to implement section 176 (c) because certain provisions apply only to highway and mass transit funding and approval actions. The transportation conformity regulations address federal actions related to highway and mass transit funding and approval actions. The General Conformity regulations, published on November 30th, 1993 and codified at 40 CFR 93.150, cover all other federal actions.

The Clean Air Act was revised in 1995 to limit the applicability of the conformity programs to areas designated as non-attainment under section 107 and areas that had been re-designated as maintenance areas with a maintenance plan under section 175A of the Clean Air Act. Therefore, only federal actions taken in designated non-attainment and maintenance areas are subject to the General Conformity regulation.

The EPA also included de minimis emission levels based on the type and severity of the non-attainment problem in an area. Before any action can be taken, federal agencies must perform an applicability analysis to determine whether the total direct and indirect emissions from their action would be below or above the de minimis levels. If the action is determined to create emissions at or above the de minimis level for any of the criteria pollutants, federal agencies must conduct a conformity determination for the pollutant (unless the action is presumed to conform under the regulation or the action is otherwise exempt). If the emissions are below all of the de minimis levels, the agency does not have to conduct a conformity determination.

---

[2] United State Environmental Protection Agency Code of Federal Regulations Title 40, Part 50 (40 CFR 50) – National Primary & Secondary Ambient Air Quality Standards; revised July 1, 2008. ttp://www/access.gpo.gov/nara/cfr/waisidx_08/40crf50_08.html

[3] Taken from EPA's "PM2.5 De Minimis Emission Levels for General Conformity Applicability", Federal Register Document ID (DOCID:fr17jy06-11).

When the applicability analysis shows that the action must undergo a conformity determination, federal agencies must first show that the action will meet all SIP control requirements. Requirements may include taking reasonably available control measures and showing that emissions from the action will not interfere with the timely attainment of the standard, the maintenance of the standards, or the area's ability to achieve an interim emission reduction milestone. Federal agencies then must demonstrate conformity by meeting one or more of the methods specified in the regulations:

1. Demonstrating that the total direct[4] and indirect[5] emissions are specifically identified and accounted for in the applicable SIP.

2. Obtaining a written statement from the State or local agency responsible for the SIP documenting that the total direct and total indirect emissions from the action along with all other emissions in the area will not exceed the SIP emission budget.

3. Obtaining a written commitment from the State to revise the SIP to include the emissions from the action.

4. Obtaining a statement from the metropolitan planning organization for the area documenting that any on-road motor vehicle emissions are included in the current regional emission analysis for the area's transportation plan or transportation improvement program.

5. Fully offset the total direct and indirect emissions by reducing emissions of the same pollutant or precursor in the same non-attainment or maintenance area.

6. Where appropriate, in accordance with 40 CFR 51.858(4), conduct air quality modeling that can demonstrate that the emissions will not cause or contribute to new violations of the standards, or increase the frequency or severity of any existing violations of the standards.

Since promulgation in 1993, the General Conformity regulations have been revised once (in 2006) to add a de minimis threshold for fine particulates (PM2.5). On January 8th, 2008, EPA published proposed revisions to the General Conformity regulations. In general, these revisions respond to comments from federal agencies that EPA has received over the course of applying the current regulations. It does not appear that the revisions proposed would make a material difference in the General Conformity determination for this project.

For more information, see http://www.epa.gov/oar/genconform/ .

1.5 Criteria Pollutants

Emissions were estimated for the following pollutants emitted by the internal combustion engines associated with the project:

[4] Direct emissions are emissions of a criteria pollutant or its precursors that are caused or initiated by the Federal action and occur at the same time and place as the action.

[5] Indirect emissions are emissions of a criteria pollutant or its precursors that: (1) are caused by the federal action, but may occur later in time and/or may be further removed in distance from the action itself but are still reasonably foreseeable; and (2) the federal agency can practically control or will maintain control over due to the controlling program responsibility of the federal action.

Oxides of nitrogen (NOx) – Oxides of nitrogen (or NOx, pronounced "knocks") are an important precursor to ozone. Ozone is a photochemical oxidant and the major component of smog. Ozone is not emitted directly but forms in the atmosphere in a reaction of oxides of nitrogen and volatile organic gases in presence of sunlight. These reactions are stimulated by sunlight and temperature so that peak ozone levels typically occur during the warmer times of the year. Ozone in the upper atmosphere is beneficial to life because it shields the earth from harmful ultraviolet radiation from the sun. However, high concentrations of ozone at ground level are a major health and environmental concern. Ozone and Nitrogen dioxide (a common type of oxide of nitrogen) are criteria pollutants.

Carbon monoxide (CO) – Carbon monoxide is a colorless, odorless, poisonous gas produced by incomplete burning of carbon in fuels. CO is a criteria pollutant.

Hydrocarbons (HC) – Hydrocarbons may also be referred to as total organic gases (TOG) or volatile organic compounds (VOC). They are an important component in the formation of ozone. Ozone is formed through complex chemical reactions between precursor emissions of VOCs and NOx in the presence of sunlight. Hydrocarbon emissions are measured and reported in a few different ways. Total hydrocarbons, or THC, are the hydrocarbons measured by a specific test called FID. This test does not properly detect some alcohols and aldehydes. Separate tests detect these compounds and when the results are added to the THC, the sum is known as TOG. Methane is orders of magnitude less reactive than other hydrocarbons so it is often measured separately, and when subtracted from THC, is known as NMHC (non-methane hydrocarbons) or NMOG (non-methane organic gases).

Some hydrocarbons are less ozone forming than others so EPA has excluded them from the definition of regulated hydrocarbons called VOCs. Although several compounds are excluded, generally speaking VOCs are the result of subtracting methane and ethane from TOG emission estimates. Ultimately, all of these terms and their varying constituents represent only slight variations in the total mass emission of hydrocarbons. For the purposes of this study, all hydrocarbon emissions are converted to and shown as VOCs.

Particulate matter 10 (PM10) – Air pollutants called particulate matter include dust, dirt, soot, smoke, and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires, and natural windblown dust. Particles formed in the atmosphere by condensation or the transformation of emitted gases such as SO_2 and VOCs are also considered particulate matter. These are called secondary PM as they are not directly emitted but form in the atmosphere. PM10 includes airborne particulates having an aerodynamic diameter of 10 microns or less. PM10 is a criteria pollutant.

Particulate matter 2.5 (PM2.5) – A subset of PM10, PM2.5 is airborne particulate of aerodynamic diameter of 2.5 microns or less. Standards for PM2.5 are relatively new. The EPA revised the PM2.5 limit to a more restrictive concentration. This new limit went into effect in December of 2006 where the 24-hr PM2.5 standard was lowered from 65 ug/m3 to 35 ug/m3. PM2.5 is a criteria pollutant.

Sulfur dioxide (SO_2) – High concentration of sulfur dioxide affects breathing and may aggravate existing respiratory and cardiovascular disease. Sensitive populations include asthmatics, individuals with bronchitis or emphysema, children, and the elderly. SO_2 is also a primary contributor to acid deposition, or acid rain, which causes acidification of lakes and streams and can damage trees, crops, historic buildings, and statues. In addition, sulfur compounds in the air contribute to visibility impairment in large parts of the country. This is especially noticeable in national parks. Sulfur dioxide emissions are directly proportional to the sulfur content of in-use fuels. Sulfur dioxide is a criteria pollutant.

In addition to the regulated pollutants listed above, lead (Pb) is also one of the pollutants in 40 CFR 93.153. Airborne lead in urban areas is primarily emitted by vehicles using leaded fuels. Lead emissions were more of a concern in past years. However with the increasing use of unleaded gasoline, lead standards are not expected to be violated in any aspect of the project and need not be addressed. The EPA model utilized to calculate vehicle emissions (discussed in Section 2.4.3) assume that all post-1975 model year vehicles that were not tampered with and all calendar years subsequent to 1991 are free from lead emissions.[6]

1.6 Local Setting

The project encompasses the Delaware River system from the Ports of Camden and Philadelphia to the mouth of Delaware Bay, about 100 river miles. The deepening follows the alignment of the existing 40-foot federally maintained channel. The project borders the states of New Jersey, Pennsylvania, and Delaware.

In addition to the channel deepening, some berths at various terminals and oil refineries along the Delaware River will also be deepened by the facility owners. The facilities that plan on performing berth deepening work are mostly located in the upper reaches of the project area. They are:

- Sun Oil Company - Marcus Hook, PA
- Conoco Phillips - Marcus Hook, PA
- Valero – Paulsboro, NJ
- Sun Oil Company – Fort Mifflin, PA
- Coastal Eagle Point – Westville, NJ
- Packer Ave. Terminal – Philadelphia, PA
- Beckett St. Terminal – Camden, NJ

Construction equipment associated with the project would emit criteria pollutants within ten counties in three states (Delaware, Pennsylvania, and New Jersey). There are currently two non-attainment areas that overlap the project boundaries.

All ten counties included within the project area are also within the "Philadelphia-Wilmington-Atlantic City" 8-hour ozone non-attainment area. This is a four state (PA-NJ-MD-DE), 18 county non-attainment area currently in moderate non-attainment for the 8-hour ozone standard. In 2004, this area was in severe non-attainment of the 8-hour ozone standard. The ozone problem has abated somewhat in the intervening years. This has an impact on the ozone and ozone precursor de minimis thresholds. The precursors to ozone include NOx and VOCs.

Five of the ten counties that make up the project area are in non-attainment for the fine particulate standard (PM2.5). These include Delaware and Philadelphia Counties in Pennsylvania, Gloucester and

[6] "User's Guide to MOBILE6.1 and MOBILE6.2: Mobile Source Emission Factor Model", EPA420-R-03-010, United States Environmental Protection Agency, August 2003

Camden Counties in New Jersey, and New Castle County in Delaware. This is generally the interior half of the project from roughly river mile 45 to the inshore terminus of the channel at roughly river mile 100. This fine particulate non-attainment area is known as the Philadelphia-Wilmington non-attainment area (a three state, nine county area in total). The precursors to PM2.5 are NOx, VOCs, and SOx.

A complication in applying General Conformity to a project that covers such a large area is that there is not one single non-attainment status for the entire project area because the project spans multiple attainment areas. The approach taken in the 2004 report, and continued in this update, is to treat all of the project area as having the attainment status of the most severe area found within the project limits for a given pollutant. This is a conservative approach and was based on discussion with EPA.

In the case of ozone, this has no effect since all 10 counties in the project area are in the same moderate non-attainment status with respect to the 8-hour ozone standard.

With respect to fine particulate matter, about half the project area is in non-attainment of the standard. Dover, Sussex, Salem, Cumberland and Cape May counties are currently in attainment of the fine particulate standard. The total PM2.5 emissions for the project are compared with the de minimis standards for the areas in non-attainment, as if the total project were in the PM2.5 non-attainment area.

1.7 Emission Sources

The emission sources for the project consist of marine and land based mobile sources that will be used during the six-year project construction (five years for the channel deepening and one year for the berth deepenings). The marine emission sources include the various types of dredges (clamshell, hydraulic, hopper and drillboat) as well as all significant support equipment. The land based emission sources include both off-road and on-road equipment. The off-road equipment consists of the heavy equipment used to construct and maintain the disposal sites. The on-road equipment consists of employee vehicles and any on-road trucks used on the project. Both the marine and off-road equipment consist primarily of diesel powered engines. The on-road vehicles are a combination of gas and diesel powered vehicles.

1.8 Emission Estimate Approach

Operational information and estimates for the equipment performing the work was obtained from the Corps of Engineers Dredge Estimating Program (CEDEP) provided[7] by the USACE Philadelphia District. This included equipment lists, horsepower of each piece of equipment, hours of operation, operating days, etc.

The channel deepening scope was broken up into fifteen project elements, each having an individual CEDEP estimate. These were grouped in seven phases of construction. Additionally, the details of the ten berth deepening estimates were provided in the 2004 study effort. Per direction from the USACE, M&N assumed no changes in the berth deepening scope. However, berth deepening emissions were recalculated as part of this study due to new emission factor guidance and updated assumptions on equipment.

[7] CEDEP estimate information on the channel deepening was provided by USACE in two emails, dated 2-9-09 and 3-4-09. Because the scope of berth dredging was assumed to be the same as the 2004 report, the scope of the berth deepenings was developed base on information from the 2004 report.

The fundamental approach to the emission estimates was to develop daily emissions of each pollutant for each group of equipment in each estimate. The resulting daily emissions were broken out into three components:

- Emissions occurring in the dredge area - this includes all cutterhead, clamshell and drillboat emissions including all associated small attendant plants that stay on-site. It also includes all hopper dredge emissions while loading.

- Emissions occurring in transit to the disposal area - this includes all booster, barge towboat and hopper sailing emissions.

- Emissions occurring at the disposal area – this includes all dredge unloading emissions, all land based non-road equipment in use at the disposal site and all on-road vehicular traffic including worker trips.

Details of this calculation for each of the fifteen channel deepening project elements can be found in Appendix C.

Land based non-road equipment emissions were estimated using EPA's NONROAD model. On-road vehicular traffic associated with worker trips were estimated using EPA's Mobile 6.2 model. Marine diesel engine emissions on dredges, tugs, and attendant plants were estimated using the latest EPA guidance including the January 2006 EPA best practices guide entitled "Current Methodologies and Best Practices Guide for Preparing Port Emission Inventories." The EPA models take into account the changes in diesel fuel sulfur level and resulting changes in emission factors. The marine emission factors were also developed based on the anticipated fuel sulfur level for the particular project element and its anticipated year of execution.

In addition to daily operating emissions, M&N also estimated the total emissions for the mobilization of each spread of equipment in each CEDEP estimate. M&N developed monthly emission profiles and total emissions for each calendar year by applying the total daily emissions of each project element (as shown in Appendices A & B), as well as the mobilization emissions, to the current project schedule (provided by the USACE and shown in Appendix D). The annual emissions for the project were then compared to the de minimis threshold level for the combined non-attainment area.

2. METHODOLOGY FOR DETERMINING GENERAL CONFORMITY

2.1 Construction Cost Estimates

As previously stated, the Philadelphia District provided fifteen cost estimates for each component of the project. Estimates were in CEDEP format. The fifteen estimates were grouped in seven separate contracts distributed over a five year period.

Each CEDEP estimate provided detailed information on the type and size of equipment, the type of material dredged, the dredging and disposal location, the hours of operation, and labor requirements. Information regarding land based work performed at the various disposal sites was detailed in additional estimates and production spreadsheets. The estimates included information on equipment types and production rates for disposal site shore crews, rock excavation rehandling, rip rap placement, embankment and groin construction, sluice box construction, and the placement and filling of geotextile tubes.

Detailed construction cost estimates for the berth deepenings at each of the benefiting oil refineries and port terminals were provided as part of the 2004 study. They contained similar information on equipment types and productions. The berth deepening work is assumed to start after the channel deepening project is completed. It was assumed that there are no changes to the berth deepening scope from the information provided for the 2004 study.

2.2 Emission Factor Sources and Emission Models

The EPA has different models or methodologies for calculating emissions depending on the sources involved – marine, off-road, or on-road. Emission calculations depend on inputs such as engine size, operating hours, fuel type, engine load factors, and emission factors. These inputs were obtained from the cost estimates described above.

The EPA guidelines and models are discussed here.

MARINE EMISSIONS

The vast majority of the emissions of this project are generated by commercial marine diesel engines. Well established methodologies and models for on-road and some non-road engine emissions exist. However, the field of marine engine emissions has no such standardized models to apply. Emission inventories for marine equipment have been evolving and are usually based on the latest literature.

The primary guide for estimating marine emissions for this study was the January 2006 EPA document titled “Current Methodologies and Best Practices Guide for Preparing Port Emission Inventories.” This decision was based on discussion with representatives of EPA Region II, Region III, and EPA head quarters during a phone conference on February 24, 2009.

The January 2006 document includes guidance for dredges as well as tug boats, ferries, crew boats etc. For dredges, the document recommends collecting engine specifics from equipment operators and using the latest technical literature for both load factor and emissions factors. Equipment specifics and operating details were drawn from the USACE CEDEP estimates for the project.

Table 2 summarizes the emissions factors used in the revised marine emissions. Emission factors for eight different engine cases were developed to cover the various engine types anticipated.

Table 2: Emission Factors

	Marine Diesel Emission Factors						Sulfur Adjusted						
			Speed	Fuel	NOx (gr/bhp-hr)	VOC (gr-bhp/hr)	PM2.5 gr/bhp-hr	PM10 gr/bhp-hr	CO gr/bhp-hr		Fuel Sulfur % in factor development	Actual Fuel Sulfur	Assumed BSFC lb/hr-hr
1	OGV Aux	Medium Speed Ship Aux Engines MGO	Medium	MGO	10.37	0.31	0.1959	0.2053	0.82	Source- EPA Best Pracitice Guide- Port Emission Inventories (except PM2.5)	0.5000%	0.0500%	0.336
2	Cat1 50-100	Harbor Craft 50 hp to 100 hp- Category 1			8.20	0.21	0.5431	0.5633	1.49	Source- EPA Best Pracitice Guide- Port Emission Inventories (except PM2.5)	0.5000%	0.0500%	0.336
3	Cat1 100-175	Harbor Craft 100 hp to 175 hp- Category 1			7.46	0.21	0.1815	0.1904	1.27	Source- EPA Best Pracitice Guide- Port Emission Inventories (except PM2.5)	0.5000%	0.0500%	0.336
4	Cat1 175-300	Harbor Craft 175 hp to 300 hp- Category 1			7.46	0.21	0.1815	0.1904	1.12	Source- EPA Best Pracitice Guide- Port Emission Inventories (except PM2.5)	0.5000%	0.0500%	0.336
5	Cat1 300-1341	Harbor Craft 300 hp to 1341 hp- Category 1			7.46	0.21	0.1091	0.1158	1.12	Source- EPA Best Pracitice Guide- Port Emission Inventories (except PM2.5)	0.5000%	0.0500%	0.336
6	Cat1 >1341	Harbor Craft >1341hp- Category 1			9.69	0.21	0.1091	0.1158	1.86	Source- EPA Best Pracitice Guide- Port Emission Inventories (except PM2.5)	0.5000%	0.0500%	0.336
7	HC-Cat2				9.84	0.39	0.1732	0.1893	0.82	Source- EPA Best Pracitice Guide- Port Emission Inventories (except PM2.5)	1.5000%	0.0500%	0.336
8	Locomotive				12.38	0.43	0.1637	0.1721	1.51	Based on EPA RSD for Locomotives	0.5000%	0.0500%	0.336

Emission factor 1 is based on the emission factors for medium speed auxiliary (generator) engines on ocean going vessels. Emission factors 2 through 6 are for harbor craft with Category I marine diesel engines of varying horsepower levels. Emission factor 7 is for harbor craft using Category 2 engines. Emission factor 8 is based on locomotive engine emission data contained in an EPA regulatory support document. Hopper dredge engines were assumed to be most similar to ocean going vessel medium speed auxiliary ship engines. Cutter suction and booster engines were assumed to be most similar to locomotive engines. Other harbor craft were assigned emission factors based on horsepower. The emission factor designator for each piece of equipment in each of the 15 channel deepening project components is shown in Appendix C.

PM2.5 calculations were based on the assumption that 92% of the PM10 emissions are fine particulate. Sulfur dioxide emissions were based on the brake specific fuel consumption and the assumed fuel sulfur level. Fuel sulfur levels were projected for each year of the project based on the EPA guidance for marine fuels.

Load factors are the assumed percentage of installed horsepower in demand while operating. Load factors for the marine equipment were developed based on M&N's best judgment of the power demand while operating as compared to the installed horsepower of the equipment assumed in the cost estimates.

Two example calculations of daily emissions from a dredging spread are shown in Table 3 and Table 4 (one cutter suction and one hopper). All 15 are included in Appendix C.

Table 3: Example Daily Emissions Calculation – Cutter Suction Dredge

Appendix C -Marine Emissions CDEP Estimate #14 (of 15)
Reach AA - National Park
Assumed Year of Analysis 2010
Assumed Fuel Sulfur Level 163 ppm 0.0163%

	From CDEP									Emission Factors						Daily Emissions						
	Primary Hp	Secondary Hp	prime fuel factor	secondary fuel factor	Hrs/Day	Primary LF	Secondary LF	Total Hourly Fuel Consumption per rig (gals)	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 Dredge	9000	3310	0.045	0.039	13.61	80%	40%	376	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0497	3,167	110	42	44	386	13	8
2 Work Tugs	250	50	0.045	0.039	13.61	20%	50%	3.2	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0497	33.6	1.0	0.8	0.9	5.0	0.2	4
1 Crew / Sur	100	40	0.045	0.039	13.61	15%	50%	1.5	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0497	7.8	0.2	0.2	0.2	1.3	0.1	3
1 Derrick	200	40	0.011	0.011	13.61	15%	50%	0.6	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0497	11.2	0.3	0.3	0.3	1.7	0.1	4
Subtotal Attnd Plnt Dredge Site								5								52.6	1.5	1.3	1.3	8.0	0.4	
Transportation Route																						
dredge enroute																						
2 boosters	5200	200	0.045	0.039	13.61	90%	50%	215	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0497	3,551	124	47	49	433	14	8
Disposal Site																						

Table 4: Example Daily Emissions Calculation – Hopper Dredge

Appendix C-Marine Emissions CDEP Estimate #15 (of 15)
Reach A to Pedricktown N.
Assumed Year of Analysis 2013
Assumed Fuel Sulfur Level 31 ppm 0.0031%
Hours per Month 657 (730hrs x 90% TE)

	From CDEP									Emission Factors						Daily Emissions						
	Propulsion Hp	Pumps Hp	Aux & Misc Hp	LF Propulsion	LF Pumps	LF Aux & Misc	% of cycle	Hrs/Day	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 7600 cy dr	9000	3000	2000	45%	50%	30%	21.6%	4.66	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	622	25	11	12	52	1	7
1 Crew/Surv	100	0	40	15%	0%	50%		21.60	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0094	12	0	0	0	2	0	3
Transportation Route																						
1 7600 cy dr	9000	3000	2000	80%	0%	25%	57.7%	12.47	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	2,083	83	37	40	174	2	7
0 5200 hp bo	0	5200	200	0%	90%	50%	p/o time	4.47	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0094	0	0	0	0	0	0	8
Subtotal along Transp Route																2,083	83	37	40	174	2	
Disposal Site																						
1 7600 cy dr	9000	3000	2000	0%	80%	25%	20.7%	4.47	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	281	11	5	5	23	0	7
1 Tender Tug	250	0	50	60%	0%	50%		21.60	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0094	62	2	2	2	9	0	4
Subtotal Dredge at Pumpout							100.0%	21.60								343.6	13.0	6.5	7.0	32.8	0.3	
								90.0%														

LAND BASED EMISSIONS

The land based emissions for the project include off-road equipment such as dozers, loaders, excavators, and cranes, as well as on-road vehicles such as cars and trucks. These emissions were calculated using two different EPA models developed specifically for use with land based equipment, NONROAD2005 Emission Inventory Model and MOBILE6 Vehicle Emission model.

NONROAD Emissions Model

The off-road emissions were calculated using the EPA computer model NONROAD. The EPA developed this model to assist states and regulatory agencies in more accurately estimating air emission inventories. The NONROAD model calculates emissions for over 300 equipment types, categorizing them by horsepower rating and fuel type. The NONROAD model estimates emissions for the following engine exhaust pollutants: HC, NOx, CO, CO_2, SOx, and PM. HC can be reported as total hydrocarbons, total organic gases, non-methane organic gases, non-methane hydrocarbons, or volatile organic compounds. PM emissions can be reported as PM10 or PM2.5.

The NONROAD model contains several different sets of data files that are used to specify the options for a model run. These data files provide the necessary information to calculate and allocate the emissions estimates. The data files contain information on load factors, emission factors, equipment population, annual hours of operation, average engine lifetime hours, engine growth estimates, equipment scrappage, and geographic and temporal allocation. The user specifies options such as fuel type, temperature ranges, period (annual, monthly, or seasonal), region, and equipment sources. The data files can be modified to reflect the project conditions relative to equipment population, annual hours of use, region of use, fuel source, equipment growth, and the engine tier emission factors.

The NONROAD Model Interface Version 2005.0.0 (NR-GUI.EXE 6/12/2006) was used for this project.

Mobile Source Emission Factor Model

The remaining source of emissions for the project is employee vehicles and other on-road trucks used during construction. EPA has an emissions model called MOBILE6, which is used to calculate emissions (in grams per mile) for different vehicle types under different operating conditions. Similar to the NONROAD model, the user specifies vehicle type, quantity, and operating conditions (speed, temperature, distance traveled, etc.). The emission quantities are then multiplied by the number of miles traveled and number of vehicles to determine the final emission amounts. The inputs used for this project are detailed in the analysis section of this report.

3. GENERAL CONFORMITY RESULTS

The annual emissions estimated in this study are shown Table 5. Because the entire area is in attainment of the PM10 and CO standards, General Conformity does not apply to those pollutants and there is no need to compare them to a de minimis threshold.

The area is in non-attainment of ozone, however. The de minimis levels for ozone precursors, NOx and VOCs, are 100 and 50 tons per year respectively.

The area is also in non-attainment for the fine particulate standard (PM2.5). The de minimis level for PM2.5 is 100 tons per year. The de minimis level for each of its precursors, NOx, VOCs, and SOx, is 100 tons per year.

Table 5: Annual Emissions Summary by Pollutant

Calendar Year Emissions - tons						
De Minimis Level (tpy)	100	50	100			100
	NOx	VOCs	PM2.5	PM10	CO	SO2
2009	387.1	13.9	5.4	5.7	52.1	2.26
2010	711.5	26.6	11.1	11.8	83.5	2.19
2011	368.3	14.7	6.7	7.2	40.2	0.59
2012	539.8	22.3	10.3	11.1	61.9	1.08
2013	902.5	33.5	13.6	14.5	111.5	0.88
2014	128.5	4.6	2.2	2.3	18.1	0.40
Total Project	3037.72	115.61	49.15	52.52	367.37	7.41

The only criteria pollutant for which the project exceeds the de minimis level is NOx (as a precursor to ozone). Hence, General Conformity applies in regard to the emission of NOx. Annual NOx emissions range from a low of roughly 130 tons to a high of roughly 905 tons. Every year is higher than the de minimis level of 100 tons per year.

4. COMPARISON TO 2004 RESULTS

4.1 Introduction

The emissions estimates developed for the 2004 General Conformity Analysis and Mitigation Report are different from the totals calculated in 2009. The differences are due to changes in the project scope, the anticipated equipment types, anticipated production rates and the emission factors applied to various sources. This section describes and explains the changes to the NOx emission estimates. Table 6 summarizes the NOx emissions estimates from the 2004 and 2009 reports.

Table 6: Comparison of Total NOx Emissions

	2004 Report	2009 Report
NOx (total tons)	3,290	3,038

In total, the estimated NOx emissions dropped by approximately 8% even though the dredge quantity dropped by nearly 40%. This means the tons of NOx per unit of dredging increased. This section of the report investigates the cause of the increase.

4.2 Changes to Dredging Scope

The seven individual channel deepening contracts cannot be directly compared from 2004 to 2009 because the contract dredging areas, quantities and disposal locations were revised. Dredging volumes for the two major pieces of equipment are shown in Table 7 below. Clamshell dredging, drilling and blasting, dredge support equipment and land based equipment are not included in this comparison because their contributions are small compared with the main dredging equipment.

Table 7: Project Dredging Volume (Cutter Dredge & Hopper Dredge Only)

Dredging Equipment	2004 Report (cy)	2009 Report (cy)
Cutter with no Booster	6,661,246	2,170,700
Cutter with 1 Booster	3,595,635	3,946,300
Cutter with 2 Boosters	1,293,522	2,044,700
Hopper Dredge with no Booster	7,133,361	3,717,700
Hopper Dredge with 1 Booster	7,328,200	4,081,700
Total	26,011,964	15,961,100

Although the volume of dredging was reduced by about 40% from the 2004 amount, the resulting total volume of emissions was not reduced by the same ratio. The emissions generated depend on the amount of horsepower applied, the duration it is applied, and the emission factor assumed for each piece of equipment. A comparison to the previous estimate is not simple because of all these factors.

M&N evaluated the installed horsepower-months for each of the major dredge types in an effort to understand the differences in the scope of dredging estimated in 2004 versus the current study.

Multiplying the estimated number of operating months by the installed horsepower for each dredge type is a way to evaluate critical inputs to the emissions estimates that are separate from the assumed load factor and emission factor. Table 8 presents the total installed hp-months of each of the major equipment spreads in the 2004 and 2009 analyses. In very general terms, this can be seen as a comparison of the energy to be expended to move the estimated dredge quantity for the two estimates.

Table 8: Comparison of Energy in Installed Horsepower-Months

Dredging Equipment	2004 Report (Work months)	2004 Report (Installed hp-months)	2009 Report (Work months	2009 Report (Installed hp-months)
Cutter with no Booster	8.77	107,959	1.35	16,619
Cutter with 1 Booster	6.97	123,439	8.47	150,004
Cutter with 2 Boosters	3.21	74,183	6.39	147,673
Hopper Dredge with no Booster	18.63	260,820	11.86	166,040
Hopper Dredge with 1 Booster	22.13	429,322	14.65	284,210
Total	59.71	995,723	42.72	764,545

This shows that although the dredge quantity dropped by 40%, the total hp-months dropped by only 23%. Dividing the cubic yards by installed hp-month (a surrogate for energy) shows that the 2004 estimate assumed an average of 26 cubic yards would be dredged per installed hp-month. A similar calculation shows the current estimate assumes an average 21 cubic yards per installed hp-month.

The changes in horsepower and productivity result in an increase in the emissions per cubic yard of dredging that is independent of the load factor or emission factor assumed. This increase is a result of a shift toward more horsepower (i.e. more quantity requiring boosters) and lower production rates.

4.3 Changes to Emissions Calculation Factors

The same emission rate formula was used to calculate the emission rate for both 2004 and 2009 reports:

ER = HP*LF*EF Where: ER = Emission Rate
HP = Engine Horsepower
LF = Load Factor
EF = Emission Factor

Horsepower - The applied equipment horsepower was determined by information contained in the CEDEP estimates provided by the USACE Philadelphia District, and were constant for individual dredge types between the 2004 and 2009 analyses.

Load Factors - The 2004 engine load factors were determined from Table 5-2 of the EPA Report "Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data" (February 2000) using the 'All non-oceangoing' vessel type. It was assumed that the primary engines on the dredges and booster pumps operated at full power (80%) for all hours of operation.

The 2009 load factors were determined from the EPA report "Current Methodologies and Best Practices Guide for Preparing Port Emission Inventories" (January 2006) as well as M&N's expert understanding of dredge operation characteristics. The load factors used are shown in Table 9 below. Other than the clamshell dredge assumption, the differences are slight. The large difference in assumed clamshell load factor does not make a significant contribution to the total emission differences because clamshell dredges represent less than 1% of the work.

Table 9: Load Factor Changes between 2004 and 2009

Dredging Equipment	2004 Report Load Factor	2009 Report Load Factor
Clamshell Dredge	80%	30%
Cutter Suction Dredge	80%	80%
Hopper Dredge	80%	80%
Booster Pump	80%	90%

Overall, the load factor differences do not contribute substantially to the differences in emissions between 2004 and the current study.

Emission Factors - The 2004 emission factors were calculated based on the following formula, according to the algorithm table detailed on page 5-3 of the February 2000 EPA report:

$$EF = a * LF^{(-x)} + b$$

The variables in the equation, (a, x, and b) had the same constant values for each type of equipment in 2004. This meant that the emission estimates for each piece of equipment varied only by the load factor.

In contrast, the 2009 emission factors were estimated using the latest EPA guidance, including the January 2006 EPA report as well as regulatory support guidance for locomotive style engines. This revised method for assigning emission factors is based on individual equipment horsepower and engine category (classified by engine displacement).

A comparison of the emission factors used for the major pieces of equipment between the two studies is shown in Table 10.

Table 10: NOx Emission Factor Changes between 2004 and 2009

Dredging Equipment	2004 Report NOx EF (g/hp-hr)	2009 Report NOx EF (g/hp-hr)
Clamshell Dredge	7.92	10.37
Cutter Suction Dredge	7.92	12.38
Hopper Dredge	7.92	9.84
Booster Pump	7.92	12.38

The NOx emission factors for all four of the major pieces of dredging equipment increased from 24% to 56%.

4.4 Comparison Conclusions

The total project NOx emissions calculated in the current analysis (3,083 tons) are only slightly less than the total project NOx emissions estimated in 2004 (3,290 tons). The marine equipment emissions for the channel deepening only (not including berth deepenings or landside emissions), is 2,859 tons of NOx. In 2004, the marine emissions associated with the channel deepening were 3,083 tons of NOx. This 7% decrease in marine NOx emissions from 2004 to the current study is surprising given that the quantities to be dredged for the channel deepening were reduced from the 2004 project by nearly 40%. The emission rate per 10,000 cubic yards of dredging increased from 1.2 tons per 10,000 cubic yards of dredging in 2004 to nearly 1.8 tons per 10,000 cubic yards of dredging in the current study.

The 50% increase in NOx emissions per volume of dredging is due to a combination of factors. The largest reason for the difference is that the NOx emission factors used in the current study are 24% to 56% higher than those used in 2004. The 2004 study did not make distinctions among the types of engines that are used in the different kinds of dredges; all dredge types used the same emission factor. According to the latest literature, hopper dredge engines are most similar to medium speed ocean-going vessel auxiliary engines and cutter suction and booster pump engines are generally older locomotive style engines. The emission factors were adjusted accordingly, see Table 10 above.

In addition, the scope of work changed, shifting the work toward higher horsepower dredging. For example, the volume of work to be performed by a cutter suction dredge using two booster pumps increased by nearly 60%. This increased the emissions per volume of dredging because boosters are a significant source of emissions. The overall production rate per dredge working month also dropped in the current project. In 2004, the overall production rate of the dredging was roughly 435,000 cubic yards per dredge-month. The current project has an overall production rate of approximately 375,000 cubic yards per dredge-month. This 15% decrease in production increases the emissions per volume of material dredged.

Offsetting some of these increases are decreases in the clamshell dredge emission rates and changes to the assumed load factors. The net result is a 50% increase in the rate of emissions per volume of dredging. After factoring in the reduced volume, the net result is a slight reduction in total tons of NOx generated by the project as compared to the 2004 study. Other pollutants also varied from the 2004 study. Most notably, SOx emissions dropped dramatically with the advent of much lower sulfur level standards in fuel.

5. NOX MITIGATION

5.1 Introduction

Various strategies for offsetting the project NOx emissions were identified for this study. The goal was to calculate a value for the cost-effectiveness (in dollars per ton of NOx reduced per year) of each proposed strategy as well as to evaluate the capacity of each strategy to offset the project emissions in total tons per year.

The following mitigation strategies, as outlined in the scope of work, were studied:

On-site Mitigation:

1. Electrify dredge equipment
2. Install selective catalytic reduction (SCR) units on dredge equipment
3. Repower dredge equipment

Off-site Mitigation:

4. USACE Hopper Dredge McFarland
    a. Installing SCRs
    b. Repowering
    c. Repowering *and* installing SCRs
5. Cape May-Lewes ferries
    d. Installing SCRs
    e. Repowering
    f. Repowering *and* installing SCRs
6. Repowering local tug boats
7. Cold ironing
    g. Packer Ave Marine Terminal
    h. Pier 82
8. Electrifying diesel container cranes at PRPA facilities
9. Purchasing Emission Reduction Credits

For each strategy, M&N calculated the unmitigated and mitigated annual NOx emissions. Subtracting those values yields the tons of NOx reduced per year. The NOx emissions for the off-site strategies are simple because they are the same every year. However, for on-site measures (#1 – 3 above), the NOx emissions and reductions are different from year to year. For these strategies, the annual NOx reduction used to calculate cost effectiveness was the reduction in *project peak annual emissions*.

This is best explained by example. Electrification of dredges is used here for illustration. The peak NOx emissions for the unmitigated project occur in Year 5 (902 tons), but the peak NOx emissions after electrification occur in Year 4 (455 tons). The Year 5 NOx emissions after electrification were only 248 tons. The "Maximum Annual Reduction" for this strategy is (902 – 248) = 654 tons and occurs in Year 5. However, the "Peak Annual NOx Reduction" for this strategy is (902 – 455) = 447 tons. The lower of the two values is used to address the fact that electrification does not achieve a 654 ton reduction every year. This method only gives NOx reduction credit for the reduction in the project's peak year emissions.

M&N used the EPA document titled "Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories" dated April 2009[8] for guidance on load factors, emission factors, and auxiliary engine sizes. The specific tables and factors that were used in this study are included in Appendix F for reference. M&N also estimated the cost for each strategy. The sources for the cost estimates are given in each section.

Dividing the cost for the project by the NOx reductions for a single year gives a cost-effectiveness value that can be used to compare all of the emission reduction strategies under consideration.

5.2 Unmitigated NOx Emissions

The total project NOx emissions are estimated to be 3,038 tons. The vast majority of these emissions (2,820 tons) are associated with the marine equipment used on the channel deepening. A breakdown for each of the seven planned deepening contracts broken out by dredge type is shown in Figure 2 below. The emissions included in the chart below are the total marine emissions for the deepening project (2,820 tons) and do not include mobilization, landside emissions or the berth deepenings.

[8] This document can be found at http://www.epa.gov/ispd/ports/bp_portemissionsfinal.pdf.

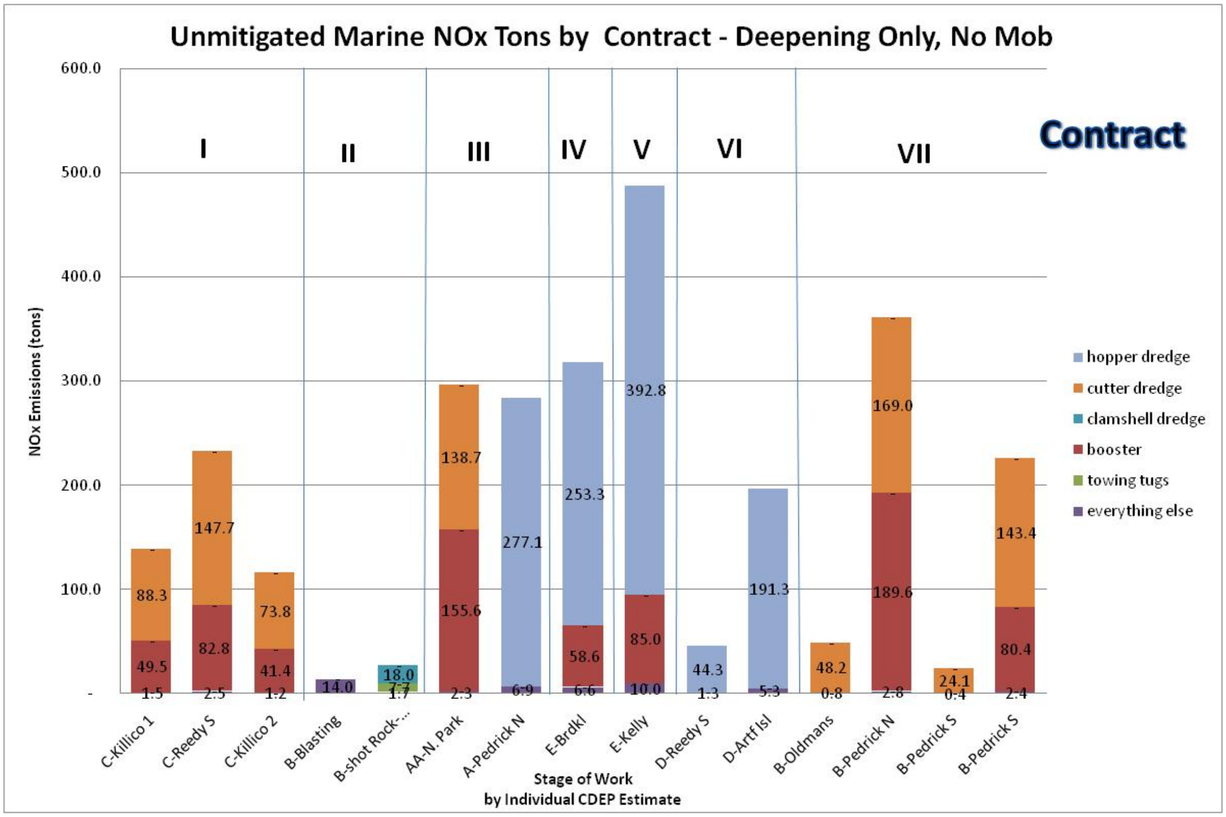


Figure 2: Unmitigated Marine NOx Emissions, channel deepening by Contract and Source Type

5.3 Cost Effectiveness Comparison

Table 11 on the next page and Figure 3 on the following page summarize the results of all 14 mitigation strategies evaluated.

Table 11: Summary of On-Site and Off-Site Results

	NOx Tons														
	On-Site Emission Reduction Strategies				Offsite Emission Reduction Strategies										
	Base	Project Mitigation			USACE TSHD McFarland			Cape May Ferries			Local Tugs	PRPA			Credits
		1	2	3	4a	4b	4c	5a	5b	5c	6	7a	7b	8	9
	Project Unmitigated	Cutter & Clam Dredges, Boosters & Towing Tugs Electrify	Dredges Boosters & Towing Tugs SCR	Dredges Boosters & Towing Tugs Repower	McFarland SCR (no repower)	McFarland Repower (no SCR)	McFarland Repower w/SCR	Cape May Ferries SCR (no repower)	Cape May Ferries Repower (no SCR)	Cape May Ferries Repower w/SCR	Local Harbor Tug Repower w/SCR	Cold Ironing PRPA Packer Ave	Cold Ironing PRPA Pier 82	Electrify Diesel Dock Cranes PRPA Packer Ave	Purchase Offsets
Total Project Tons	3,037	1,370	429	2,049											
Peak Annual Tons	902	455	107	579											
Maximum Annual Reduction	0	654	798	323											
Peak Annual NOx Reduction	0	447	795	323											
Total Annual Unmitigated Tons					198	198	198	375	375	375	108	69	33	75	n/a
Annual Tons Eliminated					182	64	187	348	138	355	28	48	31	73	1
% reduction					92.0%	32.4%	94.6%	92.9%	36.8%	94.7%	25.8%	69.3%	95.1%	97.4%	
Peak Annual Tons After Mitigation	902	455	107	579	720	838	715	554	764	547	874	854	871	829	
Reduction of Peak Annual Tons		447	795	323	182	64	187	348	138	355	28	48	31	73	1
Total Cost		$30,500,000	$7,900,000	$92,600,000	$1,700,000	$20,000,000	$21,700,000	$1,500,000	$19,100,000	$20,400,000	$12,500,000	$47,500,000	$11,000,000	$14,100,000	$10,000
$/Annual Ton (peak reduction)		$68,000	$10,000	$286,000	$9,000	$312,000	$116,000	$4,000	$138,000	$57,000	$448,000	$991,000	$355,000	$194,000	$10,000

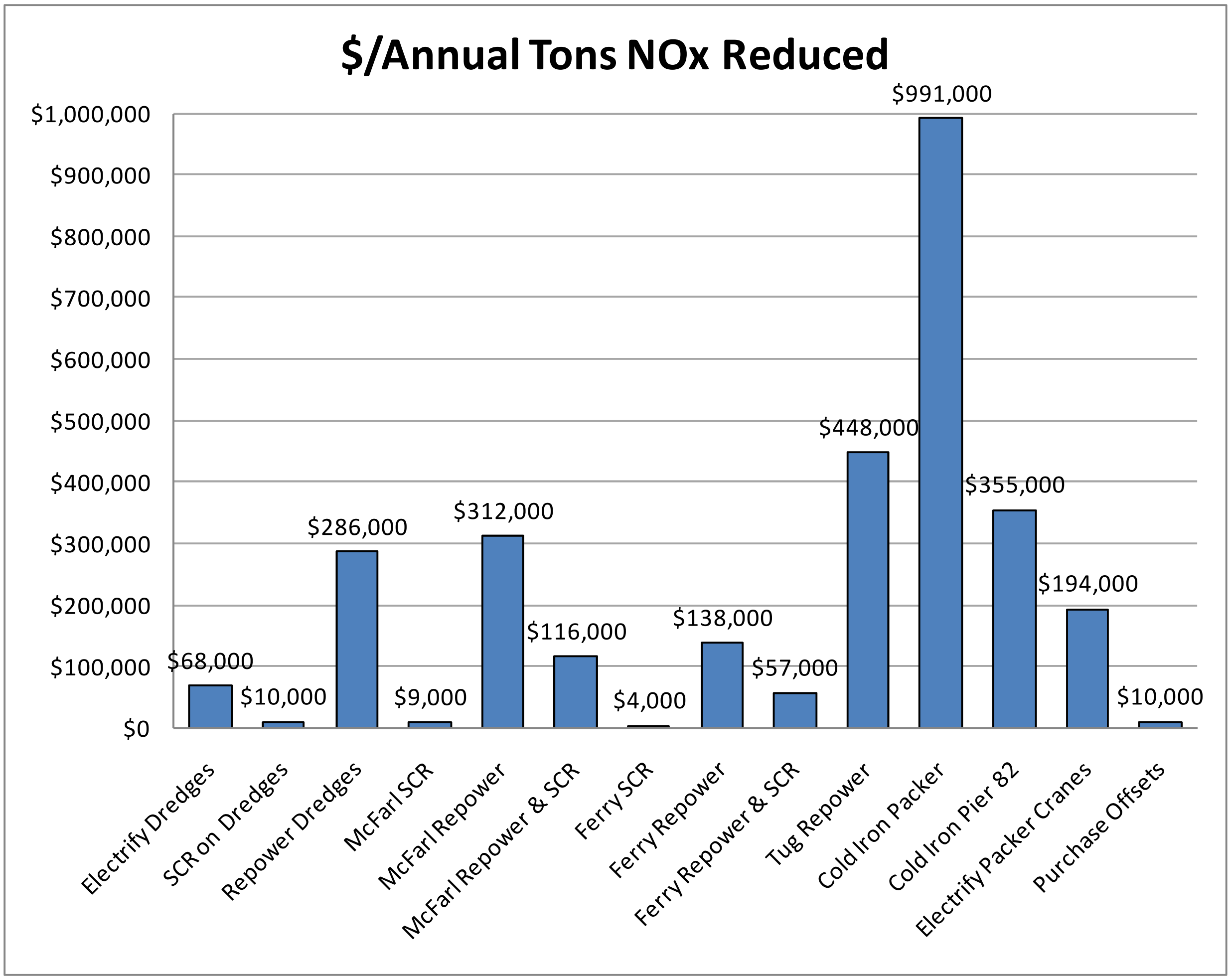


Figure 3: Cost Effectiveness of Each Strategy

On the basis of cost effectiveness, installing SCR technology on the Cape May Ferries is the most attractive option.

The number of tons estimated to be eliminated by each strategy is shown in Figure 4 below.

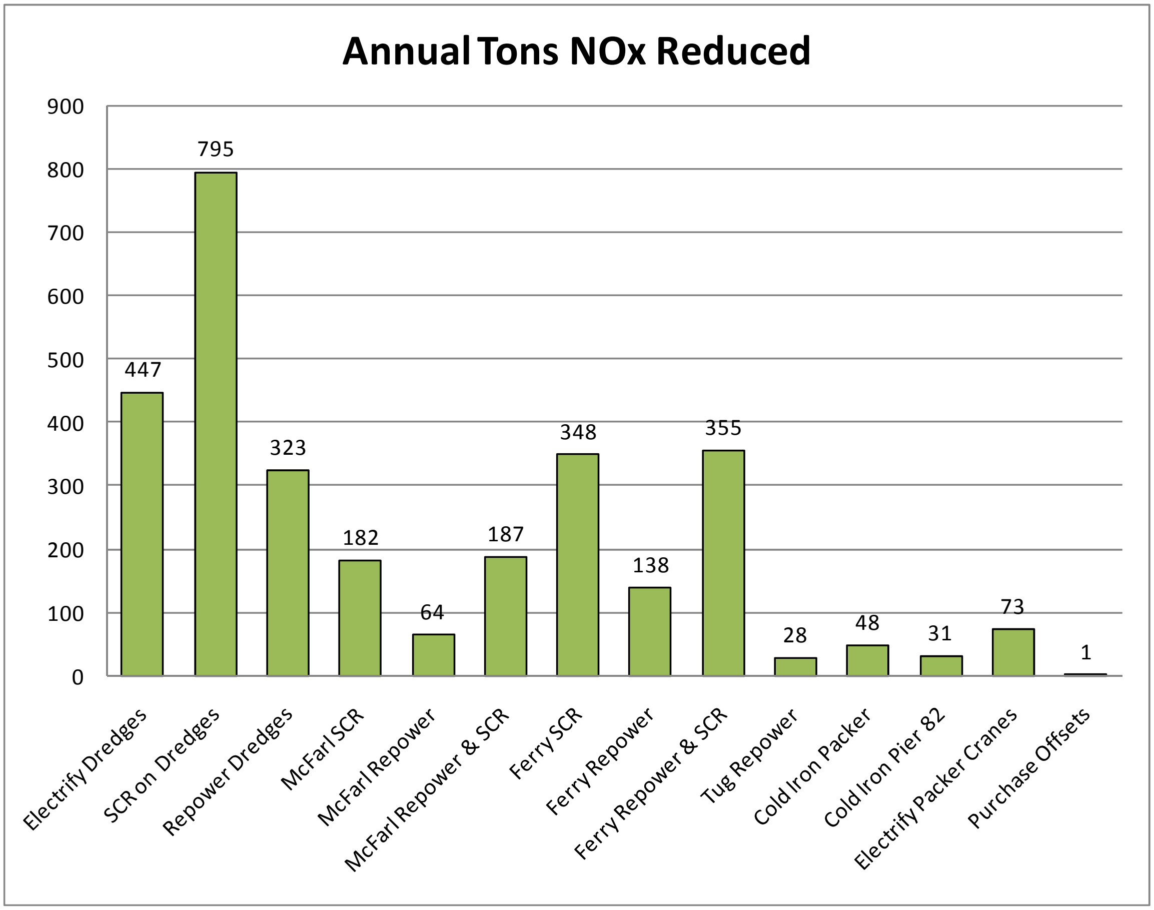


Figure 4: Annual Tons of NOx Reduced, by Strategy

The remaining peak annual emissions after the implementation of each of these strategies are shown graphically in Figure 5.

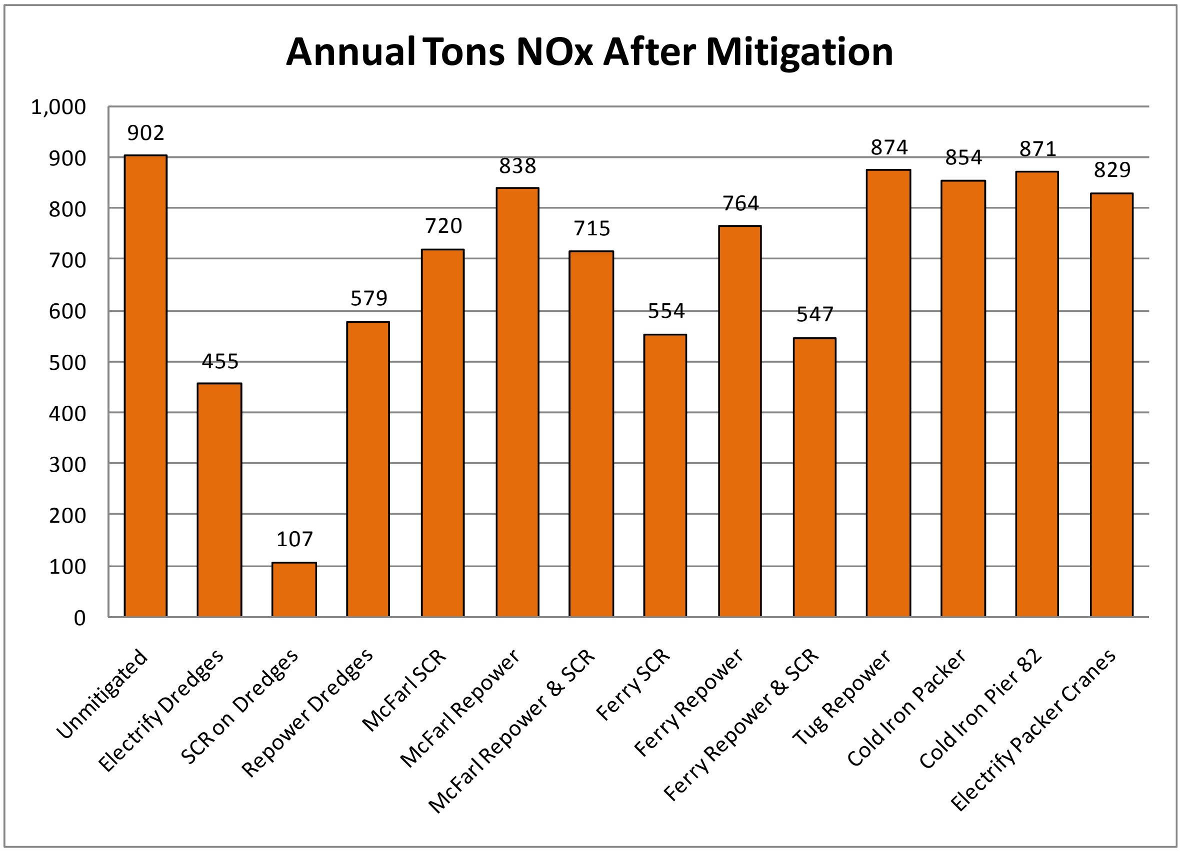


Figure 5: Annual Peak Tons of NOx for Project after Mitigation

Since none of the strategies completely offsets the project emissions, some combination of the identified mitigation measures (along with any purchased offset credits) will be required to offset the project emissions to zero. Installing SCR systems on the project dredges comes very close to getting to the 100 ton annual de minimis level.

6. ON-SITE STRATEGIES

6.1 Summary Results

Using the same project emissions model applied to the baseline emissions estimate, M&N evaluated the profile of emissions over time for each of the three on-site mitigation measures. These estimates are based on project schedules for the channel and berth deepenings provide by the USACE (given in Appendix D).

The total annual emissions are shown in Figure 6 for the unmitigated project and for each of the on-site mitigation strategies studied: repowering, electrification, installing SCRs.

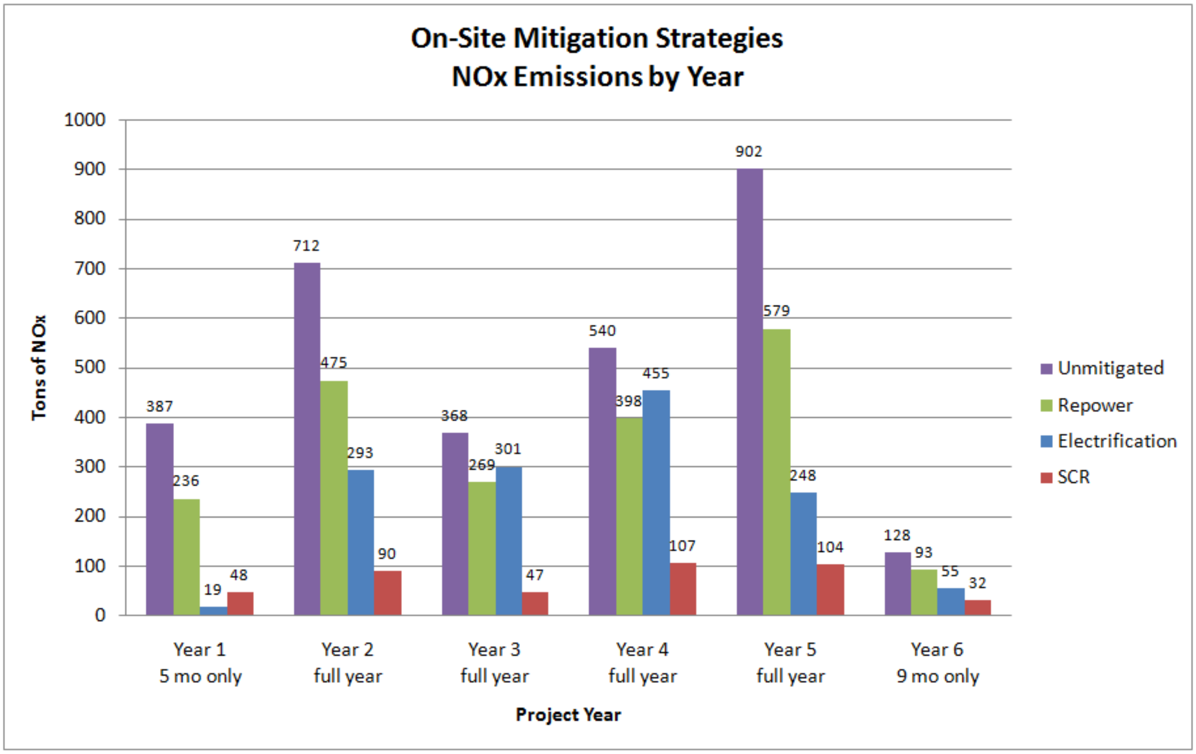


Figure 6: NOx Emissions by Year for On-Site Mitigation Strategies

Subtracting the mitigated annual emissions (the total emissions after the mitigation was applied) for each scenario from the baseline emissions yields the total tons eliminated by each on-site mitigation strategy. These NOx reductions are shown graphically in Figure 7 below.

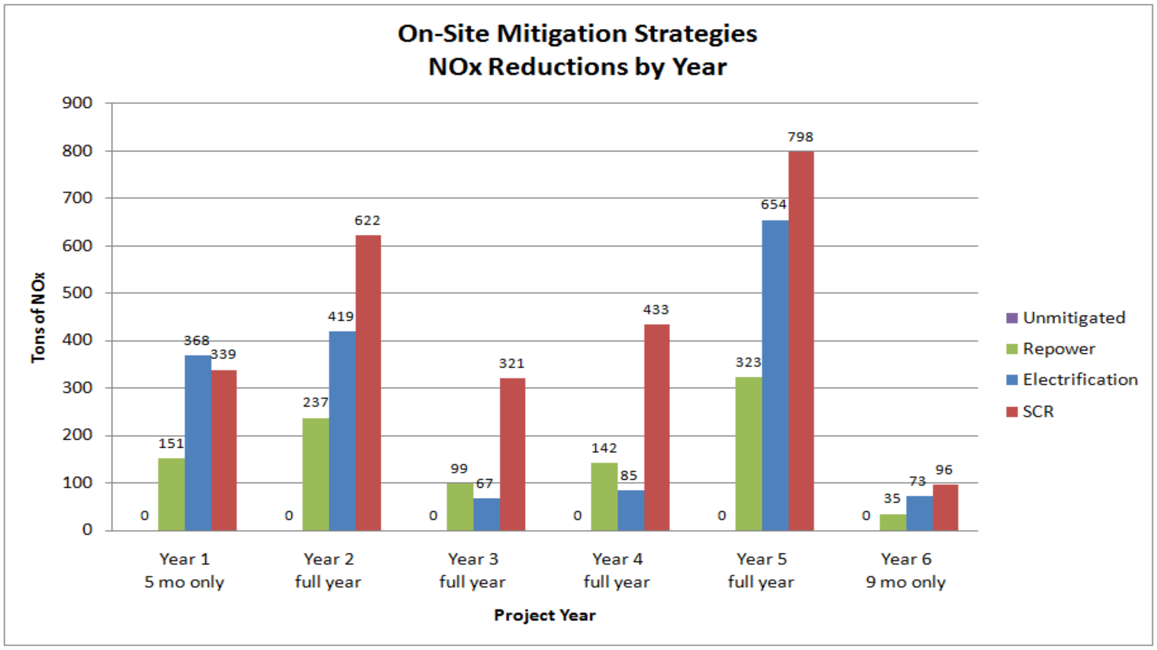


Figure 7: NOx Reductions by Year for On-Site Mitigation Strategies

Table 12: Summary of On-Site Mitigation Results

		Unmitigated	Electrification	SCR	Repower
Emission Reductions					
	Total Tons	3,037	1,370	429	2,049
	Total Tons Eliminated	0	1,667	2,608	988
	Average Tons Eliminated /yr	0	278	435	165
	Peak Tons	902	455	107	579
	Maximum Annual Reduction	0	654	798	323
	Peak Annual NOx Reduction	0	447	795	323
Cost - Electrification					
	# of Substations		6		
	$/Substation		$3,000,000		
	Dredge / Booster Converstions		5		
	$/Dredge Conversion		$2,500,000		
	Total Cost Electrification		$30,500,000		
Cost SCR & Repower					
	# of Cutter Suction Dredges			2	2
	Installed Hp of CSD			12,310	12,310
	# of Clamshell Dredges			1	1
	Installed Hp of Clamshell Dredges			8,310	8,310
	# of Towing Tugs			2	2
	Installed Hp of Towing Tugs			3,000	3,000
	# of Hopper Dredges			2	2
	Installed Hp of Hopper Dredges			15,000	15,000
	# of Boosters			2	2
	Installed Hp of Boosters			5,200	5,200
	Total Installed Hp			79,330	79,330
	Unit Cost ($/HP)			$100.00	$1,167.00
	Total Cost		$30,500,000	$7,933,000	$92,578,110
$/Annual ton (peak reduction)			$68,212	$9,979	$286,370

6.2 Strategy 1 – Electrify Dredges

In the electrification option, all cutter suction, boosters, and clamshell dredges are plugged into a shore side electrical grid. Other significant sources of emissions which are not electrified include hopper dredges and clamshell dredge towing tugs. Because these vessels are very mobile, it is not practical to plug them into the shore side grid. Drillboats and attendant plants such as crewboats, scows and tender tugs remain unmitigated in this option. The NOx emission factor for the electrified equipment is zero.

Running large cutter suction and clamshell dredges on electricity is fairly common in California. Deepening projects in Oakland, Los Angeles, and Long Beach have all used electric dredges. Cutter suction dredging in the Houston area has also been done by electrically powered dredges. In these applications, there is typically a shoreline substation installed on port property. The contractor plugs into this shoreline substation and pays the cost of the electricity used. The connection between the substation and dredge is via an electrical umbilical cord (typically 750 mcm, 3 conductor cable) laid on the seabed which is deployed and retrieved using large reels mounted on small "reel barges." The practical limit to the amount of submarine cable that can be handled and the time involved in finding a fault when submarine cable lengths are excessive requires a substation within three miles of the dredge areas. This means there would need to be a substation every six miles along the channel length for this project.

M&N had several conversations and conference calls with the local utilities to discuss the availability and location of the required power. In general, it seems that the capacity is reasonably available on the Delaware and Pennsylvania side of the river, but some areas in Southern New Jersey may have difficulty providing capacity.

The utility asked M&N to provide a written request for a drawing showing the details of the existing transmission lines. Although that letter was provided to the utility by the USACE, the utility was ultimately unwilling to send the drawing due to security concerns. In the interest of time, M&N moved forward using other drawings that were available along with information provided orally in conference calls with the utility. The transmission grid drawing used is shown in Figure 8 below.

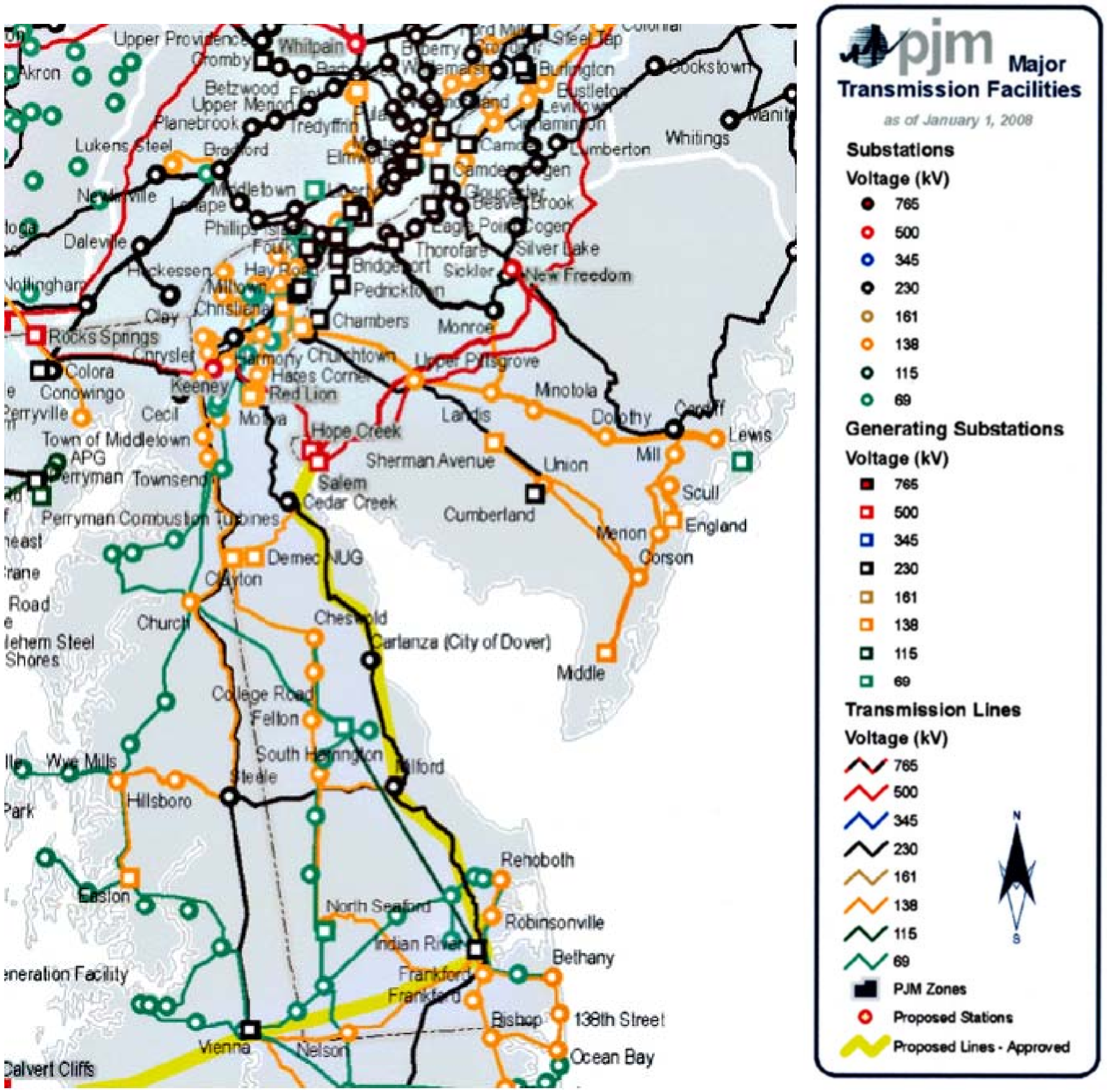


Figure 8: Electrical Transmission Grid

As described above, M&N assumed a substation would be built on the shoreline for every six miles of channel to be dredged using electric power. With most of the outer half of the project planned for hopper dredging (reaches D&E), this results in six new substations over roughly 35 miles of river. Detailed information on how much new power line would be required to connect a shore side substation to the local grid was not available from local utilities. Therefore, M&N estimated a substation installation cost of $3,000,000 each based on experience.

The number of dredges that would actually be converted to electric operation depends in part on how many different contractors execute the seven deepening contracts and whether existing dredges with electric capability are available for the work. For the purposes of this study, M&N assumed five total conversions (dredges, boosters, tugs) with an average cost of $2.5 million each.

Although this mitigation measure is technically feasible, as evidenced by its application elsewhere, M&N concluded that it is not viable for this project. The number of substations required, the uncertainty in regard to land rights, the environmental actions necessary to run new transmission lines, and the timing to achieve all of this relative to the project schedule lead to this conclusion.

6.3 Strategy 2 – Install SCR on Dredges, Boosters, and Towing Tugs

The SCR option assumes that all dredges, boosters and towing tugs are outfitted with SCR units. Drillboats and attendant plant equipment such as crewboats, scows, and tender tugs are assumed to remain as unmitigated diesel power. The NOx emission factors for equipment with SCR were reduced from the unmitigated level by 92%.

The application of SCR on large dredges is limited to one 10,000 hp cutter suction dredge on the west coast that has operated a urea injection system since the late 1990's with reportedly excellent results.

Cost for SCR installation assumes that two each of cutter suction dredges, boosters, towboats and hopper dredges will require retrofitting with SCRs throughout the seven contract execution of the deepening. One clamshell dredge is assumed to be retrofitted with an SCR. The number of dredges that will actually be retrofitted depends in part on how many different contractors execute the anticipated seven deepening contracts and if a currently SCR capable dredge is available for the work.

The estimated unit cost for SCR installation of $100/hp is based on estimates provided for an SCR installation on the dredge Essayons as well as research done with SCR vendors for the ferry SCR option (see discussion of Strategy 5 below for further details). For the purposes of this study, M&N increased the estimated unit cost from $72/hp for the Essayons and $88/hp for the ferries to $100/hp to be conservative. This was done to account for complications that may be encountered on the various installations.

6.4 Strategy 3 – Repower Dredges, Boosters, and Towing Tugs

The repower option assumes that all dredges, boosters and towing tugs are repowered with modern low emitting (Tier 2) engines. Drillboats and attendant plant such as crewboats, scows and tender tugs are assumed to remain as unmitigated diesel power. Emission factors in the emission and schedule model were reduced to 7.3 gr/bhp-hr for these engines and the model was rerun to find the mitigated emissions per year.

The application of Tier 2 engines on large dredges is fairly new but has been done for some specific engines. Some recent repowers of isolated engines on large cutter suction or hopper dredges have occurred, but an entire repowering with Tier 2 engines has not been done in the industry yet. However, M&N sees no reason to expect major difficulty implementing this alternative as the engine technology is well proven.

The repowering cost estimate assumes that two each of cutter suction dredges, boosters, towboats and hopper dredges will require repowering with Tier 2 engines throughout the seven contracts of the deepening. One clamshell dredge is assumed to be repowered as well. The number of dredges that would actually be repowered depends in part on how many different contractors execute the seven different contracts. Cost for repowering assumed a unit price of $1,167/hp based on input from the Marine Design Center (see detailed discussion in strategy 5). This cost includes both the engines and installation.

The technical feasibility of this option is not in question given that new, cleaner engines have already been installed on dredges and more will undoubtedly be installed as these engines naturally turn over with retirements and new engine replacements. However, the turnover rate for dredge engines is low, and in some cases they may be replaced with rebuilt older style engines rather than new low emitting engines. Therefore, it cannot be assumed that later phases of the project will be dredged with much lower emitting engines as a result of the normal course of engine replacement. It is expected that a minimum of 12 months would be required to secure a new engine and install it on a dredge. That schedule makes this option incompatible with the first deepening contract but it is a candidate for future phases of the deepening.

7. OFF-SITE STRATEGIES

7.1 Summary Results

Table 13, on the next page, summarizes the results of the off-site mitigation strategies.

Table 13: Summary of Off-Site Mitigation Results

	2.4.1 McFarland	2.4.2a McFarland	2.4.2b McFarland	2.4.3a Cape May Ferries	2.4.3b Cape May Ferries	2.4.3c Cape May Ferries	2.4.4 Local Tugs	2.4.5a Cold Ironing	2.4.5b Cold Ironing	2.4.6 Electrify Cranes
	Repower w/SCR	SCR (no repower)	Repower (no SCR)	SCR (no repower)	Repower (no SCR)	Repower w/SCR	Repower (no SCR)	PRPA Packer Ave	PRPA Pier 82	PRPA Packer Ave
Number of pieces of equip	1 dredge	1 dredge	1 dredge	4 of 5 ferries	4 of 5 ferries	4 of 5 ferries	2 tugs	2 berths 25 vessels 155 calls	1 berth 4 vessels 53 calls	5 of 7 cranes
Total Engine Power (hp)	6,400 (Propulsion) 6,480 (Pumps) 2,000 (Auxiliary)	6,400 (Propulsion) 6,480 (Pumps) 2,000 (Auxiliary)	6,400 (Propulsion) 6,480 (Pumps) 2,000 (Auxiliary)	4 x 4,100 = 16,400	4 x 4,100 = 16,400	4 x 4,100 = 16,400	4,200 + 3,520 + 3,000 = 10,720	7,565 (avg aux engine size per vessel)	2 vessels @ 6,080 2 vessels @ 2,230	2 x 2,000 + 1 x 1,600 + 2 x 1,800 = 9,200
Total engine hours	1,070 (Propulsion) 954 (Pumps) 2,076 (Auxiliary)	1,070 (Propulsion) 954 (Pumps) 2,076 (Auxiliary)	1,070 (Propulsion) 954 (Pumps) 2,076 (Auxiliary)	9,577	9,577	9,577	9,000	2,917	1,827	19,000
Load Factor	80%	80%	80%	85%	85%	85%	31%	19%	32%	21%
Unmitigated NOx Emission Factor (g/bhp-hr)	12.0 - 14.0	12.0 - 14.0	12.0 - 14.0	10.0	10.0	10.0	9.8	10.4	10.4	6.79 - 15.5 depending on crane
Mitigated NOx Emission Factor (g/bhp-hr)	0.53	0.96 – 1.12	6.64	0.5	6.2	0.31	7.3	0	0	0
Annual Tons of NOx Unmitigated	197.7	197.7	197.7	375.1	375.1	375.1	108.2	69.1	32.6	74.6
Annual Tons of NOx Reduced	187.0	181.9	64.1	348.3	138.1	355.2	27.8	47.9	31.0	72.6
Percent Reduction	94.6%	92.0%	32.4%	92.9%	36.8%	94.7%	25.7%	69.3%	95.1%	97.3%
Estimated Cost	$21.65M	$1.65M	$20M	$1.45M	$19.1M	$20.4M	$12.5M	$47.5M	$11M	$14.1M
$/Ton of NOx per year	$115,753	$9,071	$311,933	$4,167	$138,596	$57,384	$448,683	$991,200	$355,406	$194,235

In terms of cost-effectiveness, installing SCRs on the Cape May ferries is the best off-site strategy.

7.2 Strategy 4 – McFarland

The McFarland is the USACE dredge for regional operations and maintenance dredging. It is a hopper dredge built in 1967.

Table 14 below summarizes the average daily running hours for the different types of engines aboard the McFarland. The information in this table is from the 2004 report and was compiled from five years worth of daily reports, 1999 to 2003.

Table 14: McFarland – Engine Running Hours

		Total Hours	Propulsion Engines	Dredge Pump Engines	Generator Engines		
		avg daily hrs	avg daily hrs	avg daily hrs	avg daily hrs		
Sailing	To & from disposal	9.20	9.20		9.20	9.87	41.6%
	To & from anchorage	0.35	0.35		0.35		
	Loss time due to traffic & bridges	0.05	0.05		0.05		
	Loss due to mooring barges	0.08	0.08		0.08		
	Transferring between works	0.17	0.17		0.17		
	Fire & boat drills	0.02	0.02		0.02		
Dredging	Pumping	1.50	1.50	1.50	1.50	2.03	8.5%
	Turning	0.06	0.06		0.06		
	Loss due to natural elements	0.47	0.47		0.47		
Disposal	Bottom dumping	0.34	0.34		0.34	9.75	41.1%
	Pump off	9.41		9.41	9.41		
	Generator only	2.10			2.10	2.10	8.8%
	Average hours per day	23.75	12.24	10.91	23.75	23.75	100.0%

UNMITIGATED NOx CALCULATIONS

Table 15 shows the NOx emissions for the McFarland without any mitigation measures applied. These emissions form the baseline for this portion of the study.

Table 15: McFarland – Unmitigated NOx Emissions

Mode	Engine	Horsepower Utilized	Annual Hrs of Operation	Load Factor	NOx Factor (g/hp-hr)	Emissions (tons/hr)	Annual Tons of NOx
Propulsion Only	1967 Propulsion (x3)	4800	863	0.80	14.00	0.0593	51.1
	1982 Propulsion	1600	863	0.80	12.00	0.0169	14.6
Dredging	1967 Propulsion (x3)	2400	178	0.80	14.00	0.0296	5.3
	1982 Propulsion	800	178	0.80	12.00	0.0085	1.5
	Dredge Pump (x2)	4320	131	0.80	14.00	0.0533	7.0
Dumping	1967 Propulsion (x3)	2400	29	0.80	14.00	0.0296	0.9
	1982 Propulsion	800	29	0.80	12.00	0.0085	0.2
Pumpoff	Dredge Pump (x3)	6480	823	0.80	14.00	0.0800	65.8
All Times	Auxiliary Generator (x2)	2000	2076	0.80	14.00	0.0247	51.3
					Totals	**0.3104**	**197.7**

The 80% load factor and NOx emission factor of 12.0 – 14.0 g/bhp-hr comes from the 2004 General Conformity and mitigation analysis report. These emission factors are reasonably consistent with the new emission factors used for the locomotive style engines assumed in the channel dredging estimates, therefore they were left unchanged.

7.3 Strategy 4a – SCR Installation (no repower)

NOx CALCULATIONS

It was assumed that the NOx reductions achieved by the SCRs would be 92%, which allows for time spent in warm-up and light load. Therefore, the emission factors were reduced to 8% of the unmitigated factors in the calculation summarized in Table 16.

Table 16: McFarland –NOx Emissions with SCR Only

Mode	Engine	Horsepower Utilized	Annual Hrs of Operation	Load Factor	NOx Factor (g/hp-hr)	Emission Rate (tons/hr)	Annual Tons of NOx	Annual Reduction (Tons NOx)
Propulsion Only	1967 Propulsion (x3)	4800	863	0.80	1.12	0.0047	4.1	47.0
	1982 Propulsion	1600	863	0.80	0.96	0.0014	1.2	13.4
Dredging	1967 Propulsion (x3)	2400	178	0.80	1.12	0.0024	0.4	4.9
	1982 Propulsion	800	178	0.80	0.96	0.0007	0.1	1.4
	Dredge Pump (x2)	4320	131	0.80	1.12	0.0043	0.6	6.4
Dumping	1967 Propulsion (x3)	2400	29	0.80	1.12	0.0024	0.1	0.8
	1982 Propulsion	800	29	0.80	0.96	0.0007	0.0	0.2
Pumpoff	Dredge Pump (x3)	6480	823	0.80	1.12	0.0064	5.3	60.6
All Times	Auxiliary Generator (x2)	2000	2076	0.80	1.12	0.0020	4.1	47.2
					Totals	**0.0248**	**15.8**	**181.9**

COST ESTIMATE

The estimated cost to install SCR on the McFarland is $1.65M. This is based on an estimate prepared for a similar SCR installation on board the dredge Essayons in California.

This yields a cost-effectiveness of **$9,071 per ton of NOx reduced per year**.

The technical feasibility of this option is not in question given that SCRs have been successfully installed on dredges in the past. However, the details of an installation would need to be worked out in a design specific to this vessel. It is expected that a minimum of 12 months would be required to design, build and install the SCR system. That schedule makes this option incompatible with the first deepening contract but it is a candidate for future phases of the deepening.

7.4 Strategy 4b – Repower (no SCR)

The repower would replace the ten existing engines with three new engines – two main engines and a smaller auxiliary engine for the when the mains are off. A USACE document titled "Dredge McFarland 2005" published in August 2002 describes the repower and gives an estimate for the cost.

NOx CALCULATIONS

The same 80% load factor was used for the repower calculations, but the emission factor drops to 6.64 g/bhp-hr, as shown in Table 17.

Table 17: McFarland –NOx Emissions with Repower Only

Mode	Engine	Horsepower Utilized	Annual Hrs of Operation	Load Factor	NOx Factor (g/hp-hr)	Emissions (tons/hr)	Annual Tons of NOx
Propulsion Only	*New Main Engines (x2)*	12000	863	0.80	6.64	0.0703	60.6
Dredging	*New Main Engines (x2)*	12000	178	0.80	6.64	0.0703	12.5
Dumping	*New Main Engines (x2)*	12000	29	0.80	6.64	0.0703	2.0
Pumpoff	*New Main Engines (x2)*	12000	823	0.80	6.64	0.0703	57.8
Idle	*Auxiliary Generator*	2000	51	0.80	6.64	0.0117	0.6
					Totals	**0.2928**	**133.6**

The annual NOx emissions would drop from 197.7 tons to 133.6 tons, a reduction of 64.1 tons per year.

COST ESTIMATE

The USACE cost estimate from the August 2002 paper is $20M. This includes the design, purchase, and installation costs.

This yields a cost-effectiveness of **$311,933 per ton of NOx reduced per year**.

The technical feasibility of this option is not in question given that engine replacements have been performed on hopper dredges in the past; including the USACE hopper dredge Essayons. However, a detailed design would have to be done. It is expected that a minimum of 18 months would be required to design, build and install the new engines. That schedule makes this option incompatible with the first deepening contract but it is a candidate for future phases of the deepening.

7.5 Strategy 4c – Repower and SCR Installation

In this strategy, the McFarland would be repowered and have SCR units installed on the new engines. In this case, the SCR reduction of 92% is taken off the updated emission factor of 6.64 g/bhp-hr.

NOx CALCULATIONS

Table 18 shows the NOx calculations for the McFarland with SCRs on new engines.

Table 18: McFarland –NOx Emissions with SCR *and* Repower

Mode	Engine	Horsepower Utilized	Annual Hrs of Operation	Load Factor	NOx Factor (g/hp-hr)	Emissions (tons/hr)	Annual Tons of NOx
Propulsion Only	*New Main Engines (x2)*	12000	863	0.80	0.53	0.0056	4.9
Dredging	*New Main Engines (x2)*	12000	178	0.80	0.53	0.0056	1.0
Dumping	*New Main Engines (x2)*	12000	29	0.80	0.53	0.0056	0.2
Pumpoff	*New Main Engines (x2)*	12000	823	0.80	0.53	0.0056	4.6
Idle	*Auxilliary Generator*	2000	51	0.80	0.53	0.0009	0.0
					Totals	**0.0234**	**10.7**

The annual NOx emission would drop from 197.7 tons to 10.7 tons, a reduction of 187.0 tons per year.

COST ESTIMATE

The cost estimate for a combined repower and SCR installation was estimated at $21.65M ($20M for the repower plus $1.65M for the SCR units).

This yields a cost-effectiveness of **$115,753 per ton of NOx reduced per year**.

The technical feasibility of this option is not in question given that engine replacements and SCR installations have been performed on dredges in the past. However, the details of a repowering and SCR installation would need to be worked out in a detailed design for this specific vessel. It is expected that a minimum of 18 months would be required to design, build and install the new engines with SCR systems. That schedule makes this option incompatible with the first deepening contract but it is a candidate for future phases of the deepening.

7.6 Strategy 5 – Cape May-Lewes Ferries

The Cape May-Lewes ferries were identified as the best candidates for project mitigation of the ferries in the region. They run a fleet of five older vessels. All five ferries have the same hull and engine design. The two main engines combined are 4,100 hp. The first three were built in the early 1970's, the later two were built in the early 1980's. Two of the ferries were refurbished in the late 1990's when an upper deck was added. At that time, new generators were installed to run larger air conditioning units on board. The main engines were not modified, though.

The capacity of the ferries is approximately 900 people and 100 vehicles. The one-way passage from Cape May to Lewes takes about 80 minutes. There are anywhere from four to eleven round trips per day, depending on holidays and seasons.

M&N determined that four of the five Cape May ferries would be good candidates for mitigation (either SCR or repower). The fifth ferry only operated 220 hours in 2008 – fuel consumption is high on this vessel because of the second deck, so they use it less often – whereas the other four ferries operate 2,400 hours per year on average.

7.7 Strategy 5a - SCR Installation (no repower)

The team researched SCR installations on ferries to determine the viability and approximate cost for this strategy. SCR units have been installed on a total of six ferries in the U.S. Four of those ferries are in operation today, with a fifth ferry being delivered within a month of this writing. The sixth SCR installation on an existing ferry was not successful in the end.

For different reasons, none of the six installations is a good cost comparison for the Cape May ferries. Two of the ferries were new builds, so the engines and engine compartments were designed to accommodate SCR units. This is easier than trying to fit SCR units into existing engine compartments and layouts. Two other ferries had engine repowers done at the same time as the SCR installation, which also reduces the cost for SCR. All four of these vessels are also smaller, light weight, high speed passenger-only ferries.

The fifth SCR installation on a ferry is a fair comparison in terms of ship size and no accompanying repower, but that vessel (a Staten Island NY ferry named "Alice Austen") was the first ever SCR installation on a ferry. As such, the project cost was likely higher than it would be today because they were addressing many issues (such as safety, training, Coast Guard permitting, etc) for the first time. There have also been many improvements in SCR technology. Most notably, there have been significant advances in reducing the size of the units since the Alice Austen design started in early 2004.

NOx CALCULATIONS

Engine information for the Cape May Ferries and their 2008 running hours[9] are given in Table 19 below along with estimated NOx emissions. Emissions were calculated using a load factor of 85% and an emission factor of 10.0 g/bhp-hr (13.36 g/bkW-hr), as recommended by the EPA in Tables 3-3 and 3-5 of the April 2009 document.

Table 19: Cape May Ferries – NOx Emissions, SCR Only

Vessel Name	Engine Year	Annual Operating Hours	Unmitigated NOx (tons/yr)	NOx Reduction (tons/yr)
Cape May	1984	220	8.4	0.0
Cape Henlopen	1980	2,560	98.0	93.1
Twin Capes	1973	2,146	82.2	78.1
Delaware	1973	2,164	82.9	78.7
New Jersey	1973	2,707	103.6	98.5
		Total	375.1	348.3

It was assumed that the SCR units would reduce the NOx emissions by 95%. SCRs have been proven to reliably achieve reductions around 97%[10]. With the relatively long route (80 minutes each way) it was assumed the SCRs would be highly effective.

[9] From information given to M&N by Captain Bryan C. Helm of the Cape May – Lewes Ferries via email, phone, and fax on 5/22/09.

[10] Results for SCR performance on San Francisco Bay ferries can be found here http://www.efee.com/scr.html.

COST ESTIMATE

Without good cost comparables, the team turned to Engine Fuel and Emissions Engineering, Inc (EFEE) to get a preliminary cost estimate for the Cape May ferries. EFEE is the company that performed the design for four of the five ferries running SCR today (Argillon, Inc did the design for the Alice Austen). EFEE's estimated cost for purchase and installation is $363,000 per ferry, which corresponds to $88/hp.

EFEE recently bid on an SCR project for the USACE dredge *Essayons*. The bid cost for the purchase and installation of SCR on seven engines, totaling 23,000 hp, came in at $1.65M. On a per horsepower basis, this comes to $72/hp. This shows that the estimate of $363k per ferry is in the same range as the *Essayons* bid.

The total cost for installing SCRs on four ferries is estimated at $1.45M.

This yields a cost-effectiveness of **$4,167 per ton of NOx reduced per year**.

The technical feasibility of this option is not in question given that SCRs have been successfully installed on several ferries. However, the details of an SCR installation and the willingness of the ferry operator to participate would need to be worked out in a detailed design and negotiation. It is expected that a minimum of 18 months would be required to work out the terms of an agreement, design, build and install the SCR systems. That schedule makes this option incompatible with the first deepening contract but it is a candidate for future phases of the deepening.

7.8 Strategy 5b - Repower (no SCR)

This part of the study analyzes the NOx benefits if the ferries had new Tier II engines installed without the SCR units. Again, it was assumed that the Cape May would not be repowered since it is used so infrequently.

NOx CALCULATIONS

The NOx emission factor drops from 10.0 g/bhp-hr (13.36 g/bkW-hr) for a Tier 0 engine to 6.2 g/bhp-hr (8.33 g/bkW-hr) for a new Tier II engine, as recommended by the EPA in Table 3-5 of the April 2009 document. The same load factor of 85% is used. The NOx emission reduction results are shown in Table 20.

Table 20: Cape May Ferries – NOx Emissions, Repower Only

Vessel Name	Engine Year	Annual Operating Hrs in 2008	Unmitigated NOx (tons/yr)	Mitigated (Tier II) NOx (tons/yr)	NOx Reduction (tons/yr)
Cape May	1984	220	8.4	8.4	0
Cape Henlopen	1980	2,560	98.0	61.1	36.9
Twin Capes	1973	2,146	82.2	51.2	30.9
Delaware	1973	2,164	82.9	51.7	31.2
New Jersey	1973	2,707	103.6	64.6	39.0
		Total	375.1	237.0	138.1

COST ESTIMATE

The cost for a ferry repower, according to the Marine Design Center, is $3.5M for a 3,000 hp engine. This includes the purchase and installation cost. For a 4,100 hp vessel, the cost was extrapolated to $4.78M per ferry.

The total cost for four ferries is estimated at $19.1M.

This yields a cost-effectiveness of **$138,596 per ton of NOx reduced per year.**

The technical feasibility of this option is not in question given that engine replacements on ferries such as these are not uncommon. However, the details of an engine replacement and the willingness of the ferry operator to participate would need to be worked out in a detailed design and negotiation. It is expected that a minimum of 18 months would be required to work out the terms of an agreement, design, build and install the new engines. That schedule makes this option incompatible with the first deepening contract but it is a candidate for future phases of the deepening.

7.9 Strategy 5c - Repower and SCR Installation

This part of the study explores the cost effectiveness for both repowering and installing SCRs on the ferries. Again, it was assumed that the SCRs would reduce the NOx emissions by 95%. The SCR emission reductions in this case would be in addition to the reductions already achieved by the engine repower.

NOx CALCULATIONS

Table 21 summarizes the NOx emissions and NOx reductions from repowering and installing SCRs on the Cape May ferries.

Table 21: Cape May Ferries – NOx Emissions, Repower *and* SCR

Vessel Name	Unmitigated NOx (tons/yr)	NOx After Repower (tons/yr)	NOx After SCR Added to Repower (tons/yr)	Total NOx Reduction (tons/yr)
Cape May	8.4	8.4	8.4	0.0
Cape Henlopen	98.0	61.1	3.1	95.0
Twin Capes	82.2	51.2	2.6	79.6
Delaware	82.9	51.7	2.6	80.3
New Jersey	103.6	64.6	3.2	100.4
Total	375.1	237.0	19.9	355.2

COST ESTIMATE

The cost for repowering the ferries is $4.78M per ferry, as described in the previous section. According to EFEE, the cost for installing an SCR goes down when the installation occurs at the same time as an engine repower. Instead of $363k per ferry, the cost decreases by $50k, to $313k per ferry.

The cost for a combined engine repower and SCR installation is estimated at $5.1M per ferry, for a total of $20.4M for four ferries.

This yields a cost-effectiveness of **$57,384 per ton of NOx reduced per year**.

The technical feasibility of this option is not in question given that engine replacements and SCR installation have been successfully done on ferries in the recent past. However, the details of the project and the willingness of the ferry operator to participate would need to be worked out in a detailed design and negotiation. It is expected that a minimum of 18 months would be required to work out the terms of an agreement, design, build and install the new engines. That schedule makes this option incompatible with the first deepening contract but it is a candidate for future phases of the deepening.

7.10 Strategy 6 – Repower Local Harbor Tugs

This part of the study looks at repowering local tug boats. Ocean-going tugs were not included in this analysis, in favor of tugs that spend the majority of their time in the project area. Installing SCR was eliminated as a viable option because the load cycles of harbor assist tug boats are too unpredictable and fluctuate too much to be able to use SCR technology effectively.

Most of the vessel assist work in the Delaware River is performed by tugs from one of three local companies: Wilmington Tug, Moran, and McAllister Towing. Through a combination of internet searches, phone conversations, and emails with representatives from each company, the team was able to characterize each of the tugs in the local fleet.

<u>NOx CALCULATIONS</u>

The team obtained engine information (size and age) as well as 2008 operating hours for each tug. Each company was also asked to rank their tugs in order of preference for receiving a repower. Many of the local tugs were new builds or have been recently repowered. Most of the tug companies wanted to repower their oldest tugs first, even if those tugs were used less frequently. One company declined to rank their preference; in this case the ranking was done by engine size (largest engine first) since all the engines were Tier 0.

Table 22 lists the pertinent information for the six tugs (two from each company) identified as the best candidates for repower. These are either the oldest or biggest boats from each company. A load factor of 31%, a Tier 0 NOx emission factor of 9.8 g/bhp-hr (13.2 g/bkWhr), and a Tier II NOx emission factor of 7.3 g/bhp-hr (9.8 g/bkW-hr) were used, as recommended by the EPA in Tables 3-4 and 3-8 of the April 2009 document

Table 22: Local Harbor Tugs – NOx Emissions

Tug Name Company & Rank	Main Engine Total HP	Annual Operating Hrs	Unmitigated (Tier 0) NOx (tons/yr)	Tier II NOx (tons/yr)	NOx Reduction (tons/yr)
Lindsey Wilmington #1	2,400	3,000	24.2	18.0	6.2
Capt. Harry Wilmington #2	4,200	3,000	42.4	31.5	10.9
Valentine Moran Moran #1	3,520	3,000	35.5	26.4	9.2
Bart Turecamo Moran #2	3,000	3,000	30.3	22.5	7.8
Neill McAllister #1	1,800	3,000	18.2	13.5	4.7
Teresa McAllister #2	1,750	1,500	8.8	6.6	2.3

COST ESTIMATE

The cost for a repower, as given by the Marine Design Center, is $3.5M for a 3,000 hp engine. On a per horsepower basis, this is $1,167 per horsepower.

If the top three tugs with the most benefit in terms of NOx reductions are repowered then the cost effectiveness shown in Table 23 is calculated.

Table 23: Local Harbor Tugs – Repower Costs (Purchase and Installation)

Tug	HP	Cost for Repower	NOx Reduction (tons/yr)
Capt. Harry	4,200	$4.9M	10.9
Valentine Moran	3,520	$4.1M	9.2
Bart Turecamo	3,000	$3.5M	7.8
	Total	$12.5M	27.9

This yields a cost effectiveness of **$448,683 per ton of NOx reduced per year**.

Other strategies for selecting individual tugs, such as repowering each company's top choice or top two choices, yield similar results for cost effectiveness.

The repower cost given by the Marine Design Center includes purchase and installation costs. The Port Authority of New York and New Jersey started a program in 2004 to repower some local tugboats (also as air emission mitigation measures). As part of that program, the Port Authority paid for the purchase cost of the engine and the individual companies paid for the installation. The engine sizes and purchase costs[11] for the three tug boats in that program are shown in Table 24 below along with an average dollar per horsepower figure.

Table 24: Local Harbor Tugs – NYNJ 2004 Tug Repower Costs (Purchase Only)

Tug	hp	Cost	$/hp
Buchanan 12	3000	$1,000,000	$333
Dorothy J	1200	$311,475	$260
Robert IV	900	$115,739	$129
		average	$240

If the repower costs include the engine purchase price without the installation, the cost for repowering the three Delaware River tugs listed in Table 23 drops to $2.6M (using the average cost of $240/hp). The cost effectiveness in this scenario is $93,190 per ton of NOx reduced per year.

The technical feasibility of this option is not in question given that engine replacements on tug boats such as these are not uncommon. However, the details of an engine replacement and the willingness of the tug operators to participate would need to be worked out in a detailed design and negotiation for this specific option. It is expected that a minimum of 18 months would be required to work out the terms of an agreement, design, build and install the new engines. That schedule makes this option incompatible with the first deepening contract but it is a candidate for future phases of the deepening.

7.11 Strategy 7 – Install Shore Power (Cold Ironing)

The goal of this emission reduction strategy is to provide shore power for vessels so they can turn off their diesel auxiliary engines while they are at berth. Cold ironing eliminates the emissions while the vessel is plugged in, but does not reduce transit or maneuvering emissions.

The California Air Resources Board (CARB) recently passed a regulation requiring cold ironing at most container, cruise, and reefer terminals in California. The cost estimate portion of this study relies heavily on the published results of their research. The CARB report and the details of their cost effectiveness study can be found in Appendix E of an October 2007 staff report to the rule making body[12].

In brief, CARB uses a cost of $5M per berth and $1.5M per vessel. Their analysis also includes assumptions for fleet turnover, labor costs, fuel and electricity costs, etc, but those were not included at this level of analysis. The methodology for this analysis was to review recent vessel call data for the

[11] These details are given Tables 1, 2, and 3 of a January 13, 2005 report titled "2004 Tugboat Emission Reduction Program for the NYNJLI Ozone Non-attainment Area," written by M.J. Bradley.

[12] This report can be found on CARB's website, http://www.arb.ca.gov/regact/2007/shorepwr07/appe.pdf.

Philadelphia Regional Port Authority and determine what the costs and NOx benefit would have been had two of their terminals cold ironed a certain segment of their calls that year.

M&N obtained ship call records for 2007 and 2008 for all the PRPA terminals. The records included ship names and arrival and departure dates and times. The data were filtered and sorted to develop an understanding of the average berthing times, the number of unique vessels, and the frequency of ship calls. The number of unique vessels is very important because each individual ship must be modified to be able to use shore power. The results were used to determine which terminals would be the best candidates for cold ironing.

Table 25 summarizes the number of ships calls for each terminal by commodity. The top eight commodities listed here represent 94% of all the calls. Unlisted commodities, such as paraffin, salt, lumber, and locomotives, had very few calls.

Table 25: Cold Ironing – PRPA Ship Call Data for 2008

Commodity	Number of Calls per Terminal							
	Packer Ave	Tioga	82 South	80 South	TMTII	38-40 South	84 South	All PRPA
Containers	265	0	0	0	0	0	0	265
Fruit	1	46	54	2	0	0	0	103
Paper	1	0	0	32	0	18	0	51
Steel	15	14	0	0	0	0	0	29
Breakbulk	1	27	0	0	0	0	0	28
Chemicals	0	3	0	0	23	0	0	26
General	0	15	0	0	0	0	0	15
Cocoa	0	0	0	0	0	0	13	13
All other	23	7	0	5	3	1	0	39
TOTAL	306	112	54	39	26	19	13	569

Two different terminals were selected for this analysis. Packer Avenue Marine Terminal (PAMT) was chosen because it handles the majority of PRPA's container traffic and almost 50% of the ship calls to Philadelphia. Pier 82 South was chosen because it has a very small and well defined vessel fleet. Four reefer ships made 53 of the terminal's 54 calls in 2008.

The Packer Ave results will be presented first, followed by the Pier 82 results.

7.12 Strategy 7a – Packer Avenue Marine Terminal

Table 26 summarizes the number of container ship calls and berthing times for PAMT.

Table 26: Cold Ironing – Container Ship Calls to PAMT

	2007	2008
Total # calls	273	265
# of unique ships	73	61
Total time on berth (hrs)	3,947	4,209
Average time on berth (hrs)	14.5	16.7
Shortest time on berth (hrs)	2.5	4.5
Longest time on berth (hrs)	48.3	137.7

Even if a berth is equipped to provide shore power, it does not mean that every ship call to that berth will be cold ironed. The ships themselves must have compatible cold ironing capability. Shippers may be reluctant to modify their vessels because it is such an expensive proposition, especially if the ship only calls at a terminal with shore power a few times each year. Therefore, in keeping with CARB standards, the team looked at the benefits of cold ironing only those ships that call 5 or more times per year. The team also considered the costs and benefits of only cold ironing vessels calling 6+ times per year. Based on the 2008 vessel call data, it was determined that capturing vessels that call 5+ times per year, gave a fair cost effectiveness number (not the highest, not the lowest).

Table 27 shows the number of ships and berth hours that would be captured by cold ironing in the sample scenario.

Table 27: Cold Ironing – Container Ships Calling PAMT Five or More Times in 2008

# of vessels requiring modification	25
# of calls cold ironed	155
Percent of the calls/year cold ironed	58%
Berth hours cold ironed	2,917
Percent of the total berth hours cold ironed	69%

PACKER AVE NOx CALCULATIONS

M&N looked up the vessel characteristics in the Clarkson Register (a commercially available database of information on the world fleet), including engine size, for each of the 25 ships that are included in the 2008 cold ironing scenario. On average, each vessel was 720 feet long, had a carrying capacity of 3,000 TEUs, and a total main engine horsepower of 34,400.

According to Table 2-4 of the EPA's April 2009 guidance document on calculating port related emissions, auxiliary engines on container ships are 22% of the size of the main propulsion engines. Tables 2-7 and 2-16 list the appropriate load factors and emission factors for the auxiliary engines. These are summarized below in Table 28.

Table 28: Cold Ironing – PAMT Container Ship Emission Factors

	Auxiliary Engines
Engine Horsepower	7,564
Fuel Type	MGO 0.10% S
Load Factor	19%
NOx Emission Factor (g/bkW-hr)	13.9
NOx Emission Factor (g/bhp-hr)	10.4

For the purpose of this analysis, it is assumed that the NOx emissions are zero for the entire length of call for the calls that are cold ironed. In reality, the auxiliary engines are kept running during portions of the tie-up and cast-off procedures while the shore power connections are handled.

Table 29 shows the NOx emissions by mode for the container ships going to PAMT.

Table 29: Cold Ironing – PAMT Container Ship At-Berth NOx Emissions

	Berth Hours Not Cold Ironed	Berth Hours Cold Ironed	NOx (tons/yr)
Unmitigated	4,209	0	69.1
Cold ironing all vessels calling 5+ times	1,292	2,917	21.2
		NOx Reduction	47.9

<u>PACKER AVE COST ESTIMATE</u>

The cost to electrify two berths is estimated at $10M and the cost to modify 25 vessels is estimated at $37.5M, for a total project cost of $47.5M.

This yields a cost effectiveness of **$991,200 per ton of NOx reduced per year**.

The technical feasibility of this option is not in question given that several ship berths and container ships have been retrofitted for cold ironing in other parts of the country. However, the details of a cold ironing design, coordination with local utilities and the willingness of the ship operators to participate would need to be worked out in a detailed design and negotiation for this specific option. It is expected that a minimum of 24 months would be required to work out the terms of agreements, design, and install the necessary infrastructure. That schedule makes this option incompatible with the first deepening contract but it is a candidate for future phases of the deepening.

7.13 Strategy 7b – Pier 82

In 2008, Pier 82 handled refrigerated fruit exclusively. There were 54 calls by five different reefer vessels. One of those vessels only called one time. For this analysis, it was assumed that the other 53 calls were all cold ironed.

Table 30: Cold Ironing – Ship Call Information for Pier 82 in 2008

Total # calls	54
# of unique ships	5
Total time on berth (hrs)	1,877
Average time on berth (hrs)	34.8
Shortest time on berth (hrs)	10.3
Longest time on berth (hrs)	57.3

Table 31: Cold Ironing – Four Main Vessels Calling at Pier 82

# of vessels requiring modification	4
# of calls cold ironed	53
Percent of the calls/year cold ironed	98%
Berth hours cold ironed	1,827
Percent of the total berth hours cold ironed	97%

PIER 82 NOx CALCULATIONS

Two sets of sister ships composed the fleet of four reefer vessels. The two smaller vessels had main engines of 5,500 hp and made 17 calls; the two larger vessels had main engines of 15,000 hp and made 36 calls. According to Table 2-4 of the EPA's April 2009 guidelines, auxiliary engines on reefer vessels are 40.6% the size of the main engines on average. Table 32 summarizes the engine sizes and berthing hours for the ships calling at Pier 82.

Table 32: Cold Ironing – Pier 82 Reefer Ship Information

	Smaller Two Ships	Larger Two Ships
Main Engine Size (hp)	5,500	15,000
Auxiliary Engine Size (hp)	2,231	6,077
At-Berth Time (hrs)	573	1,254

Table 2-7 of the EPA guidelines lists the load factor for auxiliary engines on reefer ship as 32%. It is higher than the container ship load factor (19%) because the auxiliary engines are used to keep the perishable goods cold while the ship is at berth. The NOx emission factor is the same as for container ships. The factors used to calculate NOx emissions for the reefer ships are shown in Table 33 below.

Table 33: Cold Ironing – Pier 82 Reefer Ship Emission Factors

	Auxiliary Engines
Engine Horsepower	2,231 (two small ships) 6,077 (two large ships)
Fuel Type	MGO 0.10% S
Load Factor	32%
NOx Emission Factor (g/bkW-hr)	13.9
NOx Emission Factor (g/bhp-hr)	10.4

Table 34 summarizes the NOx emissions before and after cold ironing Pier 82 in 2008.

Table 34: Cold Ironing – Pier 82 Reefer Ship At-Berth NOx Emissions

	Berth Hours Not Cold Ironed	Berth Hours Cold Ironed	NOx (tons/yr)
Unmitigated	1,877	0	32.6
Cold ironing four main vessels	50	1,827	1.6
		NOx Reduction	31.0

PIER 82 COST ESTIMATE

The cost to electrify one berth is estimated at $5M and the cost to modify four vessels is estimated at $6M, for a total project cost of $11M.

This yields a cost effectiveness of **$355,406 per ton of NOx reduced per year**.

The technical feasibility of this option is not in question given that several ship berths and container ships have been retrofitted for cold ironing in other parts of the country. However, the details of a cold ironing design, coordination with local utilities and the willingness of the ship operators to participate would need to be worked out in a detailed design and negotiation for this specific option. It is expected that a minimum of 24 months would be required to work out the terms of agreements, design, and install the necessary infrastructure. That schedule makes this option incompatible with the first deepening contract but it is a candidate for future phases of the deepening.

ADDITIONAL COLD IRONING ANALYSIS

As per the scope of work, M&N calculated the number of ship-berth-days required to provide NOx offsets equal to those produced by repowering the McFarland and by electrifying the on-site dredge equipment.

A Panamax sized ship was assumed for this portion of the study. A Panamax ship can be roughly defined as one that is about 950' long with a capacity of 4,300 TEUs. This is bigger than the typical size vessel currently calling frequently at Packer Ave Marine Terminal. M&N looked up 10 different ships with 4,300 TEU capacity in the Clarkson Register and found the average propulsion engine size is 53,650 hp. Applying the same EPA factor for the ratio of auxiliary engine to main (22%) as used in the Packer Ave analysis above, the average auxiliary engine size was determined to be 11,800 hp.

The same load factor and emission factor as listed in Table 28 were used here. The auxiliary engines from a Panamax ship generate about 0.61 tons of NOx per 24-hour period, calculated as follows:

(11,800 hp) x (19% load factor) x (10.4 g/bhp-hr) x (1.1 e^{-6} tons/g) x (24 hrs/day) = 0.6155 tons/day

The McFarland repower yielded an annual reduction in NOx emissions of 64.1 tons. A Panamax ship would have to cold iron for a little more than 104 entire days per year to obtain equal NOx reductions.

Electrifying the project dredges yields different NOx reductions for different years. The electrification reductions for each year are given in Table 35 along with the number of days of cold ironing that would achieve the same NOx reductions.

Table 35: Additional Cold Ironing Analysis: Equivalent Reductions on Ship-Berth-Day Basis

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Tons of NOx reduced by project dredge electrification	368	419	67	85	654	73
Number of days of cold ironing required to get equivalent NOx emission reductions*	599	681	110	138	1,064	118
* A cold ironed day here is defined as a 24 hour period for a Panamax sized ship with zero NOx emissions from its auxiliary engines.						

7.14 Strategy 8 – Electrify Diesel Dock Cranes

The goal of this measure is to electrify the diesel dock cranes in the project area. The Packer Ave terminal in Philadelphia was identified as the best candidate for electrification because it handles the most containers and has the most cranes.

The PRPA provided data for their cranes as shown in Table 36.

Table 36: Electrify Diesel Cranes – Crane Information from PRPA

CRANE	ENGINE YEAR	HORSE POWER	ANNUAL ENGINE HOURS	LOCATION
Kocks, K-5 Crane	1982	800	500	PAMT
Kocks, K-5 Crane	1982	300	500	PAMT
Kocks, K-2 Crane	1992	2,000	3,000	PAMT
Kocks, K-3 Crane	1992	2,000	2,000	PAMT
Paceco Crane	1986	1,600	4,000	PAMT
Hyundai, H-6	2002	1,800	5,000	PAMT
Hyundai, H-7	2002	1,800	5,000	PAMT
Liebherr, LHM 400		811	400	Pier 82
Liebherr, LHM 400		811	900	Tioga Marine Terminal
Kocks, K-1 Crane		800	500	Tioga Marine Terminal
Kocks, K-1 Crane		300	500	Tioga Marine Terminal
Kocks, K-4 Crane	1982	800	500	Tioga Marine Terminal
Kocks, K-4 Crane	1982	300	500	Tioga Marine Terminal

This information shows that Packer Ave Marine Terminal has the highest crane operating hours of the three terminals. If crane electrification proves cost effective for Packer Ave, then it can be explored at other terminals (such as Tioga, Pier 82, and Wilmington) as well. The two smallest cranes at Packer Ave were not included for electrification because their annual operating hours are so low.

NOx CALCULATIONS

The unmitigated NOx emissions were calculated for all seven Packer Ave cranes using a load factor of 21% and the NOx emission factors shown in the table below. The load factor and emission factors are all from the EPA's NONROAD2005 model.

Once the cranes are electrified, their NOx emissions drop to zero. The NOx reduction results are shown in Table 37 below. The two smallest cranes show zero NOx reductions because it was assumed that they would not be electrified due to low usage.

Table 37: Electrify Diesel Cranes – NOx Emissions

Crane	Engine Year	NOx Emission Factor (g/bhp-hr)	Unmitigated NOx (tons/yr)	NOx Reduction (tons/yr)
Kocks, K-5 Crane	1982	15.45	1.4	0.0
Kocks, K-5 Crane	1982	15.45	0.5	0.0
Kocks, K-2 Crane	1992	9.25	12.8	12.8
Kocks, K-3 Crane	1992	9.25	8.6	8.6
Paceco Crane	1986	15.45	22.9	22.9
Hyundai, H-6	2002	6.79	14.1	14.1
Hyundai, H-7	2002	6.79	14.1	14.1
		Total	74.6	72.6

<u>COST ESTIMATE</u>

According to Lisa Magee of PRPA (via an email to Greg Lee on 6/5/09), the estimated cost for the crane electrification is as follows:

$8.1M for infrastructure improvements

$1.2M per crane for drive replacements

Using these figures, total project costs were calculated to be $14.1M ($8.1M plus $6M for the five cranes).

The PRPA's estimated project costs correspond nicely to those from a similar recent project. The Port of Miami electrified seven diesel dock cranes between August 2004 and November 2005[13]. The project manager for Crane Management, Nelson Ferrer, reported some budget cost figures to use for this analysis (via telephone conversation on 5/27/09).

The cost for modifying seven cranes, the on-terminal trenching, and switch gear installation was $12,226,000. This included any required structural work on the cranes, installing cable reels, removing diesel engines, and removing fuel tanks. This corresponds to $1.75M per crane.

The cost for wharf improvements, including reinforcing the crane beam, adding pilings, fender work, and installing the open cable trench was $10M for 4,700 linear feet of wharf. This corresponds to $2,128 per linear foot.

[13] The project is described at http://www.cranemgt.com/projects.html.

Using the figures from the Port of Miami project, the total cost to electrify the cranes at Packer Ave, with five cranes ($8.73M) and 2,700 linear feet of wharf ($5.74M) would be $14.5M.

Using the PRPA cost of $14.1M, this yields a cost effectiveness of **$194,235 per ton of NOx reduced per year.**

The technical feasibility of this option is not in question given that many container terminals around the country have converted from diesel to electrically powered cranes. A crane power design has already been completed for PAMT, and has been coordinated with local utilities. The crane operators are willing to participate. It is expected that a minimum of 18 months would be required to permit, contract, build, and install the necessary infrastructure. That schedule makes this option incompatible with the first deepening contract but it is a candidate for future phases of the deepening.

7.15 Strategy 9 – Purchase Emission Credits

Generally speaking, the Clean Air Act delegates authority to regulate stationary source emissions to individual states. It mandates minimum requirements for state permitting programs. In addition, there are also a variety of cap and trade programs at the regional level driven by federal regulation. Two examples are the SO_2 cap and trade program to reduce acid rain in the northeast, and the Ozone Transport Commission (OTC) to reduce regional ozone problems. There are also some relatively new regional greenhouse gas emissions budgeting and trading programs. Some regional programs which regulate emissions of NOx and other pollutants are limited to electrical generation plants. The EPA generally retains authority to regulate mobile sources.

The market for NOx emissions trading in the northeast is generally driven by New Source Review (NSR) regulations. Each state that includes areas in non-attainment of the National Ambient Air Quality Standards is required to have NSR regulations consistent with minimum federal requirements. These are customized for the specific non-attainment area. NSR regulations pertain to stationary major sources[14]. They require any new major facility or new source at an existing major facility to comply with specific NSR requirements. NSR requirements typically include: (1) the installation of the lowest achievable emission rate (LAER), (2) emission offsets, and (3) the opportunity for public involvement.

Emissions offsets are emission reductions, generally obtained from existing sources located in the vicinity of a proposed source. The reductions must offset the emission increase from the new source or modification and provide a net air quality benefit. The obvious purpose for requiring offsetting emissions decreases is to allow an area to move towards attainment of the NAAQS while still allowing some industrial growth. Emission reduction credits (ERCs) must be from "permanent[15], enforceable, quantifiable and surplus" emissions reductions. In some states, ERCs may be created by both major and non-major facilities even though the NSR program only applies to major new or modified sources.

[14] A major source is a stationary source which emits or has the potential to emit regulated air pollutants such as nitrogen oxides (NOx) at specific threshold limits (typically 100 tons/year).

[15] Emission reductions that are federally enforceable through an operating permit or a revision to the state implementation plan are considered permanent. The reductions used to generate ERCs must be assured for the duration of the corresponding emissions increase that is being offset with those emissions reductions.

Sponsors of this project have proposed buying ERCs from existing stationary source trading markets as a means to offset project emissions and demonstrate General Conformity. A precedent is the New York Channel Deepening Project which used a conditional statement of conformity along with a menu of mitigation measures including emission offsets for early phases of the work. The Port Authority of New York and New Jersey (PANYNJ) purchased 95.68 tons of NOx shutdown credits in early 2003 for $113,065 as part of the then existing open market emissions trading program (OMET) in New Jersey. The PANYNJ also owned 200 tons of NOx reduction credits from a facility on Staten Island. At the time they published their plan (December 2003), those credits were being considered for use in the General Conformity strategy for the NYNJ Harbor Deepening Project[16].

M&N understands that project sponsors and the affected states' regulators as well as the EPA have discussed the use of ERCs as a means for demonstrating General Conformity. Based on discussion with a local broker, several hundred credits are expected to be readily available in the Philadelphia area (the five counties in PA that are part of the 18 county, 4 state ozone non-attainment area). The anticipated market price is roughly $10,000 per ton. However, specific availability of credits and actual sale price are subject to negotiation when the project sponsors are ready to make an offer to purchase. As a result of a Memorandum of Understanding between Pennsylvania and New York, it is also possible to use credits generated in New York as offsets in the Philadelphia area. Credits from New Jersey are likely to be both more available and less expensive (on the order of $3,000 to $4,000 per ton[17]).

8. CONCLUSIONS

Based on a detailed evaluation of the direct (channel deepening) and indirect (berth deepening) emissions, a conformity determination is required for NOx emissions. The total direct and indirect NOx emissions, estimated at 3,040 tons over the life of the project with a peak year of 905 tons in 2013. Therefore, one of the following options must be followed.

a. The project emissions must be specifically included in the applicable SIPs, or

b. A written statement from the state agencies responsible for the SIPs must be secured documenting that the total direct and total indirect emissions from the action along with all other emissions in the area will not exceed the SIPs' emission budget, or

c. A written commitment from the states must be secured indicating that they will revise their SIPs to include the emissions from the action, or

d. The emissions must be fully offset by reducing NOx emissions in the same non-attainment area.

---

16 From the December 2003 Harbor Air Management Plan for the New York and New Jersey Harbor Deepening Project, prepared by Starcrest for the USACE NY District.

www.nan.usace.army.mil/harbor/pdf/air.pdf

17 Based on telephone conversation with emission credit broker Mason Henderson of CantorCO2e.

A variety of on-site and off-site mitigation measures are possible to fully offset the project emissions (option d above). The most cost effective strategies involve the installation of SCR units on the dredges and ferries.

The lead time necessary to implement many of the mitigation strategies is longer than the time available before the start of construction. For the first contract, it is anticipated that emission credits will be used as it is the only strategy that can meet the project schedule. M&N understands the use of emissions credits as a conformity strategy has been discussed with the EPA and relevant state agencies.

9. GENERAL CONFORMITY STRATEGY

Project NOx emissions must be offset to zero to demonstrate General Conformity. Given the project schedule, the purchase of emission reduction credits is the only feasible strategy for the first of the seven expected construction contracts. Subsequent contracts can be offset using a mix of the identified reduction measures. As the project schedule and the development of the mitigation projects evolve, the application of the various mitigation measures can be selected and managed to offset the project emissions on an annual basis.

10. REFERENCES

1) "Current Methodologies and Best Practices in Preparing Port Emission Inventories", ICF Consulting (for USEPA), January 5, 2006.

2) U.S. Army Corps of Engineers Dredge Estimating Program (CEDEP) - 26 dredge estimates and production worksheets, U.S. Army Corps of Engineers, Philadelphia District

3) United States Environmental Protection Agency Code of Federal Regulations Title 40, Part 93 (40 CFR 93) – Determining Conformity of Federal Actions to State or Federal Implementation Plans; revised July 1, 2008. http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr93_08.html

4) United States Environmental Protection Agency - June 2006 Final NONROAD2005 Emission Inventory Model. http://www.epa.gov/oms/nonrdmdl.htm

5) United States Environmental Protection Agency – Mobile6 Vehicle Emission Modeling Software. http://www.epa.gov/oms/m6.htm

6) United States Environmental Protection Agency – "Locomotive Emissions Standards Regulatory Support Document", April 1998, revised, http://www.epa.gov/OMSWWW/regs/nonroad/locomotv/frm/locorsd.pdf

APPENDICES

Appendix A – Channel Deepening Emissions Spreadsheet

Delaware River Deepening
A -Construction Emissions Summary - Channel Deepening
5/19/2009

Contract	I			II		III		IV	V	VI		VII			
Dredge-Disposal Activity	1	2	3	4	5	13	14	9	10	11	12	6	7	8	
	C-Killico 1	C-Reedy S	C-Killico 2	B-Blasting	B-shot Rock-Mifflin	AA-N. Park	A-Peddrick N	E-Brdkl	E-Kelly	D-Reedy S	D-Artf Isl	B-Oldmans	B-Peddrick N	B-Peddrick S	
Old CDEP Estimate #	2	4	6	8	9	17	18	10	15	7	16	11	12	13	14
New CDEP Estimate #	1	2	3	4	5	14	15	10	11	12	13	6	7	8	9
Estimate file	2009-jan-dr-RC01-Hyd-KillicohookNo2	2009-jan-dr-RC02-Hyd-ReedyPtSouth	2009-jan-dr-RC03-Hyd-KillicohookNo2	2008-dec-dr-RB-RcokPart02	2008-dec-dr-RB-RockPart01	2009-jan-dr-RAA-Hyd-NatPark	2009-jan-dr-RA-Hop-PedricktownNorth	2009-jan-dr-RE_HOP-Broadkill	2009-jan-dr-RE_HOP-Kellyls	2009-jan-dr-RD01B-Hop-ReedyPtSouth	2009-jan-dr-RD02-Hop-Artls	2009-jan-dr-RB01-Hyd-Oldmans	2009-jan-dr-RB-Hyd-Pedricktown North	2009-jan-dr-RB-Hyd-PedricktownSouth	2009-jan-dr-RB03-Hyd-PedricktownSouth

Dredge-Disposal Area

Reach	C	C	C	B	B	AA	A	E	E	D	D	B	B	B	B
Disposal Site	Killcohook 212+500	Reedy Point South (233+667)	Killchhook 212+500	Fort Mifflin	Fort Mifflin	National Park (58+700)	Pedricktown North (141+250)	Delaware Beaches-Broadkill Beach	Kelly Island (Sta 384+223)	Reedy Point South (233+667)	Artificial Island (264+400)	Oldmans (133+00)	Pedricktown north (141+250)	Pedricktown South (149+000)	Pedricktown South (149+000)
Dredge type	(1) 30" CSD	(1) 30" CSD	(1) 30" CSD	(2) 3 frame drillboats	(2) 26 CY Clamshell	(1) 30" CSD	(1) 7600cy HOP	(1) 7600cy HOP	(1) 7600cy HOP	(1) 7600cy HOP	(1) 7600cy HOP	(1) 30" CSD	(1) 30" CSD	(1) 30" CSD	(1) 30" CSD
Pipeline (ft)	1 booster 39,500	1 booster 40,800	1 booster 40,150		(2) towboats (8) 3k cy scows	2 boosters 44,000	no booster 6,000	(1) booster 15,000	(1) booster 18,000	no booster 6,000	no booster 6,000	no booster 15,000	2 boosters 58,750	no booster 31,000	1 booster 38,800
Low Station	183,000	206,201	225,000			19,700	32,756	461,300	351,300	249,000	270,000	124,000	90,000	124,000	137,000
High Station	206,201	225,000	242,514			32,756	90,000	512,000	461,300	270,000	324,000	end	124,000	137,000	176,000

Volumes / Productions / Durations

Pay cys	932,600	597,800	972,400	77,000	77,000	994,000	1,666,600	1,598,700	2,483,000	396,300	1,654,800	1,671,400	1,050,700	499,300	1,443,500
Gross cys	1,166,500	731,700	1,120,500	77,000	225,600	1,129,100	1,911,900	2,072,500	3,004,800	509,600	2,128,200	1,828,800	1,244,100	536,500	1,736,800
Dredging Area ft2				1,585,000	1,542,800										
Drill /Blast Area (ft2)				771,400	771,400										
# Rigs	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1
Drill Area (ft2) /12 hr day/rig				4,000											
Gross Hourly Production/rig	1,538	577	1,767		262	947	477	545	516	687	699	3,978	856	2,331	1,407
Hours/Month/rig	460	460	460		507	414	657	657	657	657	657	511	414	511	460
Monthly Gross Production all rigs	707,480	265,420	812,820	243,360	265,668	392,058	313,389	358,065	339,012	451,359	459,243	2,032,758	354,384	1,191,141	647,220
Months	1.65	2.76	1.38	3.17	0.85	2.88	6.1	5.79	8.86	1.13	4.63	0.90	3.51	0.45	2.68

0.02 (conversion from lbs/day to total NOx, need to include the timeframe (in months) from row 30)

total tons															
dredge	88.3	147.7	73.8	-	18.0	138.7	277.1	253.3	392.8	44.3	191.3	48.2	169.0	24.1	143.4
booster	49.5	82.8	41.4	-	-	155.6	-	58.6	85.0	-	-	-	189.6	-	80.4
towing tugs	-	-	-	-	7.7	-	-	-	-	-	-	-	-	-	-
everything else	1.5	2.5	1.2	14.0	1.7	2.3	6.9	6.6	10.0	1.3	5.3	0.8	2.8	0.4	2.4
	139.3	233.0	116.5	14.0	27.5	296.6	284.0	318.5	487.9	45.5	196.5	49.0	361.4	24.5	226.2

NOX

		lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	
Lbs / Day: Dredge Site	Dredge Dredging	3,518	3,518	3,518	218	1,395	3,167	622	797	755	1,124	837	3,518	3,167	3,518	3,518	
	Dredge Attendant Plant	58	58	58	73	94	53	12	12	12	12	12	58	53	58	58	
Transp Route	Dredge Transporting	0	0	0	0	635	0	2,083	1,759	1,856	998	1,467	0	0	0	0	
	Booster	1,973	1,973	1,973	0	0	3,551	0	666	631	0	0	0	3,551	0	1,973	
Disposal Site	Dredge Unloading	0	0	0	0	0	0	344	383	366	515	474	0	0	0	0	
	Disposal Site Equipment	35.4	30.3	34.3	0.0	82.3	28.6	13.8	68.0	185.7	18.5	103.1	31.8	24.5	18.2	18.2	
	Worker Trips	3.1	3.2	2.9	2.2	2.2	2.86	0.7007	1.2	2.1	0.6	0.6	2.2	2.1	2.2	2.2	
Total		5,588	5,583	5,587	293	2,208	6,802	3,076	3,686	3,808	2,670	2,894	3,611	6,797	3,597	5,570	
		tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	
Total Tons: Mob		2.80	2.65	2.53	3.55	4.73	3.85	3.58	0.83	1.54	2.19	2.06	3.18	3.40	3.18		40.09
Dredge Site	Dredge Dredging	88.29	147.69	73.84	10.51	18.03	138.70	57.73	70.16	101.73	19.32	58.93	48.16	169.04	24.08	143.40	1,169.61
	Dredge Attendant Plant	1.47	2.45	1.23	3.50	1.21	2.30	1.15	1.09	1.67	0.21	0.88	0.80	2.81	0.40	2.38	23.56
Transp Route	Dredge Transporting	0.00	0.00	0.00	0.00	8.21	0.00	193.23	154.92	250.11	17.16	103.30	0.00	0.00	0.00	0.00	726.92
	Booster	49.51	82.82	41.41	0.00	0.00	155.55	0.00	58.61	84.98	0.00	0.00	0.00	189.58	0.00	80.42	742.88
Disposal Site	Dredge Unloading	0.00	0.00	0.00	0.00	0.00	0.00	31.88	33.74	49.37	8.85	33.40	0.00	0.00	0.00	0.00	157.24
	Disposal Site Equipment	0.89	1.27	0.72	0.00	1.06	1.25	1.28	5.98	25.02	0.32	7.26	0.44	1.31	0.12	0.74	47.68
	Worker Trips	0.08	0.13	0.06	0.11	0.03	0.13	0.07	0.10	0.28	0.01	0.04	0.03	0.11	0.01	0.09	1.29
Total		143.04	237.02	119.79	17.67	33.28	301.78	288.92	325.44	514.72	48.07	205.87	52.60	366.24	27.80	227.04	2,909.26
	this row is just a check	143.04	237.02	119.79	17.67	33.28	301.78	288.92	325.44	514.72	48.07	205.87	52.60	366.24	27.80	227.04	

VOCs

		lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	
Lbs / Day: Dredge Site	Dredge Dredging	122.7	122.7	122.7	6.2	42.3	110.4	24.8	31.8	30.1	44.9	33.4	122.7	110.4	122.7	122.7	
	Dredge Attendant Plant	1.7	1.7	1.7	2.1	2.7	1.5	0.4	0.4	0.4	0.4	0.4	1.7	1.5	1.7	1.7	
Transp Route	Dredge Transporting	0.0	0.0	0.0	0.0	24.9	0.0	83.1	70.2	74.0	39.8	58.5	0.0	0.0	0.0	0.0	
	Booster	68.8	68.8	68.8	0.0	0.0	123.8	0.0	23.2	22.0	0.0	0.0	0.0	123.8	0.0	68.8	
Disposal Site	Dredge Unloading	0.0	0.0	0.0	0.0	0.0	0.0	13.0	14.6	13.9	19.8	18.2	0.0	0.0	0.0	0.0	
	Disposal Site Equipment	3.8	3.3	3.7	0.0	5.6	3.0	1.3	6.4	15.3	2.0	10.4	3.4	2.4	1.8	1.8	
	Worker Trips	3.7	3.9	3.5	2.3	2.3	3.44	0.71	1.3	1.7	0.6	0.6	2.5	2.6	2.6	2.7	
Total		200.6	200.3	200.4	10.5	77.7	242.2	123.3	147.8	157.4	107.5	121.5	130.2	240.8	128.7	197.6	
		tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	
Total Tons: Mob		0.11	0.10	0.10	0.13	0.18	0.15	0.14	0.03	0.06	0.09	0.08	0.12	0.13	0.12		1.56
Dredge Site	Dredge Dredging	3.08	5.15	2.58	0.30	0.55	4.84	2.30	2.80	4.06	0.77	2.35	1.68	5.89	0.84	5.00	42.18
	Dredge Attendant Plant	0.04	0.07	0.03	0.10	0.03	0.07	0.03	0.03	0.05	0.01	0.02	0.02	0.08	0.01	0.07	0.67
Transp Route	Dredge Transporting	0.00	0.00	0.00	0.00	0.32	0.00	7.71	6.18	9.98	0.68	4.12	0.00	0.00	0.00	0.00	28.99
	Booster	1.73	2.89	1.44	0.00	0.00	5.42	0.00	2.04	2.96	0.00	0.00	0.00	6.61	0.00	2.80	25.91
Disposal Site	Dredge Unloading	0.00	0.00	0.00	0.00	0.00	0.00	1.21	1.28	1.87	0.34	1.28	0.00	0.00	0.00	0.00	5.98
	Disposal Site Equipment	0.09	0.14	0.08	0.00	0.07	0.13	0.12	0.57	2.06	0.03	0.73	0.05	0.13	0.01	0.07	4.29
	Worker Trips	0.09	0.16	0.07	0.11	0.03	0.15	0.07	0.12	0.22	0.01	0.04	0.03	0.14	0.02	0.11	1.38
Total		5.14	8.51	4.30	0.64	1.18	10.76	11.58	13.05	21.27	1.93	8.63	1.91	12.99	1.01	8.06	110.96

PM2.5

		lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	
Lbs / Day: Dredge Site	Dredge Dredging	46.531	46.531	46.531	3.192	26.366	41.878	10.949	14.019	13.285	19.786	14.727	46.531	41.878	46.531	46.531	
	Dredge Attendant Plant	1.422	1.422	1.422	1.082	2.307	1.280	0.302	0.302	0.302	0.302	0.302	1.422	1.280	1.422	1.422	
Transp Route	Dredge Transporting	0.000	0.000	0.000	0.000	11.438	0.000	36.651	30.957	32.662	17.566	25.813	0.000	0.000	0.000	0.000	
	Booster	26.093	26.093	26.093	0.000	0.000	46.968	0.000	8.802	8.341	0.000	0.000	0.000	46.968	0.000	26.093	
Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	6.465	7.161	6.865	9.485	8.765	0.000	0.000	0.000	0.000	
	Disposal Site Equipment	3.634	2.977	4.484	0.000	4.450	2.715	1.092	5.180	11.093	1.681	6.892	2.336	1.459	1.127	1.127	
	Worker Trips	0.055	0.055	0.055	0.036	0.039	0.0547	0.0129	0.024	0.050	0.012	0.015	0.053	0.054	0.055	0.054	
Total		77.735	77.078	78.585	4.310	44.599	92.896	55.472	66.446	72.599	48.834	56.514	50.342	91.639	49.136	75.228	
		tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	
Total Tons: Mob		0.051	0.048	0.046	0.061	0.088	0.069	0.063	0.015	0.027	0.039	0.037	0.057	0.061	0.057		0.720
Dredge Site	Dredge Dredging	1.168	1.953	0.977	0.154	0.341	1.834	1.016	1.235	1.790	0.340	1.037	0.637	2.236	0.318	1.897	16.931
	Dredge Attendant Plant	0.036	0.060	0.030	0.052	0.030	0.056	0.028	0.027	0.041	0.005	0.021	0.019	0.068	0.010	0.058	0.541
Transp Route	Dredge Transporting	0.000	0.000	0.000	0.000	0.148	0.000	3.400	2.726	4.401	0.302	1.818	0.000	0.000	0.000	0.000	12.794
	Booster	0.655	1.095	0.548	0.000	0.000	2.057	0.000	0.775	1.124	0.000	0.000	0.000	2.507	0.000	1.064	9.825
Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	0.600	0.631	0.925	0.163	0.617	0.000	0.000	0.000	0.000	2.936
	Disposal Site Equipment	0.091	0.125	0.094	0.000	0.058	0.119	0.101	0.456	1.495	0.029	0.485	0.032	0.078	0.008	0.046	3.217
	Worker Trips	0.001	0.002	0.001	0.002	0.000	0.002	0.001	0.002	0.007	0.000	0.001	0.001	0.003	0.000	0.002	0.027
Total		2.001	3.284	1.695	0.268	0.665	4.138	5.209	5.866	9.810	0.878	4.016	0.747	4.953	0.394	3.066	46.990

PM10

		lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	
Lbs / Day: Dredge Site	Dredge Dredging	48.918	48.918	48.918	3.388	27.630	44.027	11.968	15.323	14.521	21.626	16.096	48.918	44.027	48.918	48.918	
	Dredge Attendant Plant	1.492	1.492	1.492	1.148	2.420	1.343	0.317	0.317	0.317	0.317	0.317	1.492	1.343	1.492	1.492	
Transp Route	Dredge Transporting	0.000	0.000	0.000	0.000	12.459	0.000	40.059	33.836	35.699	19.200	28.214	0.000	0.000	0.000	0.000	
	Booster	27.432	27.432	27.432	0.000	0.000	49.378	0.000	9.254	8.769	0.000	0.000	0.000	49.378	0.000	27.432	
Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	7.000	7.761	7.438	10.301	9.514	0.000	0.000	0.000	0.000	
	Disposal Site Equipment	3.747	3.070	3.491	0.000	4.588	2.7996	1.1258	5.341	11.437	1.734	7.104	2.409	1.505	1.162	1.162	
	Worker Trips	0.119	0.119	0.119	0.077	0.082	0.1189	0.0265	0.052	0.093	0.026	0.030	0.117	0.118	0.121	0.118	
Total		81.708	81.031	81.452	4.613	47.181	97.665	60.496	71.884	78.274	53.204	61.276	52.936	96.370	51.693	79.123	
		tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	
Total Tons: Mob		0.055	0.052	0.050	0.066	0.095	0.075	0.069	0.016	0.030	0.042	0.040	0.063	0.067	0.063		0.784
Dredge Site	Dredge Dredging	1.228	2.053	1.027	0.163	0.357	1.928	1.110	1.349	1.957	0.372	1.133	0.670	2.350	0.335	1.994	18.026
	Dredge Attendant Plant	0.037	0.063	0.031	0.055	0.031	0.059	0.029	0.028	0.043	0.005	0.022	0.020	0.072	0.010	0.061	0.568
Transp Route	Dredge Transporting	0.000	0.000	0.000	0.000	0.161	0.000	3.716	2.979	4.810	0.330	1.987	0.000	0.000	0.000	0.000	13.984
	Booster	0.688	1.151	0.576	0.000	0.000	2.163	0.000	0.815	1.182	0.000	0.000	0.000	2.636	0.000	1.118	10.329
Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	0.649	0.683	1.002	0.177	0.670	0.000	0.000	0.000	0.000	3.182
	Disposal Site Equipment	0.094	0.129	0.073	0.000	0.059	0.123	0.104	0.470	1.541	0.030	0.500	0.033	0.080	0.008	0.047	3.292
	Worker Trips	0.003	0.005	0.002	0.004	0.001	0.005	0.002	0.005	0.013	0.000	0.002	0.002	0.006	0.001	0.005	0.056
Total		2.106	3.454	1.760	0.288	0.705	4.353	5.681	6.346	10.577	0.957	4.355	0.787	5.211	0.416	3.225	50.221

CO

		lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	
Lbs / Day: Dredge Site	Dredge Dredging	429.144	429.144	429.144	32.715	110.384	386.230	51.855	66.394	62.917	93.706	69.743	429.144	386.230	429.144	429.144	
	Dredge Attendant Plant	8.938	8.938	8.938	10.926	14.304	8.044	2.113	2.113	2.113	2.113	2.113	8.938	8.044	8.938	8.938	
Transp Route	Dredge Transporting	0.000	0.000	0.000	0.000	55.539	0.000	173.573	146.608	154.683	83.192	122.249	0.000	0.000	0.000	0.000	
	Booster	240.651	240.651	240.651	0.000	0.000	433.172	0.000	81.178	76.926	0.000	0.000	0.000	433.172	0.000	240.651	
Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	32.775	36.076	34.674	47.081	43.670	0.000	0.000	0.000	0.000	
	Disposal Site Equipment	20.712	19.023	20.200	0.000	29.717	17.818	8.935	44.570	89.538	11.191	55.702	18.127	14.423	10.645	10.645	
	Worker Trips	38.232	55.850	53.306	47.417	49.665	43.8784	10.1113	21.746	20.216	13.412	11.525	28.706	36.969	32.799	47.221	
Total		737.677	753.606	752.239	91.058	259.609	889.142	279.364	398.685	441.066	250.695	305.003	484.915	878.837	481.527	736.599	
		tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	
Total Tons: Mob		0.249	0.236	0.226	0.335	0.436	0.336	0.302	0.073	0.131	0.186	0.175	0.280	0.298	0.280		3.543
Dredge Site	Dredge Dredging	10.769	18.013	9.007	1.577	1.427	16.917	4.811	5.846	8.478	1.610	4.911	5.874	20.617	2.937	17.491	130.285
	Dredge Attendant Plant	0.224	0.375	0.188	0.527	0.185	0.352	0.196	0.186	0.285	0.036	0.149	0.122	0.429	0.061	0.364	3.680
Transp Route	Dredge Transporting	0.000	0.000	0.000	0.000	0.718	0.000	16.103	12.910	20.843	1.430	8.608	0.000	0.000	0.000	0.000	60.611
	Booster	6.039	10.101	5.051	0.000	0.000	18.973	0.000	7.148	10.365	0.000	0.000	0.000	23.123	0.000	9.809	90.609
Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	3.041	3.177	4.672	0.809	3.075	0.000	0.000	0.000	0.000	14.774
	Disposal Site Equipment	0.520	0.798	0.424	0.000	0.384	0.780	0.829	3.925	12.065	0.192	3.922	0.248	0.770	0.073	0.434	25.365
	Worker Trips	0.959	2.344	1.119	2.286	0.642	1.922	0.938	1.915	2.724	0.230	0.812	0.393	1.973	0.224	1.925	20.407
Total		18.760	31.869	16.014	4.725	3.792	39.280	26.218	35.179	59.563	4.494	21.652	6.917	47.212	3.576	30.023	349.274

Sox

		lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	
Lbs / Day: Dredge Site	Dredge Dredging	30.147	14.120	14.120	1.453	6.686	12.708	0.597	0.765	0.725	1.079	0.803	2.685	2.417	1.646	1.646	
	Dredge Attendant Plant	0.831	0.389	0.389	0.483	0.624	0.350	0.016	0.016	0.016	0.016	0.016	0.074	0.067	0.045	0.045	
Transp Route	Dredge Transporting	0.000	0.000	0.000	0.000	3.268	0.000	1.999	1.689	1.782	0.958	1.408	0.000	0.000	0.000	0.000	
	Booster	16.905	7.918	7.918	0.000	0.000	14.253	0.000	0.508	0.481	0.000	0.000	0.000	2.711	0.000	0.923	
Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	0.349	0.387	0.371	0.514	0.474	0.000	0.000	0.000	0.000	
	Disposal Site Equipment	0.641	0.650	0.640	0.000	1.458	0.640	0.371	1.854	4.425	0.370	2.179	0.650	0.641	0.464	0.464	
	Worker Trips	0.034	0.034	0.034	0.022	0.024	0.0342	0.0076	0.015	0.026	0.007	0.009	0.034	0.034	0.035	0.034	
Total		48.559	23.112	23.102	1.959	12.060	27.986	3.340	5.233	7.826	2.945	4.890	3.443	5.870	2.190	3.112	
		tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	
Total Tons: Mob		0.014	0.014	0.013	0.019	0.025	0.020	0.018	0.001	0.001	0.002	0.002	0.003	0.003	0.003		0.139
Dredge Site	Dredge Dredging	0.756	0.593	0.296	0.070	0.086	0.557	0.055	0.067	0.098	0.019	0.057	0.037	0.129	0.011	0.067	2.898
	Dredge Attendant Plant	0.021	0.016	0.008	0.023	0.008	0.015	0.001	0.001	0.002	0.000	0.001	0.001	0.004	0.000	0.002	0.105
Transp Route	Dredge Transporting	0.000	0.000	0.000	0.000	0.042	0.000	0.185	0.149	0.240	0.016	0.099	0.000	0.000	0.000	0.000	0.732
	Booster	0.424	0.332	0.166	0.000	0.000	0.624	0.000	0.045	0.065	0.000	0.000	0.000	0.145	0.000	0.038	1.839
Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	0.032	0.034	0.050	0.009	0.033	0.000	0.000	0.000	0.000	0.159
	Disposal Site Equipment	0.016	0.027	0.013	0.000	0.019	0.028	0.034	0.163	0.596	0.006	0.153	0.009	0.034	0.003	0.019	1.123
	Worker Trips	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.003	0.000	0.001	0.001	0.002	0.000	0.001	0.016
Total		1.233	0.984	0.498	0.113	0.181	1.246	0.328	0.462	1.056	0.053	0.346	0.050	0.317	0.018	0.127	7.011

1141.486

Appendix B – Berth Deepening Emissions Spreadsheet

Delaware River Deepening
B -Construction Emissions Summary - Berth Deepenings
5/19/2009

	Contract	1	2	3	4	5	6	7	8	9	10
		Sun Oil Marcus Hook Rock	Sun Oil Marcus Hook Dredge 1	Sun Oil Marcus Hook Dredge 2	Phillips 66- Marcus Hook	Valero - Paulsboro	Sun Oil - Fort Mifflin	Coastal Eagle Point - Westville	Packer Ave - Terminal	Beckett St - Terminal	Whites Basin
	CDEP Estimate #										
	Estimate file	ASunocoREEVDRROCKpart2	ASunocoREEVdrrcokpart1	SunocoREEVMarcus Hook	Phillips66REEVMarcusHook	ValeroREEVPaulsboro	SunocoREEVFt Mifflin	CoastalREEVEaglePt	PhilaRPAREEVPacker	SJPortREEVBeckett	Associated Rehandling Dredging
Dredge-Disposal Area	Reach	B	B	B	B	B	B	B	B	B	B
	Disposal Site		Whites Basin	Whites Basin	Whites Basin	Whites Basin	Whites Basin	Whites Basin	Whites Basin	Whites Basin	Whites Basin
	Dredge type	Drillboat	26 CY Clamshell	21 CY Clamshell	21 CY Clamshell	21 CY Clamshell	21 CY Clamshell	21 CY Clamshell	21 CY Clamshell	21 CY Clamshell	27" CSD
	Pipeline (ft)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	5,250
Volumes / Productions / Durations	Pay cys	25,089	25,089	65,713	118,090	68,686	36,428	17,073	70,194	59,164	460,437
	Gross cys	25,089	62,189	122,213	161,690	126,086	61,328	28,573	97,094	81,364	678,348
	Dredging Area ft2	651,000	230,020	763,304	588,752	775,266	336,611	155,000	363,254	299,993	1,000,000
	Drill /Blast Area (ft2)	250,890									
	# Rigs	1	1	1	1	1	1	1	1	1	1
	Drill Area (ft2) /12 hr day/rig	4000									
	Gross Hourly Production/rig		269	899	1,046	307	1,025	349	1,046	509	1,376
	Hours/Month/rig		507	507	507	507	322	507	216	507	511
	Monthly Gross Production all rigs	121,680	136,383	455,793	530,322	155,649	329,988	176,943	226,412	258,063	703,136
	Months	2.07	0.46	0.27	0.30	0.81	0.19	0.16	0.43	0.32	1.23

0.02 (conversion from lbs/day to total NOx, need to include the timeframe (in months) from row 30)

	1	2	3	4	5	6	7	8	9	10
	total tons									
dredge	-	4.3	2.5	2.8	7.5	1.8	1.5	4.0	3.0	46.1
booster	-	-	-	-	-	-	-	-	-	-
towing tugs	-	4.9	2.9	3.2	8.7	2.0	1.7	4.6	3.4	-
everything else	4.9	0.7	0.4	0.5	1.3	0.3	0.3	0.7	0.5	1.1
	4.9	9.9	5.8	6.5	17.5	4.1	3.5	9.3	6.9	47.2

NOX

			1	2	3	4	5	6	7	8	9	10	
			lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	
Lbs / Day	Dredge Site	Dredge Dredging	109	609	609	609	609	609	609	609	609	2,463	
		Dredge Attendant Plant	46	94	94	94	94	94	94	94	94	58	
	Transp Route	Dredge Transporting	0	715	715	715	715	715	715	715	715	0	
		Booster	0	0	0	0	0	0	0	0	0	0	
	Disposal Site	Dredge Unloading	0	0	0	0	0	0	0	0	0	0	
		Disposal Site Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	
		Worker Trips	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2.3	
	Total		157	1,420	1,420	1,420	1,420	1,420	1,420	1,420	1,420	2,544	
			tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	
Total Tons	Mob		1.44	2.63	1.44	1.44	1.09	0.95	0.95	0.77	0.77	0.98	12.45
	Dredge Site	Dredge Dredging	3.43	4.26	2.50	2.78	7.51	1.76	1.48	3.99	2.97	46.07	76.75
		Dredge Attendant Plant	1.46	0.66	0.39	0.43	1.16	0.27	0.23	0.61	0.46	1.09	6.74
	Transp Route	Dredge Transporting	0.00	5.00	2.94	3.26	8.81	2.07	1.74	4.68	3.48	0.00	31.98
		Booster	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Disposal Site	Dredge Unloading	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Disposal Site Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.37
		Worker Trips	0.05	0.01	0.01	0.01	0.02	0.00	0.00	0.01	0.01	0.04	0.16
	Total		6.38	12.56	7.27	7.92	18.58	5.05	4.40	10.06	7.68	48.56	128.46
			6.38	12.56	7.27	7.92	18.58	5.05	4.40	10.06	7.68	48.56	

VOCs

			1	2	3	4	5	6	7	8	9	10	
			lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	
Lbs / Day	Dredge Site	Dredge Dredging	3.1	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	85.9	
		Dredge Attendant Plant	1.3	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	1.7	
	Transp Route	Dredge Transporting	0.0	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4	0.0	
		Booster	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Disposal Site	Dredge Unloading	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
		Disposal Site Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	
		Worker Trips	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2.5	
	Total		6.0	51.2	51.2	51.2	51.2	51.2	51.2	51.2	51.2	91.9	
			tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	
Total Tons	Mob		0.05	0.09	0.05	0.05	0.04	0.03	0.03	0.03	0.03	0.04	0.45
	Dredge Site	Dredge Dredging	0.10	0.13	0.08	0.08	0.23	0.05	0.04	0.12	0.09	1.61	2.53
		Dredge Attendant Plant	0.04	0.02	0.01	0.01	0.03	0.01	0.01	0.02	0.01	0.03	0.19
	Transp Route	Dredge Transporting	0.00	0.20	0.12	0.13	0.35	0.08	0.07	0.19	0.14	0.00	1.27
		Booster	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Disposal Site	Dredge Unloading	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Disposal Site Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04
		Worker Trips	0.05	0.01	0.01	0.01	0.02	0.00	0.00	0.01	0.01	0.05	0.17
	Total		0.24	0.45	0.26	0.29	0.67	0.18	0.16	0.36	0.28	1.76	4.65

PM2.5

			1	2	3	4	5	6	7	8	9	10	
			lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	
Lbs / Day	Dredge Site	Dredge Dredging	1.596	11.520	11.520	11.520	11.520	11.520	11.520	11.520	11.520	32.572	
		Dredge Attendant Plant	0.699	2.307	2.307	2.307	2.307	2.307	2.307	2.307	2.307	1.422	
	Transp Route	Dredge Transporting	0.000	12.652	12.652	12.652	12.652	12.652	12.652	12.652	12.652	0.000	
		Booster	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
		Disposal Site Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.50842	
		Worker Trips	0.03502	0.03751	0.03751	0.03751	0.03751	0.03751	0.03751	0.03751	0.03751	0.05374	
	Total		2.329	26.516	26.516	26.516	26.516	26.516	26.516	26.516	26.516	35.556	
			tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	
Total Tons	Mob		0.02	0.05	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.234
	Dredge Site	Dredge Dredging	0.050	0.081	0.047	0.053	0.142	0.033	0.028	0.075	0.056	0.609	1.175
		Dredge Attendant Plant	0.022	0.016	0.009	0.011	0.028	0.007	0.006	0.015	0.011	0.027	0.152
	Transp Route	Dredge Transporting	0.000	0.089	0.052	0.058	0.156	0.037	0.031	0.083	0.062	0.000	0.566
		Booster	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Disposal Site Equipment	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.028
		Worker Trips	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004
	Total		0.097	0.237	0.136	0.148	0.347	0.095	0.083	0.189	0.144	0.683	2.158

PM10

			1	2	3	4	5	6	7	8	9	10	
			lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	
Lbs / Day	Dredge Site	Dredge Dredging	1.694	12.072	12.072	12.072	12.072	12.072	12.072	12.072	12.072	34.243	
		Dredge Attendant Plant	0.741	2.420	2.420	2.420	2.420	2.420	2.420	2.420	2.420	1.492	
	Transp Route	Dredge Transporting	0.000	13.818	13.818	13.818	13.818	13.818	13.818	13.818	13.818	0.000	
		Booster	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
		Disposal Site Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.56	
		Worker Trips	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.12	
	Total		2.511	28.391	28.391	28.391	28.391	28.391	28.391	28.391	28.391	37.408	
			tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	
Total Tons	Mob		0.03	0.05	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.252
	Dredge Site	Dredge Dredging	0.053	0.084	0.050	0.055	0.149	0.035	0.029	0.079	0.059	0.641	1.234
		Dredge Attendant Plant	0.023	0.017	0.010	0.011	0.030	0.007	0.006	0.016	0.012	0.028	0.159
	Transp Route	Dredge Transporting	0.000	0.097	0.057	0.063	0.170	0.040	0.034	0.090	0.067	0.000	0.618
		Booster	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Disposal Site Equipment	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.029
		Worker Trips	0.002	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.002	0.008
	Total		0.105	0.253	0.146	0.159	0.372	0.102	0.089	0.202	0.154	0.719	2.300

CO

			1	2	3	4	5	6	7	8	9	10	
			lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	
Lbs / Day	Dredge Site	Dredge Dredging	16.357	48.229	48.229	48.229	48.229	48.229	48.229	48.229	48.229	300.401	
		Dredge Attendant Plant	6.994	14.304	14.304	14.304	14.304	14.304	14.304	14.304	14.304	8.938	
	Transp Route	Dredge Transporting	0.000	60.259	60.259	60.259	60.259	60.259	60.259	60.259	60.259	0.000	
		Booster	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
		Disposal Site Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.53	
		Worker Trips	42.10	46.32	46.32	46.32	46.32	46.32	46.32	46.32	46.32	66.82	
	Total		65.447	169.113	169.113	169.113	169.113	169.113	169.113	169.113	169.113	387.686	
			tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	
Total Tons	Mob		0.16	0.26	0.13	0.13	0.10	0.09	0.09	0.08	0.08	0.09	1.220
	Dredge Site	Dredge Dredging	0.515	0.337	0.198	0.220	0.594	0.139	0.117	0.315	0.235	5.619	8.291
		Dredge Attendant Plant	0.220	0.100	0.059	0.065	0.176	0.041	0.035	0.094	0.070	0.167	1.027
	Transp Route	Dredge Transporting	0.000	0.422	0.247	0.275	0.742	0.174	0.147	0.394	0.293	0.000	2.694
		Booster	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Disposal Site Equipment	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.216	0.216
		Worker Trips	1.325	0.324	0.190	0.211	0.571	0.134	0.113	0.303	0.225	1.250	4.646
	Total		2.220	1.444	0.828	0.905	2.188	0.581	0.504	1.184	0.901	7.338	18.094

Sox

			1	2	3	4	5	6	7	8	9	10	
			lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	
Lbs / Day	Dredge Site	Dredge Dredging	0.727	2.921	2.921	2.921	2.921	2.921	2.921	2.921	2.921	1.152	
		Dredge Attendant Plant	0.309	0.624	0.624	0.624	0.624	0.624	0.624	0.624	0.624	0.045	
	Transp Route	Dredge Transporting	0.000	3.626	3.626	3.626	3.626	3.626	3.626	3.626	3.626	0.000	
		Booster	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
		Disposal Site Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	
		Worker Trips	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	
	Total		1.058	7.195	7.195	7.195	7.195	7.195	7.195	7.195	7.195	1.761	
			tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	
Total Tons	Mob		0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.008
	Dredge Site	Dredge Dredging	0.023	0.020	0.012	0.013	0.036	0.008	0.007	0.019	0.014	0.022	0.175
		Dredge Attendant Plant	0.010	0.004	0.003	0.003	0.008	0.002	0.002	0.004	0.003	0.001	0.038
	Transp Route	Dredge Transporting	0.000	0.025	0.015	0.017	0.045	0.010	0.009	0.024	0.018	0.000	0.162
		Booster	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Disposal Site	Dredge Unloading	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Disposal Site Equipment	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.010
		Worker Trips	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002
	Total		0.034	0.052	0.030	0.034	0.089	0.021	0.018	0.048	0.036	0.034	0.396

62.166

Appendix C – Channel Deepening Daily Emission Calculations

Appendix C -Marine Emissions CDEP Estimate #1 (of 15)
Reach C to Killico #1

Assumed Year of Analysis 2009 — 74

Assumed Fuel Sulfur Level 348 ppm 0.0348%

	From CDEP									Emission Factors						Daily Emissions						
	Primary Hp	Secondary Hp	prime fuel factor	secondary fuel factor	Hrs/Day	Primary LF	Secondary LF	Total Hourly Fuel Consumption per rig (gals)	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 Dredge	9000	3310	0.045	0.039	15.12	80%	40%	376	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.1061	3,518	123	47	49	429	30	8
2 Work Tugs	250	50	0.045	0.039	15.12	20%	50%	3.2	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.1061	37.3	1.1	0.9	1.0	5.6	0.5	4
1 Crew / Survey boat	100	40	0.045	0.039	15.12	15%	50%	1.5	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.1061	8.7	0.2	0.2	0.2	1.5	0.1	3
1 Derrick	200	40	0.011	0.011	15.12	15%	50%	0.6	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.1061	12.4	0.4	0.3	0.3	1.9	0.2	4
Subtotal Attnd Plnt Dredge Site								5								58.4	1.7	1.4	1.5	8.9	0.8	
Transportation Route																						
1 Dredge Transporting boosters	5200	200	0.045	0.039	15.12	90%	50%	215	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.1061	1,973	69	26	27	241	17	8
Disposal Site																						

Appendix C -Marine Emissions CDEP Estimate #2 (of 15)

Reach C to Reedy South

Assumed Year of Analysis 2010

Assumed Fuel Sulfur Level 163 ppm 0.0163%

	From CDEP									Emission Factors						Daily Emissions						
	Primary Hp	Secondary Hp	prime fuel factor	secondary fuel factor	Hrs/Day	Primary LF	Secondary LF	Total Hourly Fuel Consumption per rig (gals)	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 Dredge	9000	3310	0.045	0.039	15.12	80%	40%	376	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0497	3,518	123	47	49	429	14	8
2 Work Tugs	250	50	0.045	0.039	15.12	20%	50%	3.2	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0497	37.3	1.1	0.9	1.0	5.6	0.2	4
1 Crew / Sur	100	40	0.045	0.039	15.12	15%	50%	1.5	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0497	8.7	0.2	0.2	0.2	1.5	0.1	3
1 Derrick	200	40	0.011	0.011	15.12	15%	50%	0.6	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0497	12.4	0.4	0.3	0.3	1.9	0.1	4
Subtotal Attnd Plnt Dredge Site								5								58.4	1.7	1.4	1.5	8.9	0.4	
Transportation Route																						
Dredging Transport																						
1 boosters	5200	200	0.045	0.039	15.12	90%	50%	215	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0497	1,973	69	26	27	241	8	8
Disposal Site																						

Appendix C -Marine Emissions CDEP Estimate #3 (of 15)

Reach C to Killico 2

Assumed Year of Analysis 2010

Assumed Fuel Sulfur Level 163 ppm 0.0163%

	From CDEP									Emission Factors						Daily Emissions						
	Primary Hp	Secondary Hp	prime fuel factor	secondary fuel factor	Hrs/Day	Primary LF	Secondary LF	Total Hourly Fuel Consumption per rig (gals)	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 Dredge	9000	3310	0.045	0.039	15.12	80%	40%	376	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0497	3,518	123	47	49	429	14	8
2 Work Tugs	250	50	0.045	0.039	15.12	20%	50%	3.2	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0497	37.3	1.1	0.9	1.0	5.6	0.2	4
1 Crew / Sur	100	40	0.045	0.039	15.12	15%	50%	1.5	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0497	8.7	0.2	0.2	0.2	1.5	0.1	3
1 Derrick	200	40	0.011	0.011	15.12	15%	50%	0.6	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0497	12.4	0.4	0.3	0.3	1.9	0.1	4
Subtotal Attnd Plnt Dredge Site								5								58.4	1.7	1.4	1.5	8.9	0.4	
Transportation Route																						
Dredge Transporting 1 boosters	5200	200	0.045	0.039	15.12	90%	50%	215	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0497	1,973	69	26	27	241	8	8
Disposal Site																						

Appendix C -Marine Emissions CDEP Estimate #4 (of 15)
Reach B - Drill & Blast

Assumed Year of Analysis 2010
Assumed Fuel Sulfur Level 163 ppm 0.0163%

	From CDEP									Emission Factors						Daily Emissions						
	Primary Hp	Secondary Hp	prime fuel factor	secondary fuel factor	Hrs/Day	Primary LF	Secondary LF	Total Hourly Fuel Consumption per rig (gals)	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	factor basis selector
Dredge Site																						
2 Drillboats (2)	500	3200	0.039	0.033	12.76	40%	10%	18	Cat1 300-1341	7.457	0.21201	0.109125	0.115836	1.11855	0.0497	218	6	3	3	33	1	5
2 Tugboats (2)	500	50	0.045	0.039	12.76	20%	50%	5.5	Cat1 300-1341	7.457	0.21201	0.109125	0.115836	1.11855	0.0497	52.4	1.5	0.8	0.8	7.9	0.3	5
1 Workboat (1)	330	40	0.045	0.039	12.76	20%	50%	3.8	Cat1 300-1341	7.457	0.21201	0.109125	0.115836	1.11855	0.0497	18.0	0.5	0.3	0.3	2.7	0.1	5
1 Sweep Barges (1)	100	0	0.011	0.011	12.76	10%	0%	0.1	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0497	2.1	0.1	0.1	0.1	0.4	0.0	3
Subtotal Attnd Plnt Dredge Site								9.3								72.6	2.1	1.1	1.1	10.9	0.5	
Transportation Route																						
Dredge Transporting																						
Boosters																						
Disposal Site																						

Appendix C -Marine Emissions CDEP Estimate #5 (of 15)
Reach B - Clamshell Rock

Assumed Year of Analysis 2010
Assumed Fuel Sulfur Level 163 ppm 0.0163%

	From CDEP									Emission Factors						Daily Emissions						
	Primary Hp	Secondary Hp	prime fuel factor	secondary fuel factor	Hrs/Day	Primary LF	Secondary LF	Total Hourly Fuel Consumption per rig (gals)	Engine Basi	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	factor basis selector
Dredge Site																						
2 26 cy clam	5000	3310	0.039	0.033	16.67	30%	10%	69	OGV Aux	10.36523	0.3140888	0.195924	0.20532	0.82027	0.0497	1,395	42	26	28	110	7	1
2 worktugs	250	50	0.045	0.039	16.67	30%	50%	4.4	Cat1 175-30	7.457	0.21201	0.181458	0.190406	1.11855	0.0497	54.8	1.6	1.3	1.4	8.2	0.4	4
1 crew/surve	100	40	0.045	0.039	16.67	20%	50%	1.7	Cat1 100-17	7.457	0.21201	0.181458	0.190406	1.26769	0.0497	11.0	0.3	0.3	0.3	1.9	0.1	3
2 derrick	200	40	0.011	0.011	16.67	15%	50%	0.6	Cat1 175-30	7.457	0.21201	0.181458	0.190406	1.11855	0.0497	27.4	0.8	0.7	0.7	4.1	0.2	4
1 Fuel/Water	0	10	0.011	0.011	16.67	0%	20%	0.0	Cat1 50-100	8.2027	0.21201	0.543122	0.563256	1.4914	0.0497	0.6	0.0	0.0	0.0	0.1	0.0	2
Subtotal Attnd Plnt Dredge Site								6.6								93.8	2.7	2.3	2.4	14.3	0.6	
Transportation Route																						
2 Towing Tu	3000	300	0.045	0.039	7.04	60%	50%	86.9	HC-Cat2	9.84324	0.3926111	0.173203	0.18931	0.82027	0.0497	595.4	23.8	10.5	11.5	49.6	3.0	7
8 3,000 cy s	0	250	0.011	0.011	24.00	0%	5%	0.1	Cat1 175-30	7.457	0.21201	0.181458	0.190406	1.11855	0.0497	39.5	1.1	1.0	1.0	5.9	0.3	4
Subtotal Transporting																634.9	24.9	11.4	12.5	55.5	3.3	
Boosters																						
Disposal Site																						

Appendix C -Marine Emissions CDEP Estimate #6 (of 15)
Reach B to Oldmans

Assumed Year of Analysis 2013
Assumed Fuel Sulfur Level 31 ppm 0.0031%

	From CDEP									Emission Factors						Daily Emissions						
	Primary Hp	Secondary Hp	prime fuel factor	secondary fuel factor	Hrs/Day	Primary LF	Secondary LF	Total Hourly Fuel Consumption per rig (gals)	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 Dredge	9000	3310	0.045	0.039	15.12	80%	40%	376	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0094	3,518	123	47	49	429	3	8
2 Work Tugs	250	50	0.045	0.039	15.12	20%	50%	3.2	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0094	37.3	1.1	0.9	1.0	5.6	0.0	4
1 Crew / Sur	100	40	0.045	0.039	15.12	15%	50%	1.5	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0094	8.7	0.2	0.2	0.2	1.5	0.0	3
1 Derrick	200	40	0.011	0.011	15.12	15%	50%	0.6	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0094	12.4	0.4	0.3	0.3	1.9	0.0	4
Subtotal Attnd Plnt Dredge Site								5								58.4	1.7	1.4	1.5	8.9	0.1	
Transportation Route																						
Dredge enroute 0 boosters	0	0	0	0	0.00	90%	50%	0	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0094	0	0	0	0	0	0	8
Disposal Site																						

Appendix C -Marine Emissions CDEP Estimate #7 (of 15)
Reach B - Pedrick N

Assumed Year of Analysis 2013
Assumed Fuel Sulfur Level 31 ppm 0.0031%

	From CDEP									Emission Factors						Daily Emissions						
	Primary Hp	Secondary Hp	prime fuel factor	secondary fuel factor	Hrs/Day	Primary LF	Secondary LF	Total Hourly Fuel Consumption per rig (gals)	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 Dredge	9000	3310	0.045	0.039	13.61	80%	40%	376	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0094	3,167	110	42	44	386	2	8
2 Work Tugs	250	50	0.045	0.039	13.61	20%	50%	3.2	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0094	33.6	1.0	0.8	0.9	5.0	0.0	4
1 Crew / Sur	100	40	0.045	0.039	13.61	15%	50%	1.5	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0094	7.8	0.2	0.2	0.2	1.3	0.0	3
1 Derrick	200	40	0.011	0.011	13.61	15%	50%	0.6	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0094	11.2	0.3	0.3	0.3	1.7	0.0	4
Subtotal Attnd Plnt Dredge Site								5								52.6	1.5	1.3	1.3	8.0	0.1	
Transportation Route																						
Dredge enroute 2 boosters	5200	200	0.045	0.039	13.61	90%	50%	215	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0094	3,551	124	47	49	433	3	8
Disposal Site																						

Appendix C -Marine Emissions CDEP Estimate #8 (of 15)
Reach B to Pendrick S (#1)

Assumed Year of Analysis 2014
Assumed Fuel Sulfur Level 19 ppm 0.0019%

	From CDEP									Emission Factors						Daily Emissions						
	Primary Hp	Secondary Hp	prime fuel factor	secondary fuel factor	Hrs/Day	Primary LF	Secondary LF	Total Hourly Fuel Consumption per rig (gals)	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 Dredge	9000	3310	0.045	0.039	15.12	80%	40%	376	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0058	3,518	123	47	49	429	2	8
2 Work Tugs	250	50	0.045	0.039	15.12	20%	50%	3.2	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0058	37.3	1.1	0.9	1.0	5.6	0.0	4
1 Crew / Sur	100	40	0.045	0.039	15.12	15%	50%	1.5	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0058	8.7	0.2	0.2	0.2	1.5	0.0	3
1 Derrick	200	40	0.011	0.011	15.12	15%	50%	0.6	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0058	12.4	0.4	0.3	0.3	1.9	0.0	4
Subtotal Attnd Plnt Dredge Site								5								58.4	1.7	1.4	1.5	8.9	0.0	
Transportation Route																						
dredge enroute 0 boosters	0	0	0	0	0.00	90%	50%	0	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0058	0	0	0	0	0	0	8
Disposal Site																						

Appendix C -Marine Emissions CDEP Estimate #9 (of 15)
Reach B to Pendrick S (#2)

Assumed Year of Analysis 2014
Assumed Fuel Sulfur Level 19 ppm 0.0019%

	From CDEP									Emission Factors						Daily Emissions						
	Primary Hp	Secondary Hp	prime fuel factor	secondary fuel factor	Hrs/Day	Primary LF	Secondary LF	Total Hourly Fuel Consumption per rig (gals)	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 Dredge	9000	3310	0.045	0.039	15.12	80%	40%	376	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0058	3,518	123	47	49	429	2	8
2 Work Tugs	250	50	0.045	0.039	15.12	20%	50%	3.2	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0058	37.3	1.1	0.9	1.0	5.6	0.0	4
1 Crew / Sur	100	40	0.045	0.039	15.12	15%	50%	1.5	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0058	8.7	0.2	0.2	0.2	1.5	0.0	3
1 Derrick	200	40	0.011	0.011	15.12	15%	50%	0.6	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0058	12.4	0.4	0.3	0.3	1.9	0.0	4
Subtotal Attnd Plnt Dredge Site								5								58.4	1.7	1.4	1.5	8.9	0.0	
Transportation Route																						
dredge enroute 1 boosters	5200	200	0.045	0.039	15.12	90%	50%	215	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0058	1,973	69	26	27	241	1	8
Disposal Site																						

Appendix C- Marine Emissions CDEP Estimate #10 (of 15)
Reach E to Broadkill

Assumed Year of Analysis 2011
Assumed Fuel Sulfur Level 31 ppm 0.0031%

	From CDEP									Emission Factors						Daily Emissions						
	Propulsion Hp	Pumps Hp	Aux & Misc Hp	LF Propulsion	LF Pumps	LF Aux & Misc	% of cycle	Hrs/Day	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 7600 cy dredge	9000	3000	2000	45%	50%	30%	27.6%	5.97	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	797	32	14	15	66	1	7
1 Crew/Survey Vsl	100	0	40	15%	0%	50%		21.60	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0094	12	0	0	0	2	0	3
Transportation Route																						
1 7600 cy dredge	9000	3000	2000	80%	0%	25%	48.7%	10.53	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	1,759	70	31	34	147	2	7
1 5200 hp booster	0	5200	200	0%	90%	50%	p/o time	5.10	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0094	666	23	9	9	81	1	8
Subtotal along Transp Route																2,425	93	40	43	228	2	
Disposal Site																						
1 7600 cy dredge	9000	3000	2000	0%	80%	25%	23.6%	5.10	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	321	13	6	6	27	0	7
1 Tender Tug	250	0	50	60%	0%	50%		21.60	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0094	62	2	2	2	9	0	4
Subtotal Dredge at Pumpout							100.0%	21.60								383.2	14.6	7.2	7.8	36.1	0.4	
								90.0%														

Appendix C -Marine Emissions CDEP Estimate #11 (of 15)

Reach E to Kelly Isl

Hours per Month 657 (730hrs x 90% TE)

Assumed Year of Analysis 2012

Assumed Fuel Sulfur Level 31 ppm 0.0031%

	From CDEP									Emission Factors						Daily Emissions						
	Propulsion Hp	Pumps Hp	Aux & Misc Hp	LF Propulsion	LF Pumps	LF Aux & Misc	% of cycle	Hrs/Day	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 7600 cy dr	9000	3000	2000	45%	50%	30%	26.2%	5.66	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	755	30	13	15	63	1	7
1 Crew/Surv	100	0	40	15%	0%	50%		21.60	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0094	12	0	0	0	2	0	3
Transportation Route																						
1 7600 cy dr	9000	3000	2000	80%	0%	25%	51.4%	11.11	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	1,856	74	33	36	155	2	7
1 5200 hp bo	0	5200	200	0%	90%	50%	p/o time	4.83	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0094	631	22	8	9	77	0	8
Subtotal along Transp Route																2,487	96	41	44	232	2	
Disposal Site																						
1 7600 cy dr	9000	3000	2000	0%	80%	25%	22.4%	4.83	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	304	12	5	6	25	0	7
1 Tender Tu	250	0	50	60%	0%	50%		21.60	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0094	62	2	2	2	9	0	4
Subtotal Dredge at Pumpout							100.0%	21.60								366.4	13.9	6.9	7.4	34.7	0.4	
								90.0%														

Appendix C -Marine Emissions CDEP Estimate #12 (of 15)

Reach D to Reedy Pt S.

Hours per Month 657 (730hrs x 90% TE)

Assumed Year of Analysis 2013

Assumed Fuel Sulfur Level 31 ppm 0.0031%

	From CDEP									Emission Factors						Daily Emissions						
	Propulsion Hp	Pumps Hp	Aux & Misc Hp	LF Propulsion	LF Pumps	LF Aux & Misc	% of cycle	Hrs/Day	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 7600 cy dr	9000	3000	2000	45%	50%	30%	39.0%	8.43	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	1,124	45	20	22	94	1	7
1 Crew/Surv	100	0	40	15%	0%	50%		21.60	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0094	12	0	0	0	2	0	3
Transportation Route																						
1 7600 cy dr	9000	3000	2000	80%	0%	25%	27.7%	5.97	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	998	40	18	19	83	1	7
0 5200 hp bo	0	5200	200	0%	90%	50%	p/o time	7.20	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0094	0	0	0	0	0	0	8
Subtotal along Transp Route																998	40	18	19	83	1	
Disposal Site																						
1 7600 cy dr	9000	3000	2000	0%	80%	25%	33.3%	7.20	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	453	18	8	9	38	0	7
1 Tender Tu	250	0	50	60%	0%	50%		21.60	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0094	62	2	2	2	9	0	4
Subtotal Dredge at Pumpout							100.0%	21.60								515.3	19.8	9.5	10.3	47.1	0.5	
								90.0%														

Appendix C -Marine Emissions CDEP Estimate #13 (of 15)

Reach D to Artfcl Isl

Hours per Month 657 (730hrs x 90% TE)

Assumed Year of Analysis 2013

Assumed Fuel Sulfur Level 31 ppm 0.0031%

	From CDEP									Emission Factors						Daily Emissions						
	Propulsion Hp	Pumps Hp	Aux & Misc Hp	LF Propulsion	LF Pumps	LF Aux & Misc	% of cycle	Hrs/Day	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 7600 cy dred	9000	3000	2000	45%	50%	30%	29.0%	6.27	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	837	33	15	16	70	1	7
1 Crew/Survey	100	0	40	15%	0%	50%		21.60	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0094	12	0	0	0	2	0	3
Transportation Route																						
1 7600 cy dred	9000	3000	2000	80%	0%	25%	40.6%	8.78	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	1,467	59	26	28	122	1	7
0 5200 hp boos	0	5200	200	0%	90%	50%	p/o time	6.55	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0094	0	0	0	0	0	0	8
Subtotal along Transp Route																1,467	59	26	28	122	1	
Disposal Site																						
1 7600 cy dred	9000	3000	2000	0%	80%	25%	30.3%	6.55	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	412	16	7	8	34	0	7
1 Tender Tug	250	0	50	60%	0%	50%		21.60	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0094	62	2	2	2	9	0	4
Subtotal Dredge at Pumpout							100.0%	21.60								474.3	18.2	8.8	9.5	43.7	0.5	
								90.0%														

Appendix C -Marine Emissions CDEP Estimate #14 (of 15)
Reach AA - National Park

Assumed Year of Analysis 2010
Assumed Fuel Sulfur Level 163 ppm 0.0163%

	From CDEP									Emission Factors						Daily Emissions						
	Primary Hp	Secondary Hp	prime fuel factor	secondary fuel factor	Hrs/Day	Primary LF	Secondary LF	Total Hourly Fuel Consumption per rig (gals)	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 Dredge	9000	3310	0.045	0.039	13.61	80%	40%	376	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0497	3,167	110	42	44	386	13	8
2 Work Tugs	250	50	0.045	0.039	13.61	20%	50%	3.2	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0497	33.6	1.0	0.8	0.9	5.0	0.2	4
1 Crew / Sur	100	40	0.045	0.039	13.61	15%	50%	1.5	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0497	7.8	0.2	0.2	0.2	1.3	0.1	3
1 Derrick	200	40	0.011	0.011	13.61	15%	50%	0.6	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0497	11.2	0.3	0.3	0.3	1.7	0.1	4
Subtotal Attnd Plnt Dredge Site								5								52.6	1.5	1.3	1.3	8.0	0.4	
Transportation Route																						
dredge enroute																						
2 boosters	5200	200	0.045	0.039	13.61	90%	50%	215	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0497	3,551	124	47	49	433	14	8
Disposal Site																						

Appendix C-Marine Emissions CDEP Estimate #15 (of 15)

Reach A to Pedricktown N.

Hours per Month 657 (730hrs x 90% TE)

Assumed Year of Analysis 2013

Assumed Fuel Sulfur Level 31 ppm 0.0031%

	From CDEP									Emission Factors						Daily Emissions						
	Propulsion Hp	Pumps Hp	Aux & Misc Hp	LF Propulsion	LF Pumps	LF Aux & Misc	% of cycle	Hrs/Day	Engine Basis	NOx gr-bhp/hr	VOC gr-bhp/hr	PM2.5 gr-bhp/hr	PM10 gr-bhp/hr	CO gr-bhp/hr	Sox gr-bhp/hr	NOx lbs/day	VOC lb/day	PM2.5 lbs/day	PM10 lbs/day	CO lbs/day	Sox lbs/day	Factor basis selector
Dredge Site																						
1 7600 cy dr	9000	3000	2000	45%	50%	30%	21.6%	4.66	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	622	25	11	12	52	1	7
1 Crew/Surv	100	0	40	15%	0%	50%		21.60	Cat1 100-175	7.457	0.21201	0.181458	0.190406	1.26769	0.0094	12	0	0	0	2	0	3
Transportation Route																						
1 7600 cy dr	9000	3000	2000	80%	0%	25%	57.7%	12.47	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	2,083	83	37	40	174	2	7
0 5200 hp bo	0	5200	200	0%	90%	50%	p/o time	4.47	Locomotive	12.38	0.43173	0.163726	0.172126	1.51	0.0094	0	0	0	0	0	0	8
Subtotal along Transp Route																2,083	83	37	40	174	2	
Disposal Site																						
1 7600 cy dr	9000	3000	2000	0%	80%	25%	20.7%	4.47	HC-Cat2	9.84324	0.392611	0.173203	0.18931	0.82027	0.0094	281	11	5	5	23	0	7
1 Tender Tug	250	0	50	60%	0%	50%		21.60	Cat1 175-300	7.457	0.21201	0.181458	0.190406	1.11855	0.0094	62	2	2	2	9	0	4
Subtotal Dredge at Pumpout							100.0%	21.60								343.6	13.0	6.5	7.0	32.8	0.3	
								90.0%														

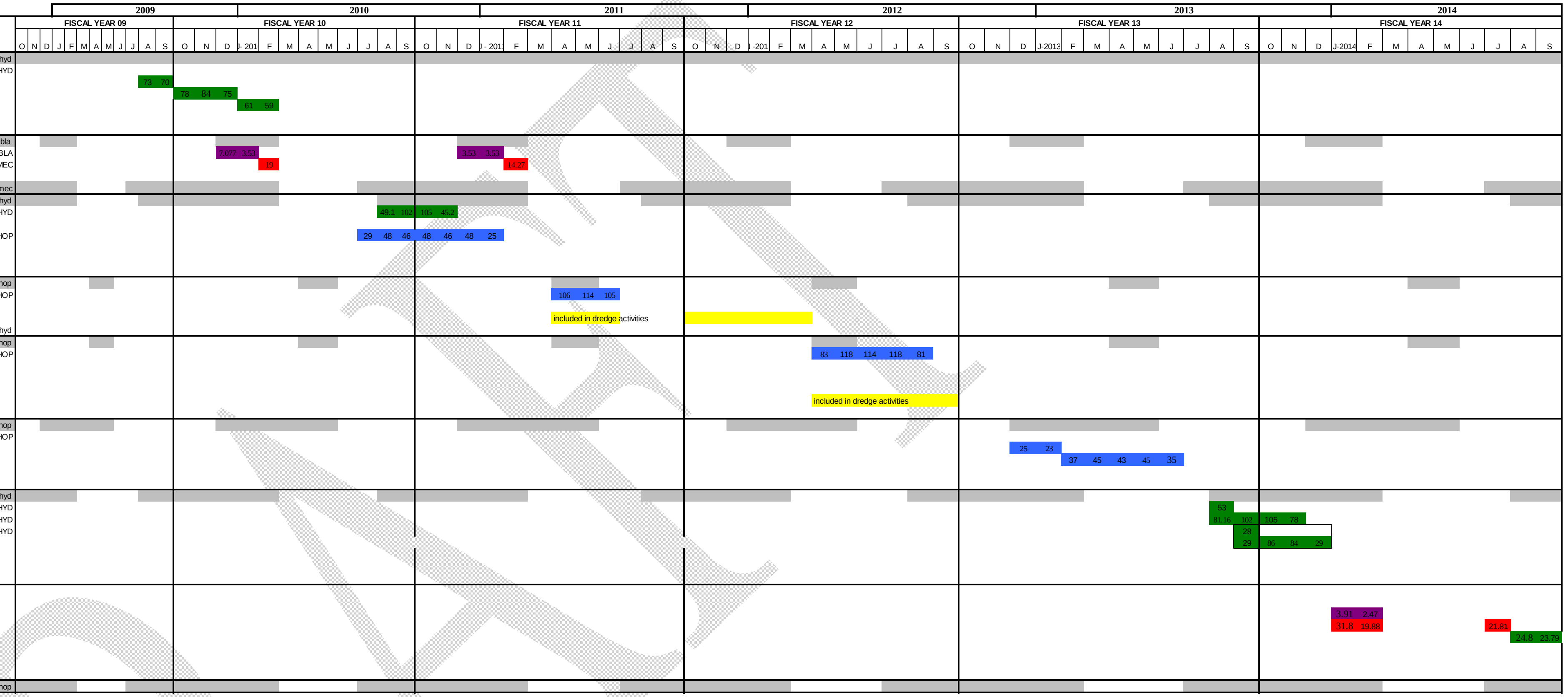
Appendix D – Project Schedule and Monthly Emissions Profile for Each Pollutant

Delaware River Deepening
Construction Emissions (NOx)
Based on USACE CDEP Esimates and 09 March Construction Schedule Update
4/16/2009

Code	Legend
HOP	HOPPER DREDGE
HYD	CUTTER SUCTION DREDGE
	LANDSIDE CONSTRUCTION
MEC	CLAMSHELL DREDGE
BLA	DRILLBOAT (BLASTING)
	DREDGING WINDOW

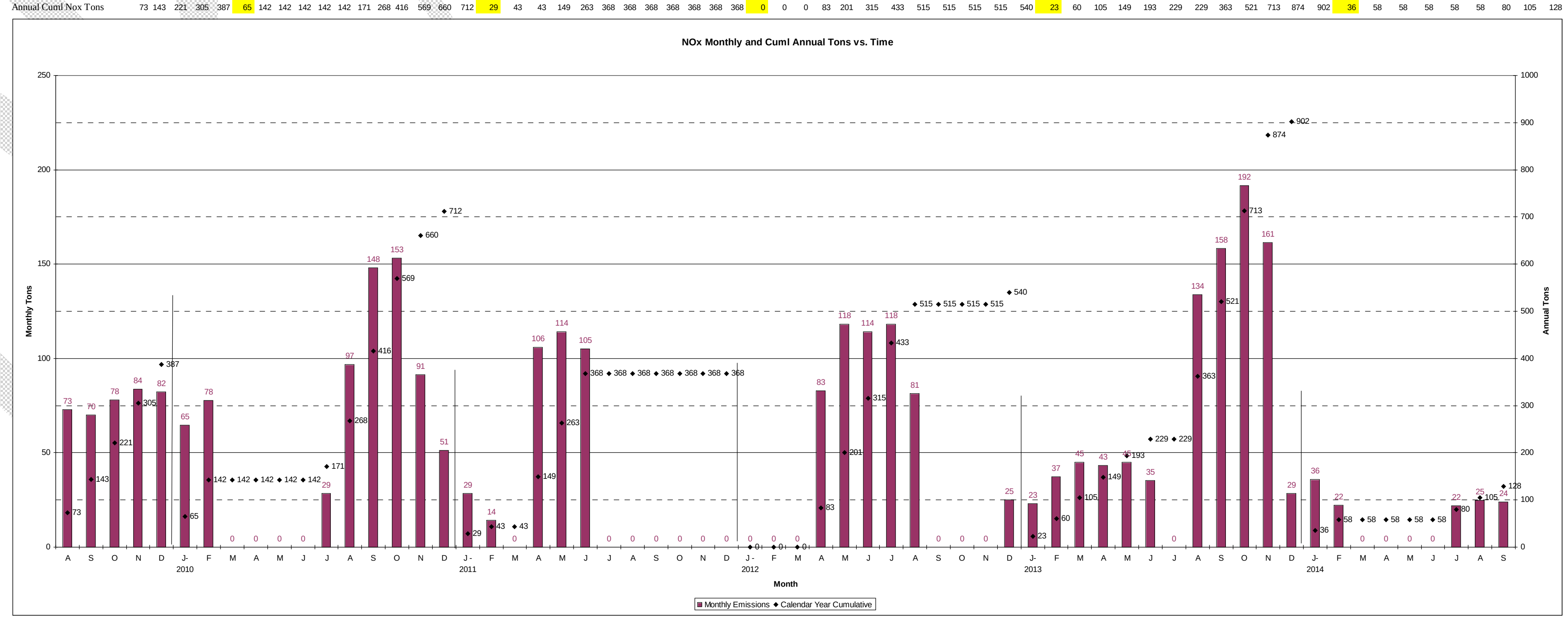
DELAWARE DEEPENING DREDGING CONTRACTS	River Mile	Duration (Mo)	Estimated Quantity (cy)	CDEP Est #	CDEP Pay Cys	CDEP Months	CDEP # of Machines	Dredging NOx lbs / Day	Mobilization Tons Nox	Total Nox Tons	Dredge		
Contract No. 1 (award year 1)													hyd
Reach C- Bulkhead Bar													HYD
183+000 to 206+201 - Killicohook	68.3	1.65	932,600	1	932,600	1.65	1	5,588	2.80	143.0	1	0.00	
206+201 to 225+000 - Reedy Pt South	63.9	2.76	597,800	2	597,800	2.76	1	5,583	2.65	237.0	1	0.00	
225+000 to 242+514 - Killicohook	60.3	1.38	972,400	3	972,400	1.38	1	5,587	2.53	119.8	1	0.00	
Construct Project			**2,502,800**		**2,502,800**					**499.8**			
Contract No. 2 (award year 1)													bla
Reach B - Rock Blasting		3.17		4	77,000	3.17	2	293	3.55	17.7	1	0.00	BLA
Reach B - Rock Dredging - Fort Mifflin		1.27		5	77,000	0.85	2	2,208	4.73	33.3	1	0.00	MEC
Construct Project			**77,000**		**77,000**					**50.9**			mec
Contract No. 3 (award year 2)													hyd
Reach AA - National Park		2.88	994,000	14	994,000	2.88	1	6,802	3.85	301.8	1	0.00	HYD
19+700 to 32+756	99.2												
Reach A - Pedricktown North		6.1	1,666,600	15	1,666,600	6.10	1	3,076	3.58	288.9	1	0.00	HOP
32+756 to 90+000	96.8												
Construct Project			**2,660,600**		**2,660,600**					**590.7**			
Contract No. 4 (award year 3)													hop
Reach E - Broadkill Beach - Dredge		3		10	1,598,700	5.79	1	3,686	0.83	325.4	2	0.00	HOP
461+300 to 512+000	15.6												
Construct Project			**1,598,700**		**1,598,700**					**325.4**			hyd
Contract No. 5 (award year 4)													hop
Reach E - Kelly Island -Dredge		4.5		11	2,483,000	8.86	1	3,808	1.54	514.7	2	0.00	HOP
351+300 to 360+000	36.4		345,800										
360+000 to 381+000	32.1		55,500										
381+000 to 461+300	30.8		2,081,700										
Construct Project			**2,483,000**		**2,483,000**					**514.7**			
Contract No. 6 (award year 5)													hop
Reach D -											1		HOP
249+000 to 270+000 - Reedy Pt. South	55.8	1.13	396,300	12	396,300	1.13	1	2,670	2.19	48.1		0.00	
270+000 to 324+000 - Artificial Island	51.8	4.63	1,654,800	13	1,654,800	4.63	1	2,894	2.06	205.9			
Construct Project			**2,051,100**		**2,051,100**					**253.9**			
Contract No. 7 (award year 6)													hyd
Reach B - Oldmans		0.89	1,671,400	6	1,671,400	0.90	1	3,611	3.18	52.6	1	0.00	HYD
Reach B - Pedricktown North		3.51	1,050,700	7	1,050,700	3.51	1	6,797	3.40	366.2	1	0.00	HYD
Reach B - Pedricktown South		3.13	1,942,800	8	499,300	0.45	1	3,597	3.18	27.8	1	0.00	HYD
90+000 to 176+000	0.0			9	1,443,500	2.68	1	5,570		227.0		0.00	
Construct Project			**4,664,900**		**4,664,900**					**673.7**			
Total Channel		**40.0**	**16,038,100**		**16,038,100**					**2,909.3**			
Berth Deepenings													
Berth Deepenings Drill/Blast					25,089	2.07	1	157	1.44	6.4			
Berth Deepening Clamshell					460,437	2.94	1	1,420	10.03	73.5			
Berth Deepening CSD Rehandling WP					460,437	1.23	1	2,544	0.98	48.6			
Total Berth Deepenings					**460,437**					**128.5**			
Total Project					**16,498,537**					**3,037.7**			hop

UPDATED 9 March 2009 (2:00 a.m.) 0.000



Monthly Nox Tons	73	70	78	84	82	65	78	0	0	0	0	29	97	148	153	91	51	29	14	0	106	114	105	0	0	0	0	0	0	0	0	0	83	118	114	118	81	0	0	0	25	23	37	45	43	45	35	0	134	158	192	161	29	36	22	0	0	0	0	22	25	24
Cumulative Nox Tons	73	143	221	305	387	452	529	529	529	529	529	558	655	803	956	1047	1099	1127	1141	1141	1247	1362	1467	1467	1467	1467	1467	1467	1467	1467	1467	1467	1550	1668	1782	1900	1982	1982	1982	1982	2007	2030	2067	2112	2155	2200	2236	2236	2369	2528	2719	2881	2909	2945	2967	2967	2967	2967	2967	2989	3014	3038
Annual Cuml Nox Tons	73	143	221	305	387	65	142	142	142	142	142	171	268	416	569	660	712	29	43	43	149	263	368	368	368	368	368	368	368	0	0	0	83	201	315	433	515	515	515	515	540	23	60	105	149	193	229	229	363	521	713	874	902	36	58	58	58	58	58	80	105	128

Total Tons NOx	
Calendar 2009	387.1
Calendar 2010	711.5
Calendar 2011	368.3
Calendar 2012	539.8
Calendar 2013	902.5
Calendar 2014	128.5
	3,037.7

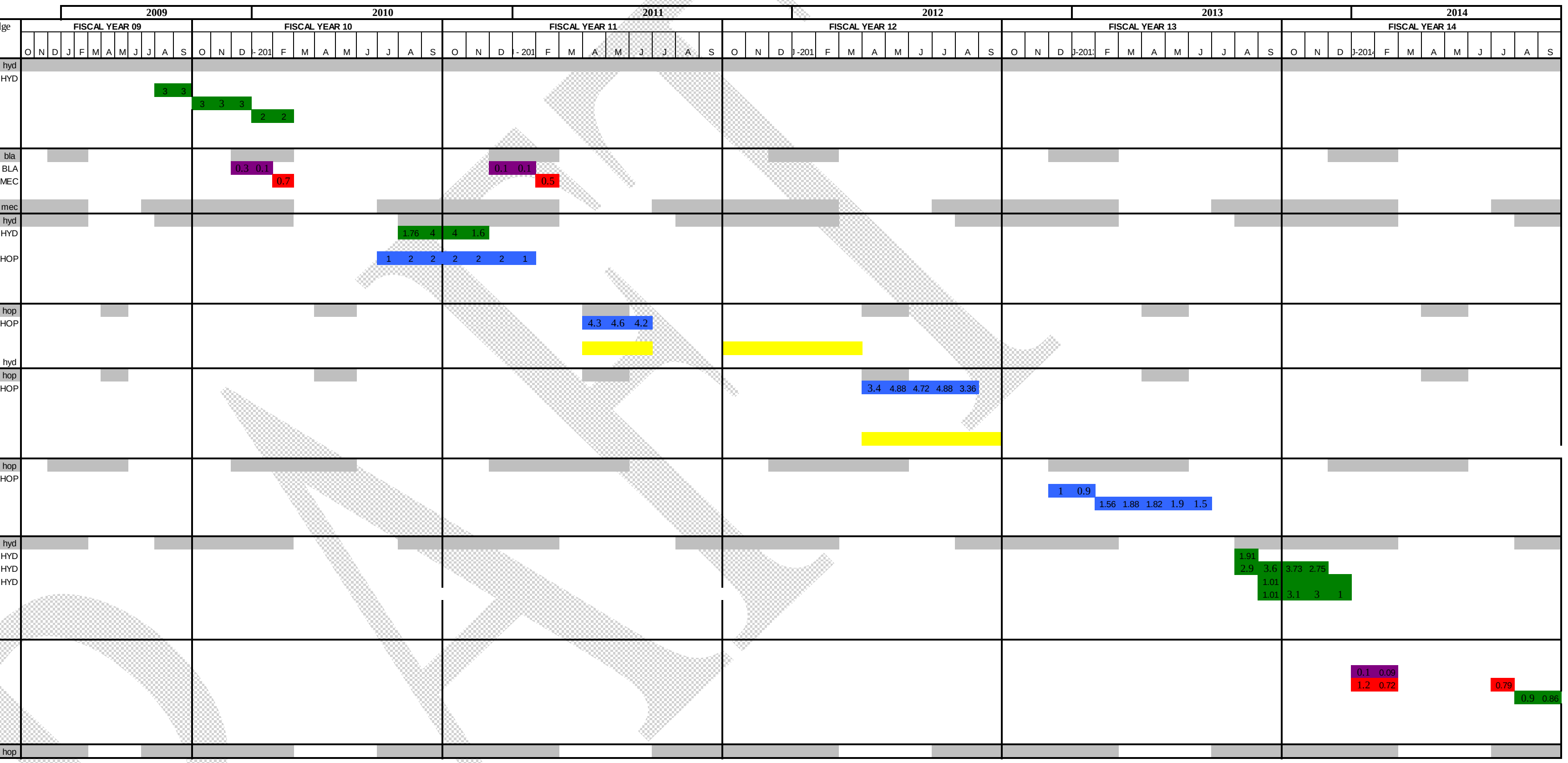


Delaware River Deepening
Construction Emissions (VOC)
Based on USACE CDEP Esimates and 09 March Construction Schedule Update
4/16/2009

HOP HOPPER DREDGE
HYD CUTTER SUCTION DREDGE
LANDSIDE CONSTRUCTION
MEC CLAMSHELL DREDGE
BLA DRILLBOAT (BLASTING)
DREDGING WINDOW

DELAWARE DEEPENING / DREDGING CONTRACTS	River Mile	Duration (Mo)	Estimated Quantity (cy)	CDEP Est #	CDEP Pay Cys	CDEP Months	CDEP # of Machines	Dredging VOCs lbs / Day	Mobilization Tons VOCs	Total VOCs Tons	Dredge	
Contract No. 1 (award year 1)												hyd
Reach C- Bulkhead Bar												HYD
183+000 to 206+201 - Killicohook	68.3	1.65	932,600	1	932,600	1.65	1	200.6	0.11	5.1	1	
206+201 to 225+000 - Reedy Pt South	63.9	2.76	597,800	2	597,800	2.76	1	200.3	0.10	8.5	1	
225+000 to 242+514 - Killicohook	60.3	1.38	972,400	3	972,400	1.38	1	200.4	0.10	4.3	1	
Construct Project			**2,502,800**		**2,502,800**					**18.0**		
Contract No. 2 (award year 1)												bla
Reach B - Rock Blasting		3.17		4	77,000	3.17	2	10.5	0.13	0.6	1	BLA
Reach B - Rock Dredging - Fort Mifflin		1.27		5	77,000	0.85	2	77.7	0.18	1.2	1	MEC
Construct Project			**77,000**		**77,000**					**1.8**		mec
Contract No. 3 (award year 2)												hyd
Reach AA - National Park		2.88	994,000	14	994,000	2.88	1	242.2	0.15	10.8	1	HYD
19+700 to 32+756	99.2											
Reach A - Pedricktown North		6.1	1,666,600	15	1,666,600	6.10	1	123.3	0.14	11.6	1	HOP
32+756 to 90+000	96.8											
Construct Project			**2,660,600**		**2,660,600**					**22.3**		
Contract No. 4 (award year 3)												hop
Reach E - Broadkill Beach - Dredge		3		10	1,598,700	5.79	1	147.8	0.03	13.1	2	HOP
461+300 to 512+000	15.6											
Construct Project			**1,598,700**		**1,598,700**					**13.1**		hyd
Contract No. 5 (award year 4)												hop
Reach E - Kelly Island -Dredge		4.5		11	2,483,000	8.86	1	157.4	0.06	21.3	2	HOP
351+300 to 360+000	36.4		345,800									
360+000 to 381+000	32.1		55,500									
381+000 to 461+300	30.8		2,081,700									
Construct Project			**2,483,000**		**2,483,000**					**21.3**		
Contract No. 6 (award year 5)												hop
Reach D -											1	HOP
249+000 to 270+000 - Reedy Pt. South	55.8	1.13	396,300	12	396,300	1.13	1	107.5	0.09	1.9		
270+000 to 324+000 - Artificial Island	51.8	4.63	1,654,800	13	1,654,800	4.63	1	121.5	0.08	8.6		
Construct Project			**2,051,100**		**2,051,100**					**10.6**		
Contract No. 7 (award year 6)												hyd
Reach B - Oldmans		0.89	1,671,400	6	1,671,400	0.90	1	130.2	0.12	1.9	1	HYD
Reach B - Pedricktown North		3.51	1,050,700	7	1,050,700	3.51	1	240.8	0.13	13.0	1	HYD
Reach B - Pedricktown South		3.13	1,942,800	8	499,300	0.45	1	128.7	0.12	1.0	1	HYD
90+000 to 176+000	0.0			9	1,443,500	2.68	1	197.6	0.00	8.1		
Construct Project			**4,664,900**		**4,664,900**					**24.0**		
Total Channel		**40.0**	**16,038,100**		**16,038,100**					**111.0**		
Berth Deepenings												
Berth Deepenings Drill/Blast					25,089	2.07	1	6.0	0.05	0.2		
Berth Deepening Clamshell					460,437	2.94	1	51.2	0.36	2.7		
Berth Deepening CSD Rehandling WP					460,437	1.23	1	91.9	0.04	1.8		
Total Berth Deepenings					**460,437**					**4.6**		
Total Project					**16,498,537**					**115.6**		hop

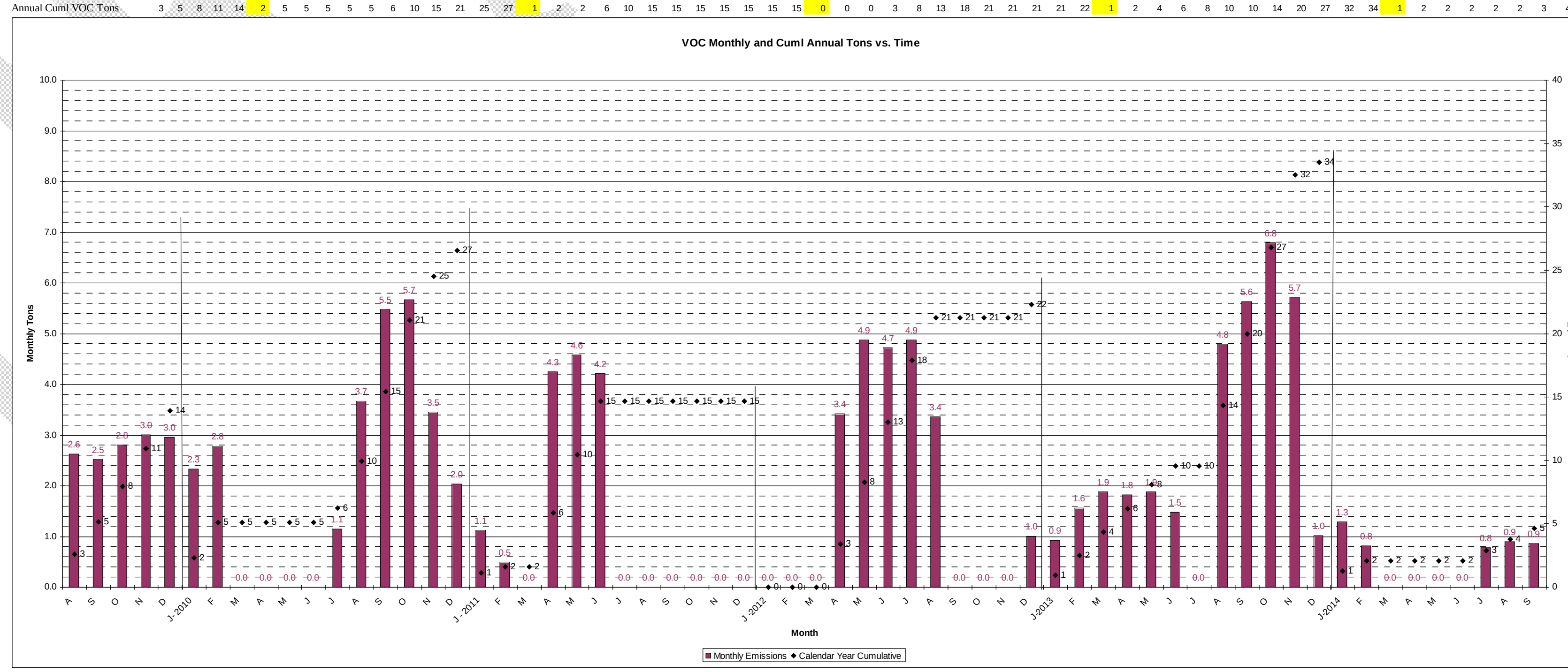
UPDATED 9 March 2009 (2:00 a.m.) 0.00



Monthly VOC Tons	2.6	2.5	2.8	3.0	3.0	2.3	2.8	0.0	0.0	0.0	0.0	1.1	3.7	5.5	5.7	3.5	2.0	1.1	0.5	0	4.25	4.58	4.22	0	0	0	0	0	0	0	0	0	3.4	4.9	4.7	4.9	3.4	0	0	0	1	0.9	1.6	1.9	1.8	1.9	1.5	0	4.8	5.6	6.8	5.7	1	1.3	0.8	0	0	0	0	0.8	0.9	0.9
Cumulative VOC Tons	2.6	5.1	7.9	11.0	13.9	16.2	19.0	19.0	19.0	19.0	19.0	20.2	23.8	29.3	35.0	38.5	40.5	41.6	42.1	42.1	46.4	51	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55	55	55	59	63	68	73	76	76	76	76	77	78	80	82	84	86	87	87	92	97	104	110	111	112	113	113	113	113	113	114	115	116
Annual Cuml VOC Tons	3	5	8	11	14	2	5	5	5	5	5	6	10	15	21	25	27	1	2	2	6	10	15	15	15	15	15	15	15	0	0	0	3	8	13	18	21	21	21	21	22	1	2	4	6	8	10	10	14	20	27	32	34	1	2	2	2	2	2	3	4	5

Total Tons VOC

Calendar 2009	**13.9**
Calendar 2010	**26.6**
Calendar 2011	**14.7**
Calendar 2012	**22.3**
Calendar 2013	**33.5**
Calendar 2014	**4.6**
	115.6



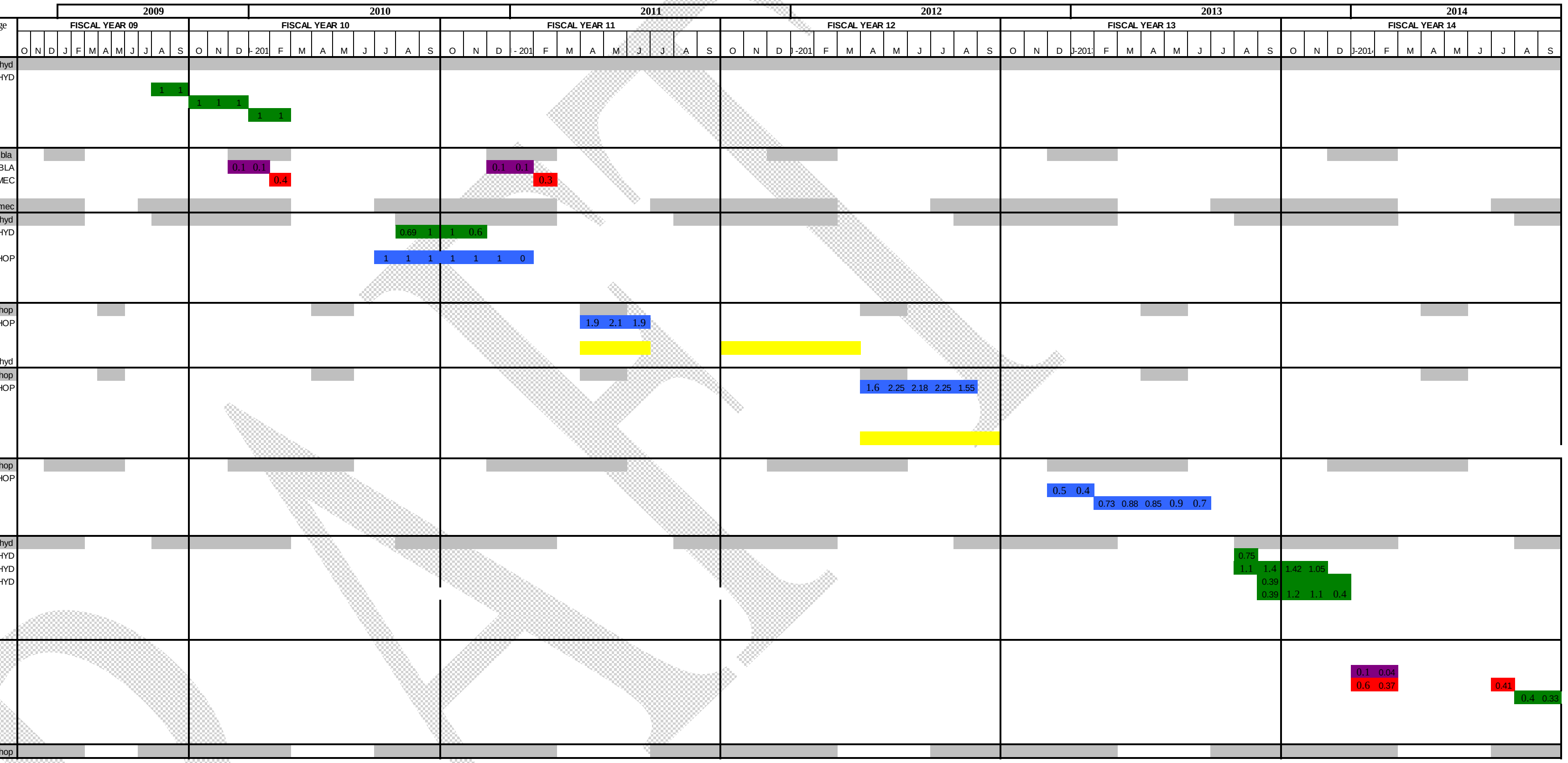
Delaware River Deepening
Construction Emissions (PM2.5)
Based on USACE CDEP Esimates and 09 March Construction Schedule Update
4/16/2009

Code	Legend
HOP	HOPPER DREDGE
HYD	CUTTER SUCTION DREDGE
	LANDSIDE CONSTRUCTION
MEC	CLAMSHELL DREDGE
BLA	DRILLBOAT (BLASTING)
	DREDGING WINDOW

DELAWARE DEEPENING DREDGING CONTRACTS	River Mile	Duration (Mo)	Estimated Quantity (cy)	CDEP Est #	CDEP Pay Cys	CDEP Months	CDEP # of Machines	Dredging PM2.5 lbs / Day	Mobilization Tons PM2.5	Total PM2.5 Tons	Dredge	
Contract No. 1 (award year 1)												hyd
Reach C- Bulkhead Bar												HYD
183+000 to 206+201 - Killicohook	68.3	1.65	932,600	1	932,600	1.65	1	77.7	0.051	2.0	1	
206+201 to 225+000 - Reedy Pt South	63.9	2.76	597,800	2	597,800	2.76	1	77.1	0.048	3.3	1	
225+000 to 242+514 - Killicohook	60.3	1.38	972,400	3	972,400	1.38	1	78.6	0.046	1.7	1	
Construct Project			**2,502,800**		**2,502,800**					**7.0**		
Contract No. 2 (award year 1)												bla
Reach B - Rock Blasting		3.17		4	77,000	3.17	2	4.3	0.061	0.3	1	BLA
Reach B - Rock Dredging - Fort Mifflin		1.27		5	77,000	0.85	2	44.6	0.088	0.7	1	MEC
Construct Project			**77,000**		**77,000**					**0.9**		
												mec
Contract No. 3 (award year 2)												hyd
Reach AA - National Park		2.88	994,000	14	994,000	2.88	1	92.9	0.069	4.1	1	HYD
19+700 to 32+756	99.2											
Reach A - Pedricktown North		6.1	1,666,600	15	1,666,600	6.10	1	55.5	0.063	5.2	1	HOP
32+756 to 90+000	96.8											
Construct Project			**2,660,600**		**2,660,600**					**9.3**		
Contract No. 4 (award year 3)												hop
Reach E - Broadkill Beach - Dredge		3		10	1,598,700	5.79	1	66.4	0.01	5.9	2	HOP
461+300 to 512+000	15.6											
Construct Project			**1,598,700**		**1,598,700**					**5.9**		
												hyd
Contract No. 5 (award year 4)												hop
Reach E - Kelly Island -Dredge		4.5		11	2,483,000	8.86	1	72.6	0.03	9.8	2	HOP
351+300 to 360+000	36.4		345,800									
360+000 to 381+000	32.1		55,500									
381+000 to 461+300	30.8		2,081,700									
Construct Project			**2,483,000**		**2,483,000**					**9.8**		
Contract No. 6 (award year 5)												hop
Reach D -											1	HOP
249+000 to 270+000 - Reedy Pt. South	55.8	1.13	396,300	12	396,300	1.13	1	48.8	0.04	0.9		
270+000 to 324+000 - Artificial Island	51.8	4.63	1,654,800	13	1,654,800	4.63	1	56.5	0.04	4.0		
Construct Project			**2,051,100**		**2,051,100**					**4.9**		
Contract No. 7 (award year 6)												hyd
Reach B - Oldmans		0.89	1,671,400	6	1,671,400	0.90	1	50.3	0.06	0.7	1	HYD
Reach B - Pedricktown North		3.51	1,050,700	7	1,050,700	3.51	1	91.6	0.06	5.0	1	HYD
Reach B - Pedricktown South		3.13	1,942,800	8	499,300	0.45	1	49.1	0.06	0.4	1	HYD
90+000 to 176+000	0.0			9	1,443,500	2.68	1	75.2	0.00	3.1		
Construct Project			**4,664,900**		**4,664,900**					**9.2**		
Total Channel		**40.0**	**16,038,100**		**16,038,100**					**47.0**		
Berth Deepenings												
Berth Deepenings Drill/Blast					25,089	2.07	1	2	0.02	0.1		
Berth Deepening Clamshell					460,437	2.94	1	27	0.19	1.4		
Berth Deepening CSD Rehandling WP					460,437	1.23	1	36	0.02	0.7		
Total Berth Deepenings					**460,437**					**2.2**		
Total Project					**16,498,537**					**49.1**		hop

UPDATED 9 March 2009 (2:00 a.m.)

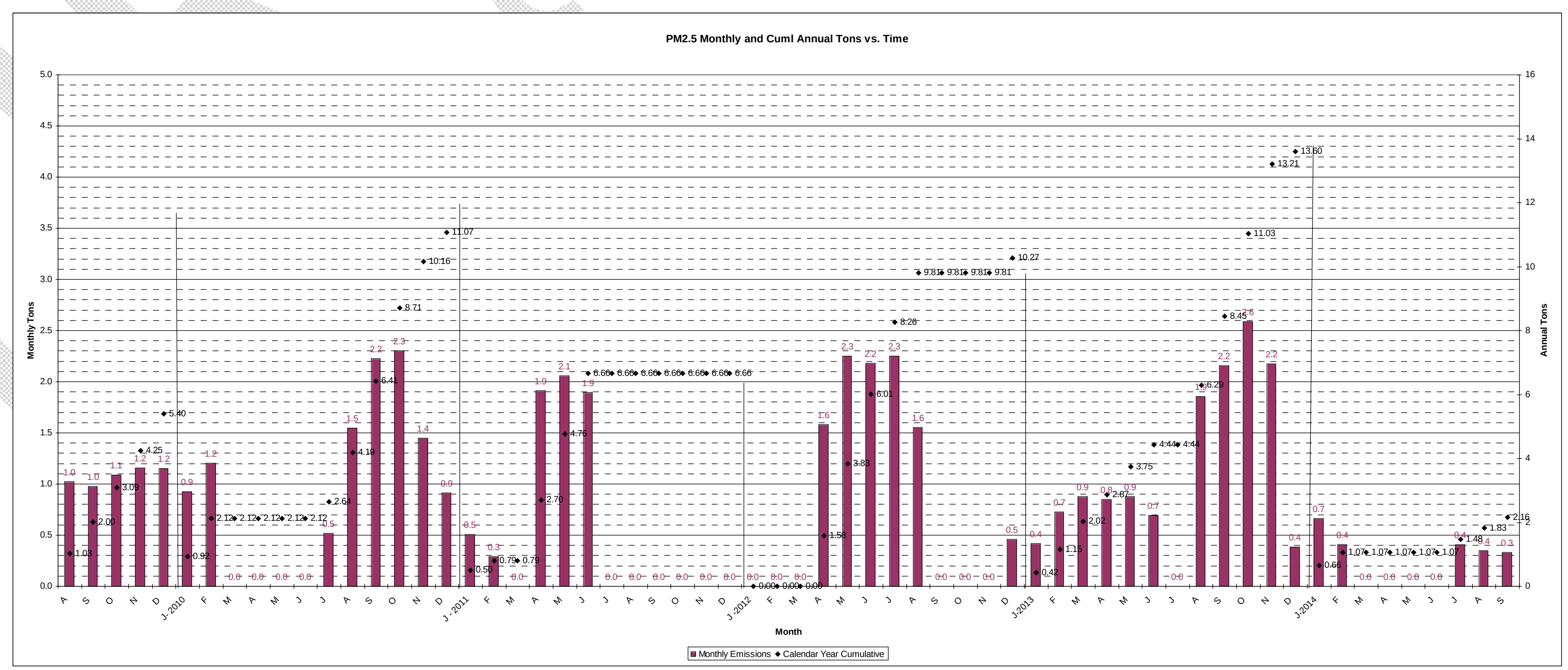
0.00



Total Tons VOC	
Calendar 2009	**5.40**
Calendar 2010	**11.07**
Calendar 2011	**6.66**
Calendar 2012	**10.27**
Calendar 2013	**13.60**
Calendar 2014	**2.16**
	49.15

Monthly PM2.5 Tons	1.0	1.0	1.1	1.2	1.2	0.9	1.2	0.0	0.0	0.0	0.0	0.5	1.5	2.2	2.3	1.4	0.9	0.5	0.3	0	1.91	2.06	1.9	0	0	0	0	0	0	0	0
Cumulative PM2.5 Tons	1	2	3	4	5	6	8	8	8	8	8	8	10	12	14	16	16	17	17	17	19	21	23	23	23	23	23	23	23	23	23
Annual Cuml PM2.5 Tons	1	2	3	4.2	5.4	0.9	2.1	2.1	2.1	2.1	2.1	2.6	4.19	6.4	8.71	10.2	11.1	0.5	0.8	0.79	2.7	4.76	6.66	6.66	6.66	6.66	6.66	6.66	6.66	0	0

Monthly PM2.5 Tons	0	1.6	2.3	2.2	2.3	1.6	0	0	0	0.5	0.4	0.7	0.9	0.8	0.9	0.7	0	1.9	2.2	2.6	2.2	0.4	0.7	0.4	0	0	0	0	0.4	0.4	0.3
Cumulative PM2.5 Tons	23	25	27	29	31	33	33	33	33	33	34	35	35	36	37	38	38	40	42	44	47	47	48	48	48	48	48	48	48	49	49
Annual Cuml PM2.5 Tons	0	1.6	3.8	6	8.3	9.8	9.8	9.8	9.8	10	0.4	1.1	2	2.9	3.7	4.4	4.4	6.3	8.4	11	13	14	0.7	1.1	1.1	1.1	1.1	1.1	1.5	1.8	2.2



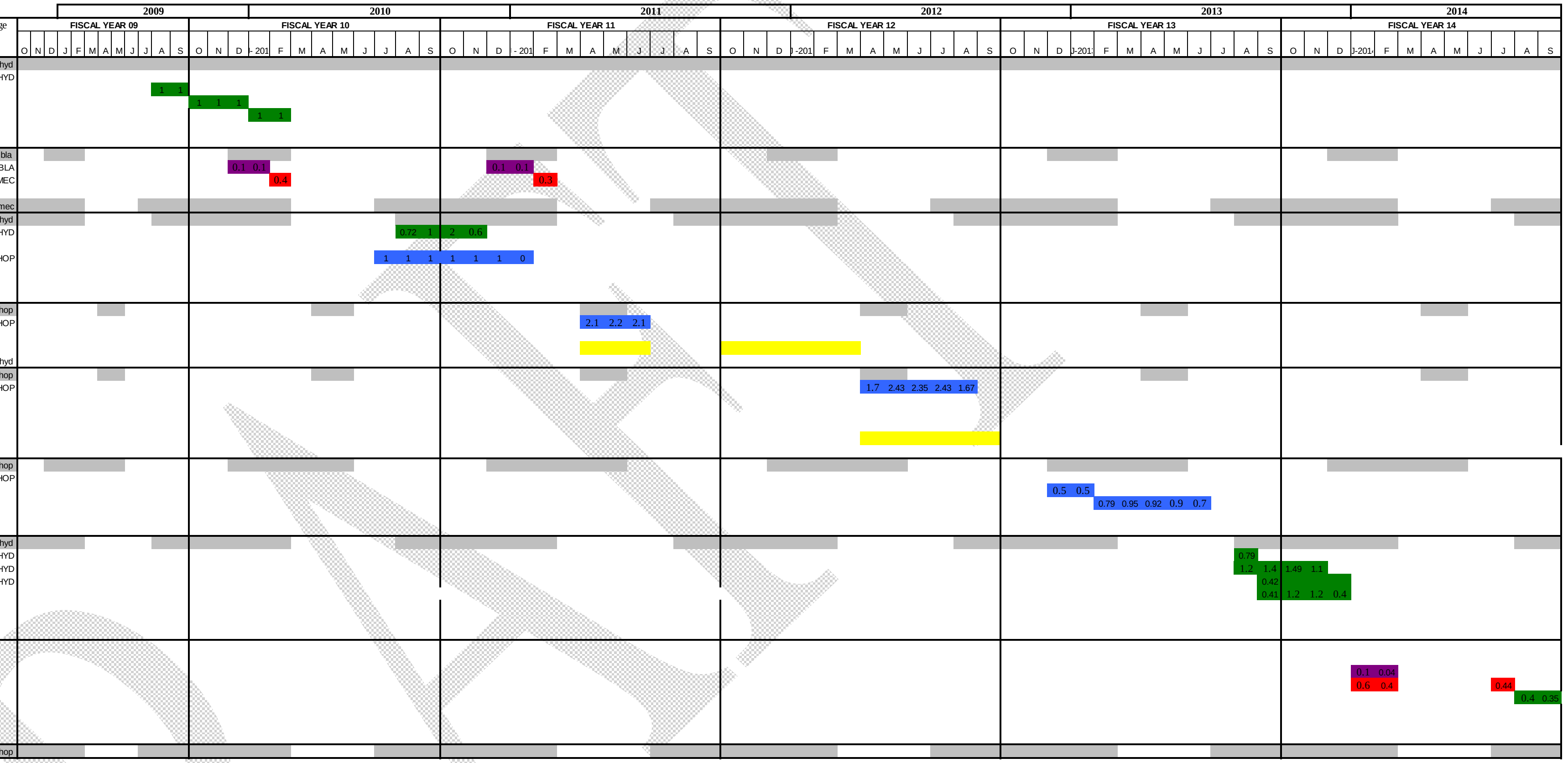
Delaware River Deepening
Construction Emissions (PM10)
Based on USACE CDEP Esimates and 09 March Construction Schedule Update
4/16/2009

- HOP HOPPER DREDGE (blue)
- HYD CUTTER SUCTION DREDGE (green)
- LANDSIDE CONSTRUCTION (yellow)
- MEC CLAMSHELL DREDGE (red)
- BLA DRILLBOAT (BLASTING) (purple)
- DREDGING WINDOW (grey)

DELAWARE DEEPENING DREDGING CONTRACTS	River Mile	Duration (Mo)	Estimated Quantity (cy)	CDEP Est #	CDEP Pay Cys	CDEP Months	CDEP # of Machines	Dredging PM10 lbs / Day	Mobilization Tons PM10	Total PM10 Tons	Dredge	
Contract No. 1 (award year 1)												hyd
Reach C- Bulkhead Bar												HYD
183+000 to 206+201 - Killicohook	68.3	1.65	932,600	1	932,600	1.65	1	81.7	0.055	2.11	1	
206+201 to 225+000 - Reedy Pt South	63.9	2.76	597,800	2	597,800	2.76	1	81.0	0.052	3.45	1	
225+000 to 242+514 - Killicohook	60.3	1.38	972,400	3	972,400	1.38	1	81.5	0.050	1.76	1	
Construct Project			**2,502,800**		**2,502,800**					**7.32**		
Contract No. 2 (award year 1)												bla
Reach B - Rock Blasting		3.17		4	77,000	3.17	2	4.6	0.066	0.29	1	BLA
Reach B - Rock Dredging - Fort Mifflin		1.27		5	77,000	0.85	2	47.2	0.095	0.71	1	MEC
Construct Project			**77,000**		**77,000**					**0.99**		mec
Contract No. 3 (award year 2)												hyd
Reach AA - National Park		2.88	994,000	14	994,000	2.88	1	97.7	0.075	4.35	1	HYD
19+700 to 32+756	99.2											
Reach A - Pedricktown North		6.1	1,666,600	15	1,666,600	6.10	1	60.5	0.069	5.68	1	HOP
32+756 to 90+000	96.8											
Construct Project			**2,660,600**		**2,660,600**					**10.03**		
Contract No. 4 (award year 3)												hop
Reach E - Broadkill Beach - Dredge		3		10	1,598,700	5.79	1	72	0.02	6.35	2	HOP
461+300 to 512+000	15.6											
Construct Project			**1,598,700**		**1,598,700**					**6.35**		hyd
Contract No. 5 (award year 4)												hop
Reach E - Kelly Island -Dredge		4.5		11	2,483,000	8.86	1	78	0.03	10.58	2	HOP
351+300 to 360+000	36.4		345,800									
360+000 to 381+000	32.1		55,500									
381+000 to 461+300	30.8		2,081,700									
Construct Project			**2,483,000**		**2,483,000**					**10.58**		
Contract No. 6 (award year 5)												hop
Reach D -											1	HOP
249+000 to 270+000 - Reedy Pt. South	55.8	1.13	396,300	12	396,300	1.13	1	53	0.04	0.96		
270+000 to 324+000 - Artificial Island	51.8	4.63	1,654,800	13	1,654,800	4.63	1	61	0.04	4.35		
Construct Project			**2,051,100**		**2,051,100**					**5.31**		
Contract No. 7 (award year 6)												hyd
Reach B - Oldmans		0.89	1,671,400	6	1,671,400	0.90	1	53	0.06	0.79	1	HYD
Reach B - Pedricktown North		3.51	1,050,700	7	1,050,700	3.51	1	96	0.07	5.21	1	HYD
Reach B - Pedricktown South		3.13	1,942,800	8	499,300	0.45	1	52	0.06	0.42	1	HYD
90+000 to 176+000	0.0			9	1,443,500	2.68	1	79	0.00	3.22		
Construct Project			**4,664,900**		**4,664,900**					**9.64**		
Total Channel		**40.0**	**16,038,100**		**16,038,100**					**50.2**		
Berth Deepenings												
Berth Deepenings Drill/Blast					25,089	2.07	1	3	0.03	0.10		
Berth Deepening Clamshell					460,437	2.94	1	28	0.21	1.48		
Berth Deepening CSD Rehandling WP					460,437	1.23	1	37	0.02	0.72		
Total Berth Deepenings					**460,437**					**2.3**		
Total Project					**16,498,537**					**52.5**		hop

UPDATED 9 March 2009 (2:00 a.m.)

0.00



Monthly PM10 Tons	1.1	1.0	1.1	1.2	1.2	1.0	1.3	0.0	0.0	0.0	0.0	0.6	1.7	2.4	2.5	1.6
Cumulative PM10 Tons	1	2	3	4	6	7	8	8	8	8	8	8	10	12	15	17
Annual Cuml PM10 Tons	1.1	2.1	3	4.5	5.7	1	2.2	2.2	2.2	2.2	2.2	2.8	4.44	6.8	9.26	10.8

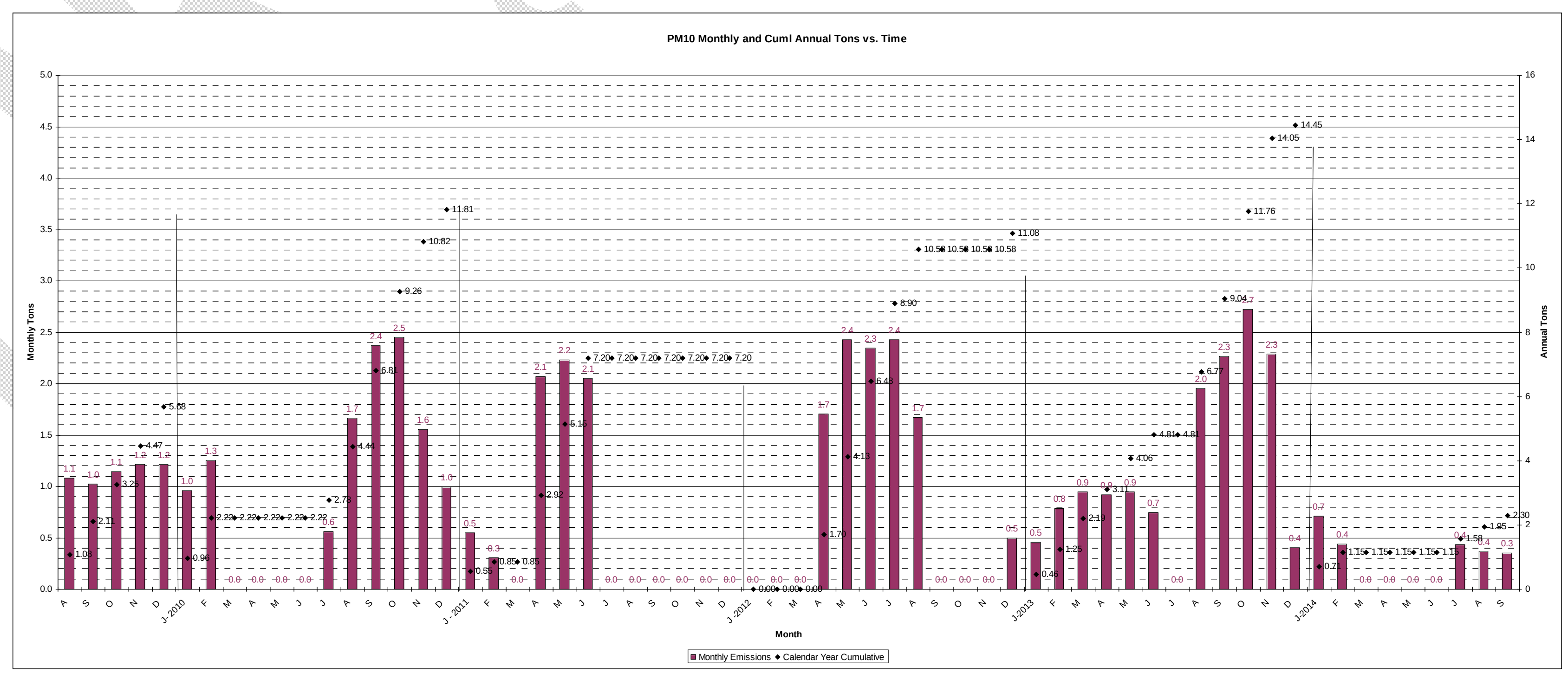
Monthly PM10 Tons	1.0	0.5	0.3	0	2.07	2.23	2.05	0	0	0	0	0	0	0	0	0
Cumulative PM10 Tons	17	18	18	18	20	23	25	25	25	25	25	25	25	25	25	25
Annual Cuml PM10 Tons	11.8	0.55	0.9	0.85	2.92	5.15	7.2	7.2	7.2	7.2	7.2	7.2	7.2	0	0	0

Monthly PM10 Tons	1.7	2.4	2.3	2.4	1.7	0	0	0	0.5	0.5	0.8	0.9	0.9	0.9	0.7	0
Cumulative PM10 Tons	26	29	31	34	35	35	35	35	36	36	37	38	39	40	41	41
Annual Cuml PM10 Tons	1.7	4.1	6.5	8.9	11	11	11	11	11	0.5	1.2	2.2	3.1	4.1	4.8	4.8

Monthly PM10 Tons	2	2.3	2.7	2.3	0.4	0.7	0.4	0	0	0	0	0.4	0.4	0.3
Cumulative PM10 Tons	43	45	48	50	50	51	51	51	51	51	51	52	52	53
Annual Cuml PM10 Tons	6.8	9	12	14	14	0.7	1.1	1.1	1.1	1.1	1.1	1.6	2	2.3

	Total Tons PM10
Calendar 2009	**5.68**
Calendar 2010	**11.81**
Calendar 2011	**7.20**
Calendar 2012	**11.08**
Calendar 2013	**14.45**
Calendar 2014	**2.30**

52.52



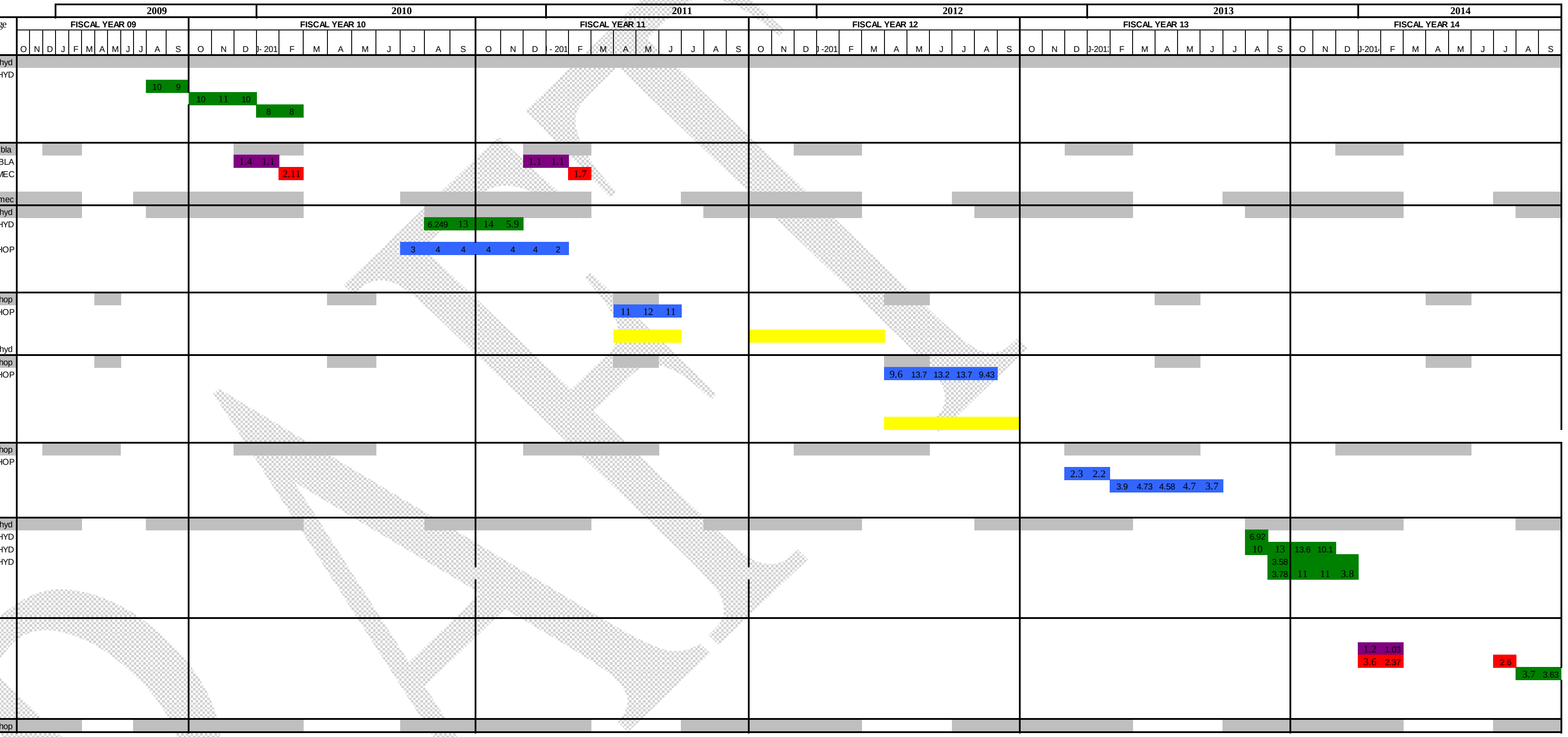
Delaware River Deepening
Construction Emissions (CO)
Based on USACE CDEP Esimates and 09 March Construction Schedule Update
4/16/2009

Legend	
HOP	HOPPER DREDGE
HYD	CUTTER SUCTION DREDGE
	LANDSIDE CONSTRUCTION
MEC	CLAMSHELL DREDGE
BLA	DRILLBOAT (BLASTING)
	DREDGING WINDOW

DELAWARE DEEPENING DREDGING CONTRACTS	River Mile	Duration (Mo)	Estimated Quantity (cy)	CDEP Est #	CDEP Pay Cys	CDEP Months	CDEP # of Machines	Dredging CO lbs / Day	Mobilization Tons CO	Total CO Tons	Dredge	
Contract No. 1 (award year 1)												hyd
Reach C- Bulkhead Bar												HYD
183+000 to 206+201 - Killicohook	68.3	1.65	932,600	1	932,600	1.65	1	737.7	0.249	18.8	1	
206+201 to 225+000 - Reedy Pt South	63.9	2.76	597,800	2	597,800	2.76	1	753.6	0.236	31.9	1	
225+000 to 242+514 - Killicohook	60.3	1.38	972,400	3	972,400	1.38	1	752.2	0.226	16.0	1	
Construct Project			**2,502,800**		**2,502,800**					**66.6**		
Contract No. 2 (award year 1)												bla
Reach B - Rock Blasting		3.17		4	77,000	3.17	2	91.1	0.335	4.7	1	BLA
Reach B - Rock Dredging - Fort Mifflin		1.27		5	77,000	0.85	2	259.6	0.436	3.8	1	MEC
Construct Project			**77,000**		**77,000**					**8.5**		mec
Contract No. 3 (award year 2)												hyd
Reach AA - National Park		2.88	994,000	14	994,000	2.88	1	889.1	0.336	39.3	1	HYD
19+700 to 32+756	99.2											
Reach A - Pedricktown North		6.1	1,666,600	15	1,666,600	6.10	1	279.4	0.302	26.2	1	HOP
32+756 to 90+000	96.8											
Construct Project			**2,660,600**		**2,660,600**					**65.5**		
Contract No. 4 (award year 3)												hop
Reach E - Broadkill Beach - Dredge		3		10	1,598,700	5.79	1	399	0.07	35.2	2	HOP
461+300 to 512+000	15.6											
Construct Project			**1,598,700**		**1,598,700**					**35.2**		hyd
Contract No. 5 (award year 4)												hop
Reach E - Kelly Island -Dredge		4.5		11	2,483,000	8.86	1	441	0.13	59.6	2	HOP
351+300 to 360+000	36.4		345,800									
360+000 to 381+000	32.1		55,500									
381+000 to 461+300	30.8		2,081,700									
Construct Project			**2,483,000**		**2,483,000**					**59.6**		
Contract No. 6 (award year 5)												hop
Reach D -											1	HOP
249+000 to 270+000 - Reedy Pt. South	55.8	1.13	396,300	12	396,300	1.13	1	251	0.19	4.5		
270+000 to 324+000 - Artificial Island	51.8	4.63	1,654,800	13	1,654,800	4.63	1	305	0.17	21.7		
Construct Project			**2,051,100**		**2,051,100**					**26.1**		
Contract No. 7 (award year 6)												hyd
Reach B - Oldmans		0.89	1,671,400	6	1,671,400	0.90	1	485	0.28	6.9	1	HYD
Reach B - Pedricktown North		3.51	1,050,700	7	1,050,700	3.51	1	879	0.30	47.2	1	HYD
Reach B - Pedricktown South		3.13	1,942,800	8	499,300	0.45	1	482	0.28	3.6	1	HYD
90+000 to 176+000	0.0			9	1,443,500	2.68	1	737	0.00	30.0		
Construct Project			**4,664,900**		**4,664,900**					**87.7**		
Total Channel		**40.0**	**16,038,100**		**16,038,100**					**349.3**		
Berth Deepenings												
Berth Deepenings Drill/Blast					25,089	2.07	1	65	0.16	2.2		
Berth Deepening Clamshell					460,437	2.94	1	169	0.97	8.5		
Berth Deepening CSD Rehandling WP					460,437	1.23	1	388	0.09	7.3		
Total Berth Deepenings					**460,437**					**18.1**		
Total Project					**16,498,537**					**367.4**		hop

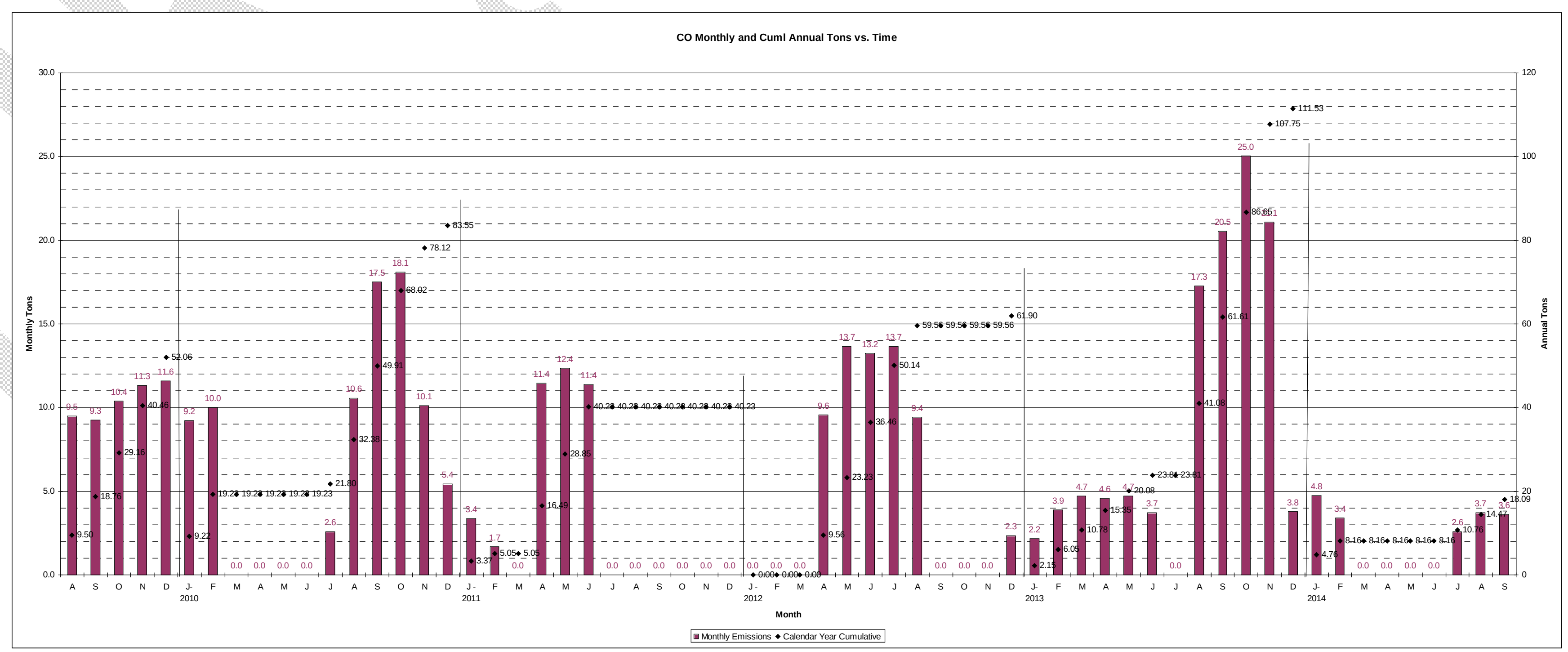
UPDATED 9 March 2009 (2:00 a.m.)

0.00



Monthly CO Tons	9.5	9.3	10.4	11.3	11.6	9.2	10.0	0.0	0.0	0.0	0.0	2.6	10.6	17.5	18.1	10.1	5.4	3.4	1.7	0	11.4	12.4	11.4	0	0	0	0	0	0	0	0	0	9.6	14	13	14	9.4	0	0	0	2.3	2.2	3.9	4.7	4.6	4.7	3.7	0	17	21	25	21	3.8	4.8	3.4	0	0	0	0	2.6	3.7	3.6
Cumulative CO Tons	10	19	29	40	52	61	71	71	71	71	71	74	84	102	120	130	136	139	141	141	152	164	176	176	176	176	176	176	176	176	176	176	185	199	212	226	235	235	235	235	238	240	244	249	253	258	262	262	279	299	324	345	349	354	357	357	357	357	357	360	364	367
Annual Cuml CO Tons	9.5	18.8	29	40	52	9.2	19.2	19.2	19.2	19.2	19.2	21.8	32.38	49.91	68.02	78.1	83.5	3.37	5	5.05	16.5	28.9	40.2	40.2	40.2	40.2	40.2	40.2	40.2	0	0	0	9.6	23	36	50	60	60	60	60	62	2.2	6.1	11	15	20	24	24	41	62	87	108	112	4.8	8.2	8.2	8.2	8.2	8.2	11	14	18

Total Tons PM10	
Calendar 2009	52.1
Calendar 2010	83.5
Calendar 2011	40.2
Calendar 2012	61.9
Calendar 2013	111.5
Calendar 2014	18.1
	367.4



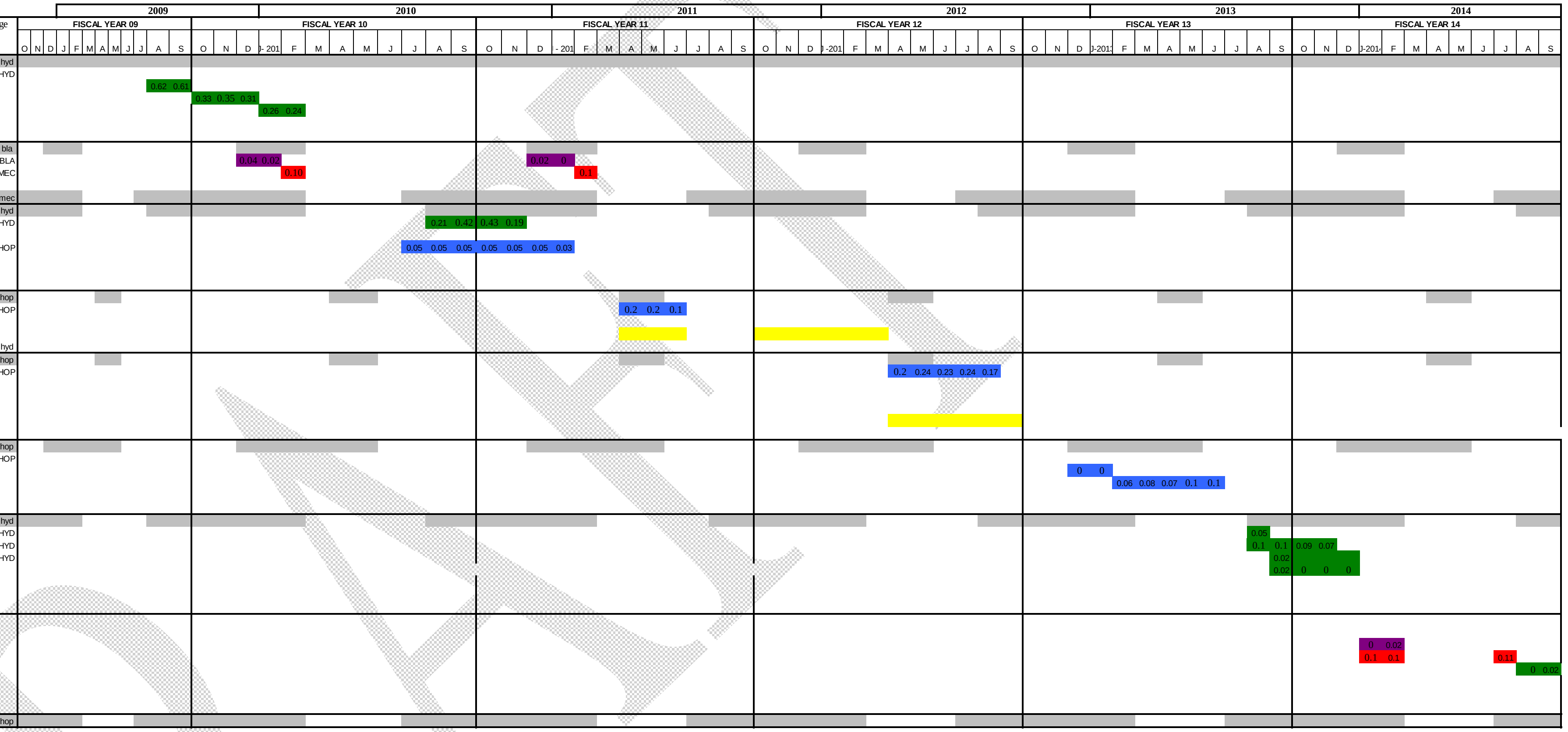
Delaware River Deepening
Construction Emissions (SOx)
Based on USACE CDEP Esimates and 09 March Construction Schedule Update
4/16/2009

Code	Legend
HOP	HOPPER DREDGE
HYD	CUTTER SUCTION DREDGE
	LANDSIDE CONSTRUCTION
MEC	CLAMSHELL DREDGE
BLA	DRILLBOAT (BLASTING)
	DREDGING WINDOW

DELAWARE DEEPENING DREDGING CONTRACTS	River Mile	Duration (Mo)	Estimated Quantity (cy)	CDEP Est #	CDEP Pay Cys	CDEP Months	CDEP # of Machines	Dredging SO2 lbs / Day	Mobilization Tons SO2	Total SO2 Tons	Dredge	
Contract No. 1 (award year 1)												hyd
Reach C- Bulkhead Bar												HYD
183+000 to 206+201 - Killicohook	68.3	1.65	932,600	1	932,600	1.65	1	48.6	0.014	1.23	1	
206+201 to 225+000 - Reedy Pt South	63.9	2.76	597,800	2	597,800	2.76	1	23.1	0.014	0.98	1	
225+000 to 242+514 - Killicohook	60.3	1.38	972,400	3	972,400	1.38	1	23.1	0.013	0.50	1	
Construct Project			**2,502,800**		**2,502,800**					**2.71**		
Contract No. 2 (award year 1)												bla
Reach B - Rock Blasting		3.17		4	77,000	3.17	2	2.0	0.019	0.11	1	BLA
Reach B - Rock Dredging - Fort Mifflin		1.27		5	77,000	0.85	2	12.1	0.025	0.18	1	MEC
Construct Project			**77,000**		**77,000**					**0.29**		mec
Contract No. 3 (award year 2)												hyd
Reach AA - National Park		2.88	994,000	14	994,000	2.88	1	28.0	0.020	1.25	1	HYD
19+700 to 32+756	99.2											
Reach A - Pedricktown North		6.1	1,666,600	15	1,666,600	6.10	1	3.3	0.018	0.33	1	HOP
32+756 to 90+000	96.8											
Construct Project			**2,660,600**		**2,660,600**					**1.57**		
Contract No. 4 (award year 3)												hop
Reach E - Broadkill Beach - Dredge		3		10	1,598,700	5.79	1	5.2	0.00	0.46	2	HOP
461+300 to 512+000	15.6											
Construct Project			**1,598,700**		**1,598,700**					**0.46**		hyd
Contract No. 5 (award year 4)												hop
Reach E - Kelly Island -Dredge		4.5		11	2,483,000	8.86	1	7.8	0.00	1.06	2	HOP
351+300 to 360+000	36.4		345,800									
360+000 to 381+000	32.1		55,500									
381+000 to 461+300	30.8		2,081,700									
Construct Project			**2,483,000**		**2,483,000**					**1.06**		
Contract No. 6 (award year 5)												hop
Reach D -											1	HOP
249+000 to 270+000 - Reedy Pt. South	55.8	1.13	396,300	12	396,300	1.13	1	2.9	0.00	0.05		
270+000 to 324+000 - Artificial Island	51.8	4.63	1,654,800	13	1,654,800	4.63	1	4.9	0.00	0.35		
Construct Project			**2,051,100**		**2,051,100**					**0.40**		
Contract No. 7 (award year 6)												hyd
Reach B - Oldmans		0.89	1,671,400	6	1,671,400	0.90	1	3.4	0.00	0.05	1	HYD
Reach B - Pedricktown North		3.51	1,050,700	7	1,050,700	3.51	1	5.9	0.00	0.32	1	HYD
Reach B - Pedricktown South		3.13	1,942,800	8	499,300	0.45	1	2.2	0.00	0.02	1	HYD
90+000 to 176+000	0.0			9	1,443,500	2.68	1	3.1	0.00	0.13		
Construct Project			**4,664,900**		**4,664,900**					**0.51**		
Total Channel		**40.0**	**16,038,100**		**16,038,100**					**7.0**		
Berth Deepenings												
Berth Deepenings Drill/Blast					25,089	2.07	1	1.1	0.00	0.03		
Berth Deepening Clamshell					460,437	2.94	1	7.2	0.01	0.33		
Berth Deepening CSD Rehandling WP					460,437	1.23	1	1.8	0.00	0.03		
Total Berth Deepenings					**460,437**					**0.4**		
Total Project					**16,498,537**					**7.4**		hop

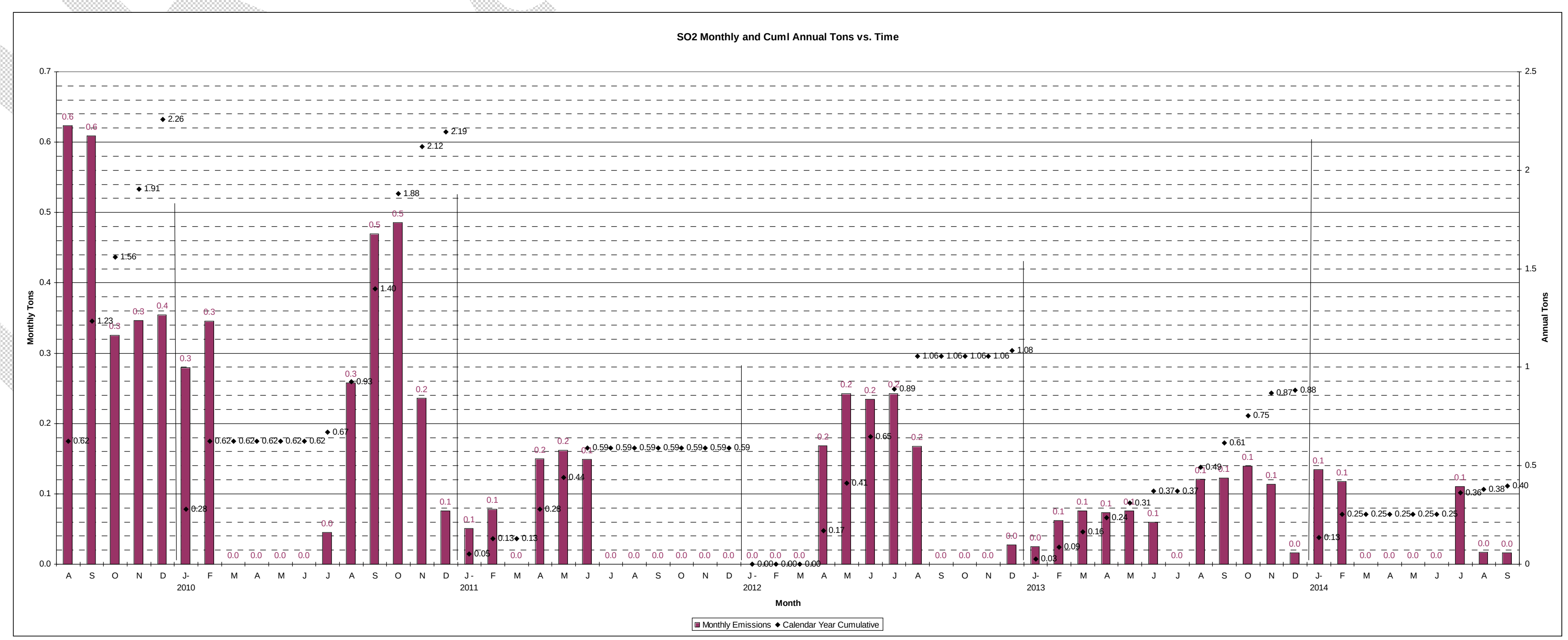
UPDATED 9 March 2009 (2:00 a.m.)

0.00

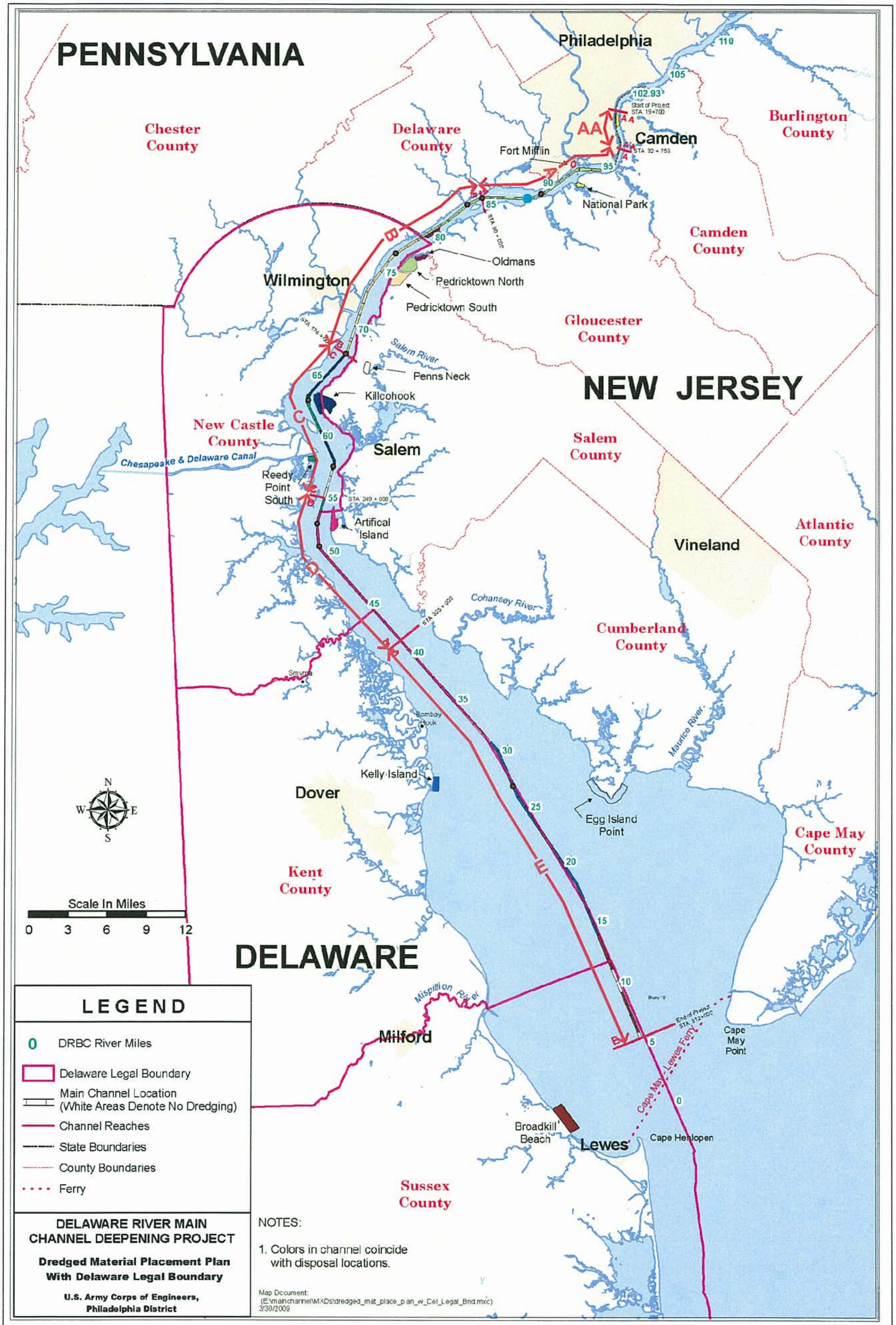


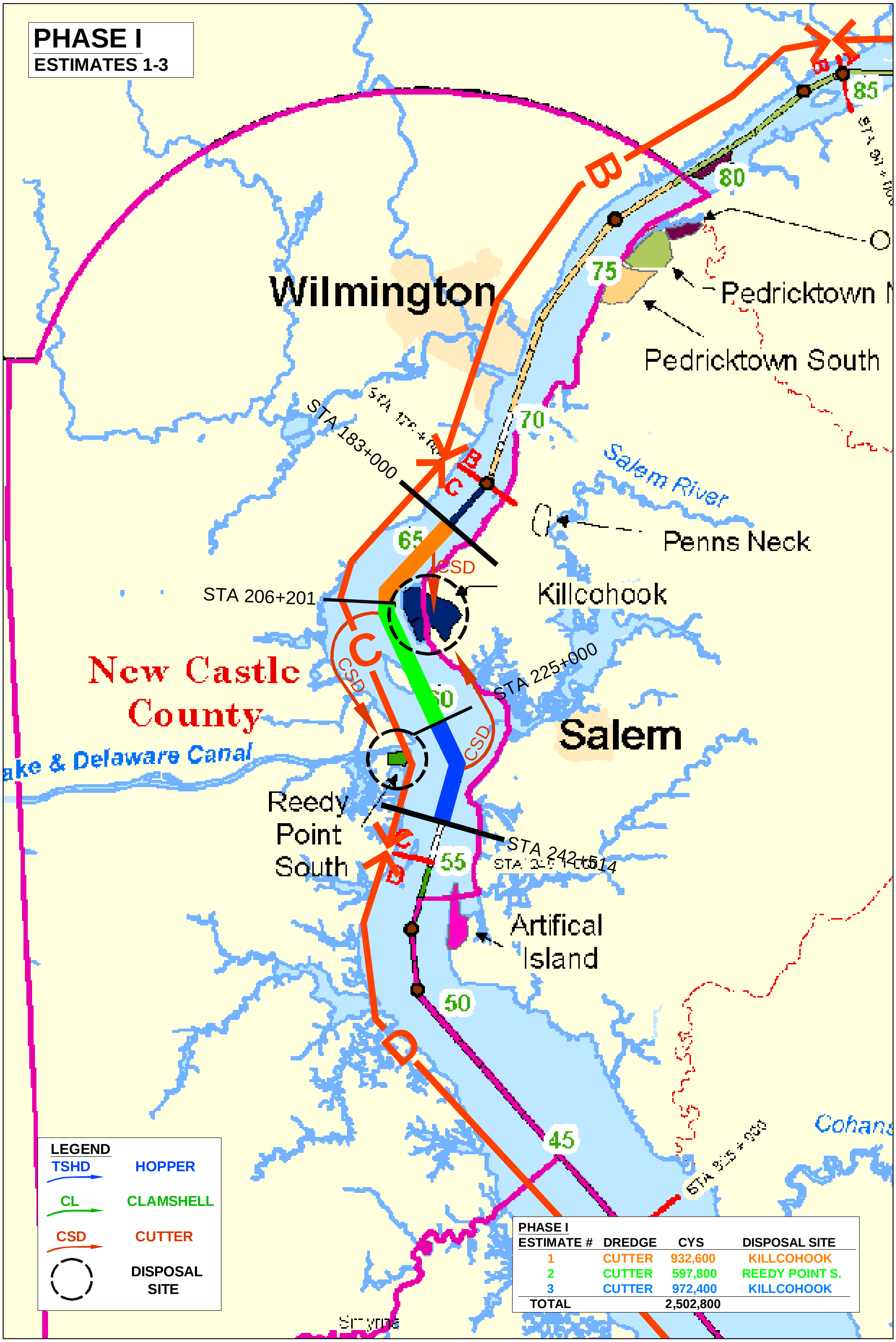
Monthly SO2 Tons	0.6	0.6	0.3	0.3	0.4	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.5	0.2	0.1	0.1	0.1	0	0.15	0.16	0.15	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0.2	0	0	0	0	0	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1	0.1	0.1	0	0.1	0.1	0	0	0	0	0.1	0	0
Cumulative SO2 Tons	1	1	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Annual Cuml SO2 Tons	0.62	1.23	1.6	1.9	2.3	0.3	0.62	0.62	0.62	0.62	0.62	0.67	0.927	1.397	1.883	2.119	2.194	0.05	0.1	0.13	0.28	0.44	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0	0	0	0.2	0.4	0.6	0.9	1.1	1.1	1.1	1.1	1.1	0	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8	0.9	0.9	0.1	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4

Total Tons SO2	
Calendar 2009	**2.26**
Calendar 2010	**2.19**
Calendar 2011	**0.59**
Calendar 2012	**1.08**
Calendar 2013	**0.88**
Calendar 2014	**0.40**
	7.41

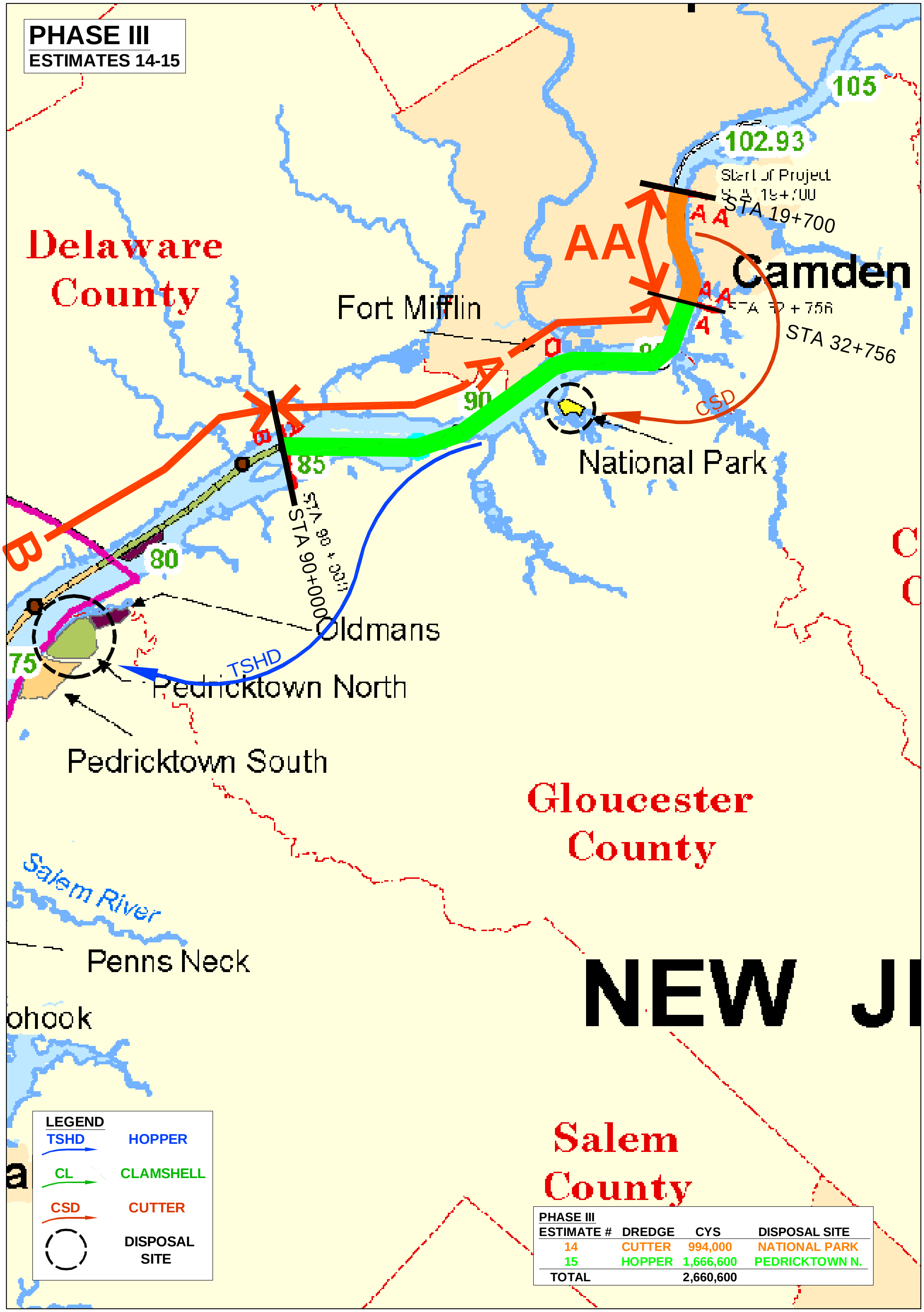


Appendix E – Project Figures


PENNSYLVANIA
Philadelphia
Chester County
Delaware County
Burlington County
Camden
Start of Project STA 19+700
STA 92 + 755
AA
Fort Mifflin
National Park
Camden County
Oldmans
Pedricktown North
Pedricktown South
Wilmington
Gloucester County
Salem River
Penns Neck
Killcohook
NEW JERSEY
New Castle County
Chesapeake & Delaware Canal
Salem
Salem County
Reedy Point South
STA 249 + 000
Artifical Island
Vineland
Atlantic County
Cohansey River
Cumberland County
Smyrna
Bombay Hook
Maurice River
Kelly Island
Dover
Egg Island Point
Cape May County
Kent County
DELAWARE
Mispillion River
End of Project STA 512+000
Cape May Point
Milford
Cape May - Lewes Ferry
Broadkill Beach
Lewes
Cape Henlopen
Sussex County
N
W
E
S
Scale In Miles
0 3 6 9 12
LEGEND
0 DRBC River Miles
Delaware Legal Boundary
Main Channel Location (White Areas Denote No Dredging)
Channel Reaches
State Boundaries
County Boundaries
Ferry
DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT
Dredged Material Placement Plan With Delaware Legal Boundary
U.S. Army Corps of Engineers, Philadelphia District
NOTES:
1. Colors in channel coincide with disposal locations.
Map Document: (E:\mainchannel\MXDs\dredged_mat_place_plan_w_Del_Legal_Bnd.mxd)
3/30/2009

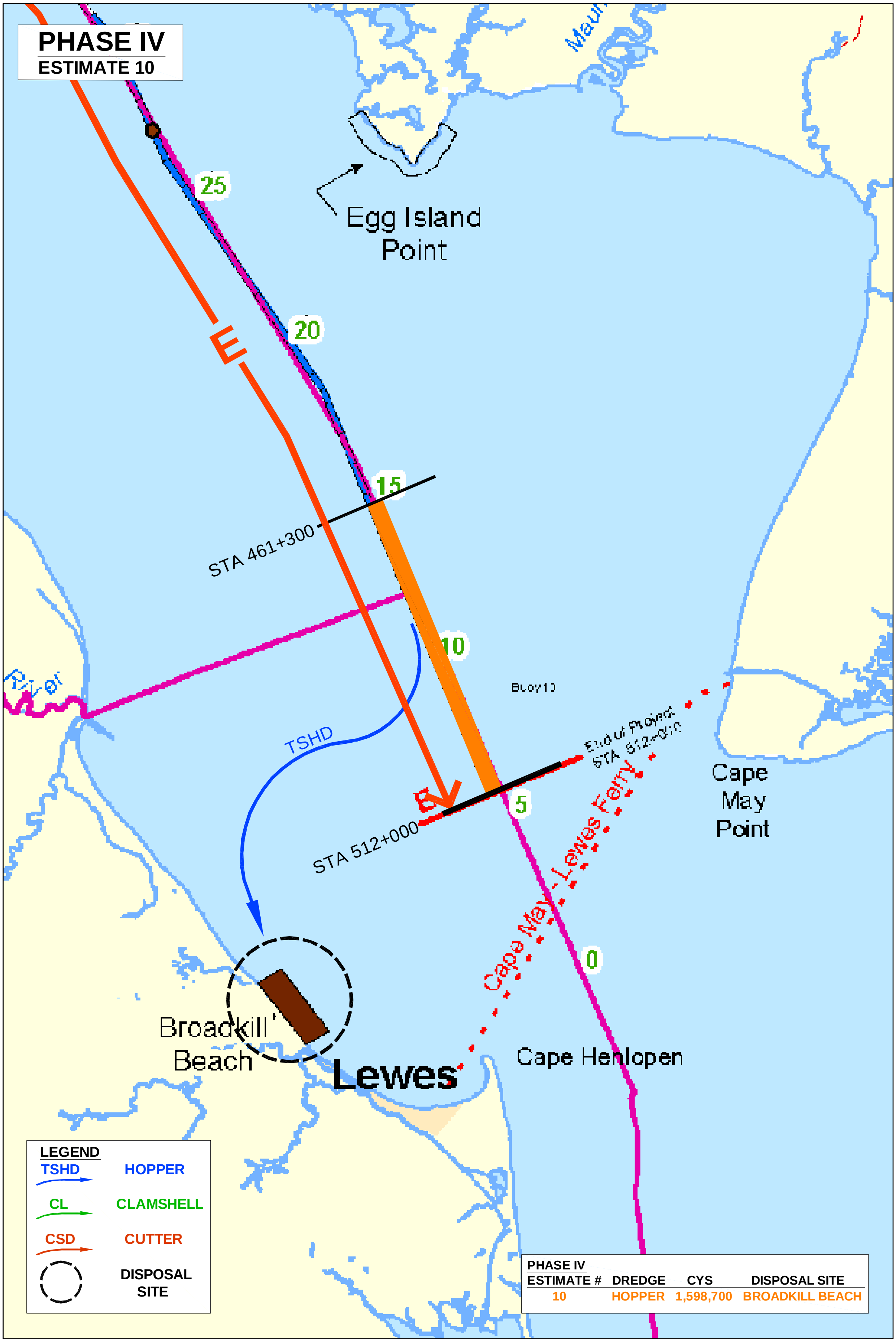

PHASE I
ESTIMATES 1-3
Wilmington
Pedricktown South
Pedricktown N
Salem River
Penns Neck
Killcohook
New Castle County
Salem
Reedy Point South
Artifical Island
STA 183+000
STA 206+201
STA 225+000
STA 242+514
CSD
B
C
D
85
80
75
70
65
60
55
50
45
LEGEND
TSHD HOPPER
CL CLAMSHELL
CSD CUTTER
DISPOSAL SITE
PHASE I
ESTIMATE # DREDGE CYS DISPOSAL SITE
1 CUTTER 932,600 KILLCOHOOK
2 CUTTER 597,800 REEDY POINT S.
3 CUTTER 972,400 KILLCOHOOK
TOTAL 2,502,800


PHASE II
ESTIMATES 4-5
ROCK EXCAVATION
Delaware County
Fort Mifflin
AA
A
B
C
National
STA 90+000
Oldmans
Pedricktown North
Pedricktown South
Wilmington
Gloucester County
STA 176+000
Salem River
Penns Neck
Killcohook
Salem
Salem County
NE
STA 279 + 000
Artifical Island
95
90
85
80
75
70
65
60
50
LEGEND
TSHD HOPPER
CL CLAMSHELL
CSD CUTTER
DISPOSAL SITE
PHASE II
ESTIMATE # DREDGE CYS DISPOSAL SITE
4 DRILLBOAT 77,000 FORT MIFFLIN
5 CLAMSHELL 77,000 FORT MIFFLIN
TOTAL 154,000

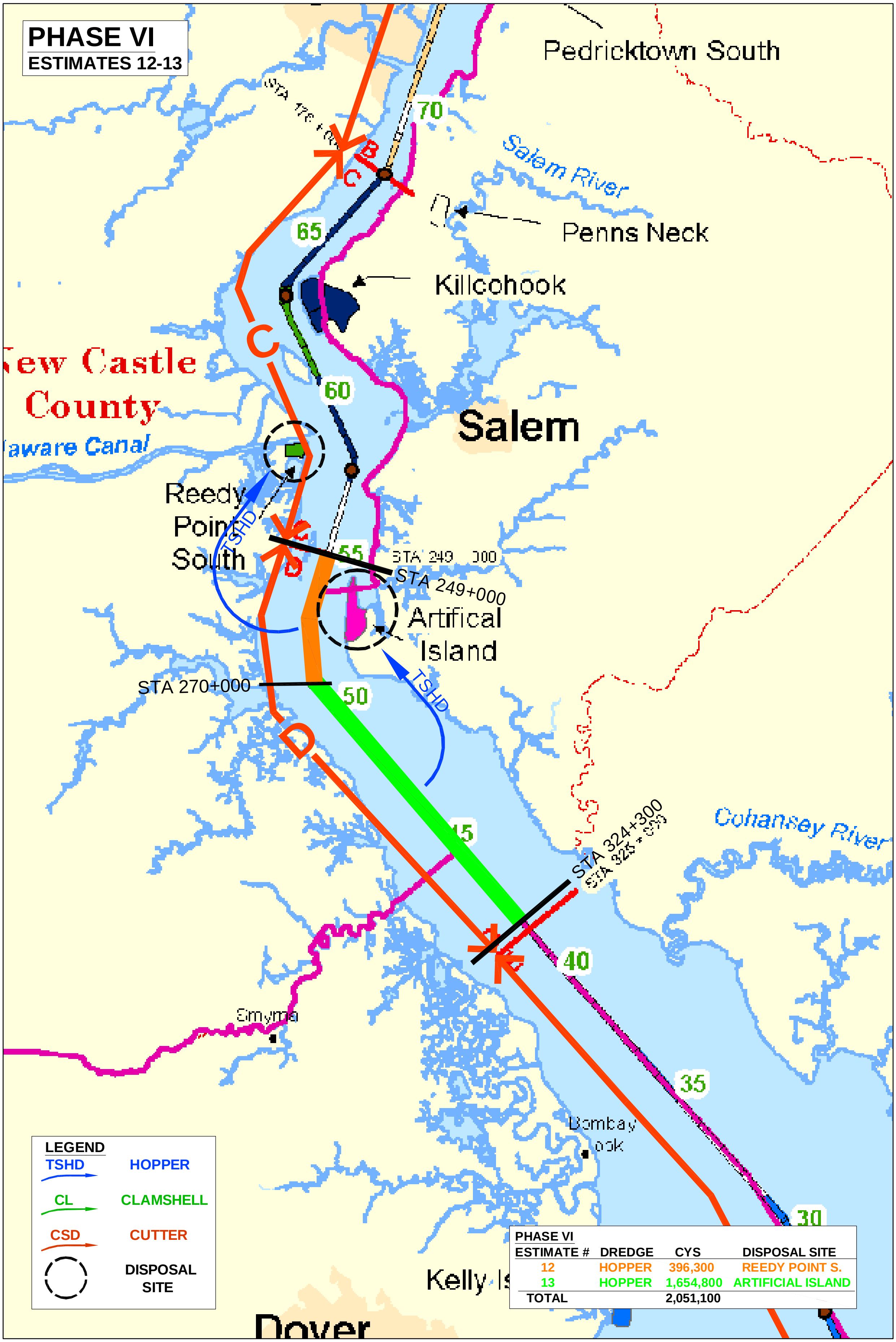


PHASE III

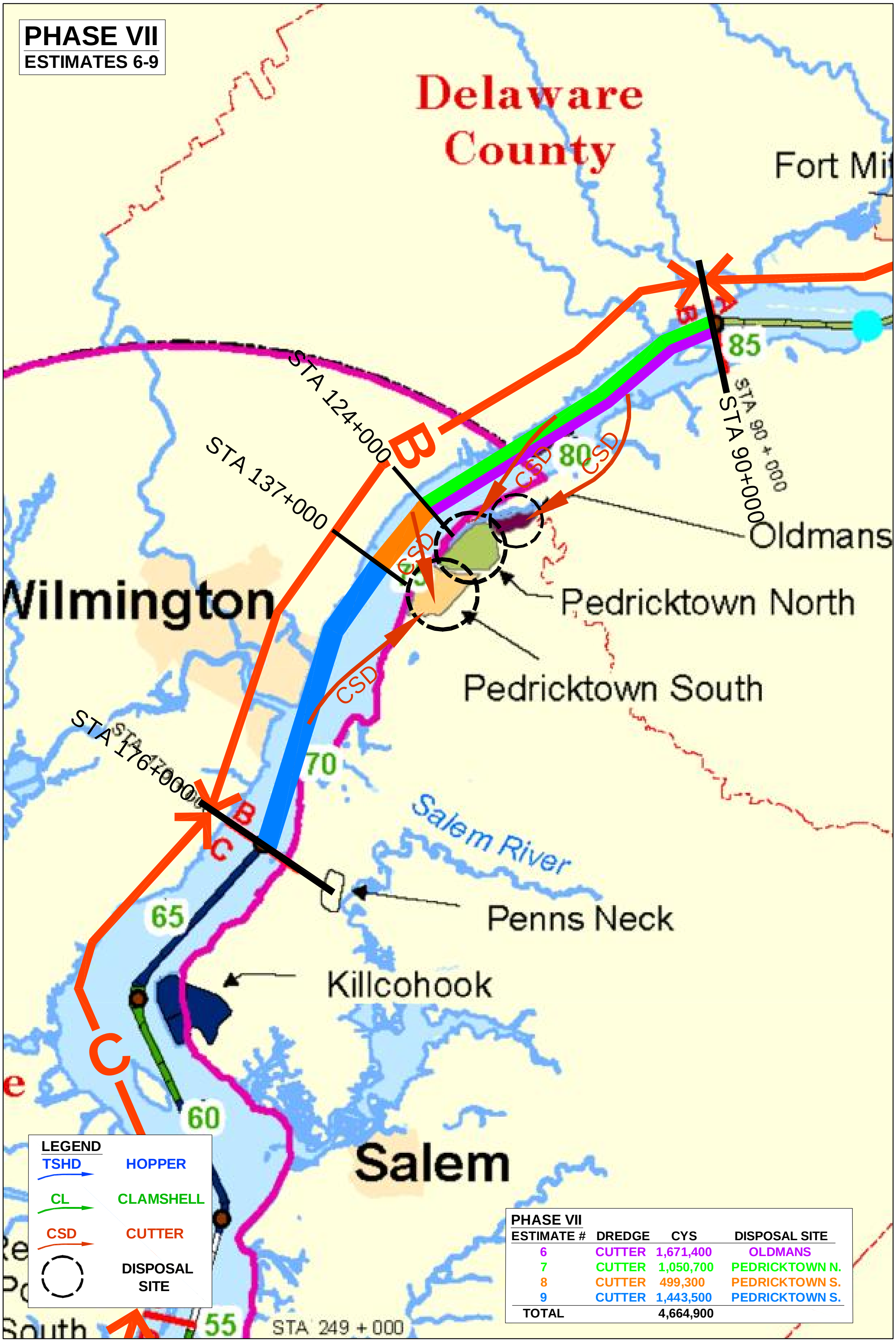
ESTIMATE #	DREDGE	CYS	DISPOSAL SITE
14	CUTTER	994,000	NATIONAL PARK
15	HOPPER	1,666,600	PEDRICKTOWN N.
TOTAL		2,660,600	


PHASE IV
ESTIMATE 10
25
20
15
10
5
0
E
Egg Island
Point
STA 461+300
STA 512+000
TSHD
Cape May - Lewes Ferry
Cape
May
Point
Broadkill
Beach
Lewes
Cape Henlopen
River
LEGEND
TSHD HOPPER
CL CLAMSHELL
CSD CUTTER
DISPOSAL SITE
PHASE IV
ESTIMATE # DREDGE CYS DISPOSAL SITE
10 HOPPER 1,598,700 BROADKILL BEACH

PHASE V ESTIMATE #	DREDGE	CYS	DISPOSAL SITE
11	HOPPER	2,483,000	KELLY ISLAND



PHASE VI ESTIMATE #	DREDGE	CYS	DISPOSAL SITE
12	HOPPER	396,300	REEDY POINT S.
13	HOPPER	1,654,800	ARTIFICIAL ISLAND
TOTAL		2,051,100	



PHASE VII

ESTIMATE #	DREDGE	CYS	DISPOSAL SITE
6	CUTTER	1,671,400	OLDMANS
7	CUTTER	1,050,700	PEDRICKTOWN N.
8	CUTTER	499,300	PEDRICKTOWN S.
9	CUTTER	1,443,500	PEDRICKTOWN S.
TOTAL		4,664,900	

Appendix F – EPA Tables Used for NOx Calculations

Pertinent tables from EPA's document titled "Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories" (written by ICF and dated April 2009) are included here for reference.

Tables 3-3, 3-4, 3-5, and 3-8 are from the Harbor Craft chapter. The specific factors that were used in the ferry and tug boat NOx calculations are circled in red.

Table 3-3: EPA Load Factors for Harbor Craft

Engine Category	Engine Size	Likely Annual Transit Days	Average Annual Activity	Load Factor
Category 2		219		0.85
Category 1 Main	<805 HP		943	0.45
	>805 HP		4503	0.79
Category 1 Aux	<805 HP		798	0.56
	>805 HP		2500	0.65

Table 3-4: Load Factors for Harbor Craft (Port of Los Angeles and Long Beach)

Vessel Category	Load Factor	Source
Assist Tugboat	31%	PoLA
Dredge Tenders	69%	PoLA
Recreational	21%	PoLA
Recreational, Auxiliary	32%	PoLA
Crew Boat	45%	PoLB
Excursion	42%	PoLB
Ferry	42%	PoLB
Government	51%	PoLB
Ocean Tug	68%	PoLB
Tugboat	31%	PoLB
Work Boat	43%	PoLB
Other Categories	43%	PoLA
Other Auxiliaries	43%	PoLA

Table 3-5: Harbor Craft Emission Factors

Engine Type	Disp Category (Max L/Cyl)	Engine EFs (g/kW hr)											
		PM_{10}			NOx			HC			CO		
		Tier 0	Tier1	Tier2	Tier 0	Tier1	Tier2	Tier 0	Tier1	Tier2	Tier 0	Tier1	Tier2
Cat 1 Main	<0.9	0.54	0.54	0.23	10.0	9.8	5.7	0.41	0.41	0.41	1.6	1.6	1.6
	<1.2	0.47	0.47	0.12	10.0	9.8	6.1	0.32	0.32	0.32	1.6	1.6	0.9
	<2.5	0.34	0.34	0.13	10.0	9.8	6.0	0.27	0.27	0.19	1.6	1.6	1.1
	<3.5	0.30	0.30	0.13	10.0	9.1	6.0	0.27	0.27	0.19	1.6	1.6	1.1
	<5	0.30	0.30	0.13	11.0	9.2	6.0	0.27	0.27	0.19	1.8	1.8	1.1
Cat 1 Auxillary	<0.9	0.84	0.84	0.23	11.0	9.8	5.7	0.41	0.41	0.41	2.0	2.0	1.6
	<1.2	0.53	0.53	0.21	10.0	9.8	5.4	0.32	0.32	0.32	1.7	1.7	0.8
	<2.5	0.34	0.34	0.15	10.0	9.8	6.1	0.27	0.27	0.21	1.5	1.5	0.9
	<3.5	0.32	0.32	0.15	10.0	9.1	6.1	0.27	0.27	0.21	1.5	1.5	0.9
	<5	0.30	0.30	0.15	11.0	9.2	6.1	0.27	0.27	0.21	1.8	1.8	0.9
Cat2		0.32	0.32	0.32	13.36	10.55	8.33	0.134	0.134	0.134	2.48	2.48	2.00

Table 3-8: Harbor Craft Emission Factors (g/kWh)

Minimum Power (kW)	NOx (g/kWh)	VOC (g/kWh)	CO (g/kWh)	PM_{10} (g/kWh)	SO_2 (g/kWh)	CO_2 (g/kWh)	N_2O (g/kWh)	CH_4 (g/kWh)
Tier 0 Engines								
37	11	0.27	2	0.9	1.3	690	0.02	0.09
75	10	0.27	1.7	0.4	1.3	690	0.02	0.09
130	10	0.27	1.5	0.4	1.3	690	0.02	0.09
225	10	0.27	1.5	0.3	1.3	690	0.02	0.09
450	10	0.27	1.5	0.3	1.3	690	0.02	0.09
560	10	0.27	1.5	0.3	1.3	690	0.02	0.09
1,000	13	0.27	2.5	0.3	1.3	690	0.02	0.09
Cat 2	13.2	0.5	1.1	0.72	1.3	690	0.02	0.09
Tier 1 Engines								
37	9.8	0.27	2	0.9	1.3	690	0.02	0.09
75	9.8	0.27	1.7	0.4	1.3	690	0.02	0.09
130	9.8	0.27	1.5	0.4	1.3	690	0.02	0.09
225	9.8	0.27	1.5	0.3	1.3	690	0.02	0.09
450	9.8	0.27	1.5	0.3	1.3	690	0.02	0.09
560	9.8	0.27	1.5	0.3	1.3	690	0.02	0.09
1,000	9.8	0.27	2.5	0.3	1.3	690	0.02	0.09
Cat 2	9.8	0.5	1.1	0.72	1.3	690	0.02	0.09
Tier 2 Engines								
37	6.8	0.27	5	0.4	1.3	690	0.02	0.09
75	6.8	0.27	5	0.3	1.3	690	0.02	0.09
130	6.8	0.27	5	0.3	1.3	690	0.02	0.09
225	6.8	0.27	5	0.3	1.3	690	0.02	0.09
450	6.8	0.27	5	0.3	1.3	690	0.02	0.09
560	6.8	0.27	5	0.3	1.3	690	0.02	0.09
1,000	6.8	0.27	5	0.3	1.3	690	0.02	0.09
Cat 2	9.8	0.5	5	0.72	1.3	690	0.02	0.09

Tables 2-4, 2-7, and 2-16 are from the Ocean Going Vessel chapter. The specific factors that were used in the cold ironing analysis are circled in red.

Table 2-4: Auxiliary Engine Power Ratios (ARB Survey)

Ship Type	Average Propulsion Engine (kW)	Average Auxiliary Engines				Auxiliary to Propulsion Ratio
		Number	Power Each (kW)	Total Power (kW)	Engine Speed	
Auto Carrier	10,700	2.9	983	2,850	Medium	0.266
Bulk Carrier	8,000	2.9	612	1,776	Medium	0.222
Container Ship	30,900	3.6	1,889	6,800	Medium	0.220
Cruise Ship[a]	39,600	4.7	2,340	11,000	Medium	0.278
General Cargo	9,300	2.9	612	1,776	Medium	0.191
RORO	11,000	2.9	983	2,850	Medium	0.259
Reefer	9,600	4.0	975	3,900	Medium	0.406
Tanker	9,400	2.7	735	1,985	Medium	0.211

[a] Cruise ships typically use a different engine configuration known as diesel-electric. These vessels use large generator sets for both propulsion and ship-board electricity. The figures for cruise ships above are estimates taken from the Starcrest Vessel Boarding Program.

Table 2-7: Auxiliary Engine Load Factor Assumptions

Ship-Type	Cruise	RSZ	Maneuver	Hotel
Auto Carrier	0.15	0.30	0.45	0.26
Bulk Carrier	0.17	0.27	0.45	0.10
Container Ship	0.13	0.25	0.48	0.19
Cruise Ship	0.80	0.80	0.80	0.64
General Cargo	0.17	0.27	0.45	0.22
Miscellaneous	0.17	0.27	0.45	0.22
OG Tug	0.17	0.27	0.45	0.22
RORO	0.15	0.30	0.45	0.26
Reefer	0.20	0.34	0.67	0.32
Tanker	0.24	0.28	0.33	0.26

Table 2-16: Auxiliary Engine Emission Factors, g/kWh

Fuel Type	Sulfur	Emission Factors (g/kWh)							
		NOx	PM_{10}	$PM_{2.5}$	HC	CO	SOx	CO_2	BSFC
RO	2.70%	14.7	1.44	1.32	0.40	1.10	11.98	722.54	227
MDO	1.00%	13.9	0.49	0.45	0.40	1.10	4.24	690.71	217
MGO	0.50%	13.9	0.32	0.29	0.40	1.10	2.12	690.71	217
MGO	0.10%	13.9	0.18	0.17	0.40	1.10	0.42	690.71	217