APPENDIX F

Nonroad Sources

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APPENDIX F-1

Nonroad Sources Emissions Estimation Methodology

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APPENDIX F-1

PENNSYLVANIA NONROAD SOURCE EMISSIONS ESTIMATION METHODOLOGY

Bureau of Air Quality
Department of Environmental Protection
Division of Air Information

METHODOLOGY FOR ESTIMATING NONROAD EMISSIONS

I. INTRODUCTION

This following methodology provides a description of the procedures used to generate 2002 and 2009 county-level pollutant emission estimates for nonroad mobile engines included in the United States Environmental Protection Agency's (EPA's) NONROAD2005 model, as well as locomotive engines, commercial marine vessel engines, and aircraft operations. For the NONROAD2005 model engines, emission estimates were calculated for volatile organic compounds (VOCs), oxides of nitrogen (NO_x), carbon monoxide (CO), particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), and sulfur dioxide (SO_2).. Revised geographic allocation files for NONROAD model option files and revised housing unit data used for the model runs are also included. The National Mobile Inventory Model (NMIM) was used to develop emissions of ammonia (NH_3) for 2002 and 2009 since the NONROAD2005 Model does not have that capability.

II. 2002 NONROAD MODEL SOURCE CATEGORY EMISSIONS

The Department used EPA's Final NONROAD2005 Model to generate 2002 and 2009 annual emissions for the Pittsburgh, Pennsylvania area, which consists of Beaver, Butler, Washington, and Westmoreland counties and portions of Allegheny, Armstrong, and Greene counties. The Department prepared NONROAD2005 model option files that account for temperatures and gasoline Reid vapor pressure (RVP) values representative of the area for summer weekdays. The Pittsburgh area was treated as its own climate zone. The summertime RVP value used for the area was 7.8 for the summer with the exception of Lawrence and Greene counties which used an RVP value of 9.0. Minimum, maximum, and average temperatures for July for each region were obtained from the Pennsylvania State Climatologist website, Pennsylvania State Climatologist, Penn State University, *2002 Temperature Data by Weather Station* which is available at http://pasc.met.psu.edu/PA_Climatologist/cityform.html. The RVP and temperature input were applied to all equipment categories to obtain both summer and annual emissions.

Table 1 lists the counties included in the Pittsburgh area and the weather station where the temperature data were obtained for each of the regions. Table 2a and 2b presents the RVP and temperature data used in the model runs for the region. Annual emissions were obtained by adding all of the four seasonal totals in order to account for both seasonal variations in RVP and temperature.

Table 1. Regions of Pennsylvania and Associated Maintenance Areas

Region	Weather Station	Counties in Region	FIPSST	FIPSCNTY
Pittsburgh	Pittsburgh	Allegheny County (p)	42	003
		Armstrong County (p)	42	005
		Beaver County	42	007
		Butler County	42	019
		Greene County (p)	42	059
		Lawrence County (p)	42	073
		Washington County	42	125
		Westmoreland County	42	129

Table 2a. Summer Day NONROAD Model Temperature and RVP Inputs					
		Temperature*			
Region	Season	Maximum	Minimum	Average	RVP**
Pittsburgh	Summer	84	63	73	7.8

* Temperature in degrees Fahrenheit
** RVP in pounds per square inch (psi)

Table 2b. Seasonal NONROAD Model Temperature and RVP Inputs					
		Temperature*			
Region	Season	Maximum	Minimum	Average	RVP
Pittsburgh	Spring	60	39	46	9.0
Pittsburgh	Summer	84	63	71	7.8
Pittsburgh	Autumn	61	44	53	8.8
Pittsburgh	Winter	41	27	33	9.0

* Temperature in degrees Fahrenheit
** RVP in pounds per square inch (psi)

EPA-recommended diesel fuel sulfur levels for marine and land equipment for all years were used as inputs to the model, as outlined in *Diesel Fuel Sulfur Inputs for the Draft NONROAD2004 Model used in the 2004 Nonroad Diesel Engine Fuel Rule*, April 27, 2004.

In past versions of the NONROAD model, state recreational marine vessels populations were underestimated when compared to boat registrations tracked by the Pennsylvania Fish and Boat Commission (PFBC). EPA's population of recreational marine vessels in the model now seem more representative of the number of boat registrations that the Pennsylvania Fish and Boat Commission tracks. We used EPA's default values in the model runs. We also examined geographic allocation factors for residential lawn and garden equipment. These improvements are discussed further in the next section. All other categories rely on default data included in the model for population and activity estimates.

Residential Lawn and Garden Equipment

The EPA's NONROAD2005 model uses 2003 U.S. Census data of all housing units in Pennsylvania to allocate residential lawn and garden equipment, even though EPA guidance states that emissions should be based only on the number of single detached, single attached, and double housing units. EPA's method in the NONROAD2005 model alters the allocation of lawn and garden emissions in some Pennsylvania counties significantly. The Department will use data obtained by E.H. Pechan from the 2000 Census, updated to 2002, and used in the state's 2002 inventory on the number of single detached, single attached, and double housing units for both the State and all counties in the state. Table 3 presents the Census data (Bureau of the Census, 2003), which can be found in *2000 County and State Housing Units by Unit Type, Census 2000*, http://factfinder.census.gov/servlet/. The total number of housing units was incorporated into the NONROAD2005 model geographic allocation factor file, PA HOUSE.ALO, for use in allocating state-level lawn and garden equipment populations to all Pennsylvania counties for 2002.

Table 3. Number of Single and Double-Family Housing Units from 2002 Census

County	# 1-Unit Detached Housing Units	# 1-Unit Attached Housing Units	# 2-Unit Housing Units	Total # of Housing Units
Adams	24,549	2,206	1,490	28,245
Allegheny	**345,479**	**46,899**	**29,002**	**421,380**
Armstrong	**22,268**	**824**	**1,014**	**24,106**
Beaver	**54,418**	**2,312**	**2,863**	**59,593**
Bedford	14,684	248	501	15,433
Berks	78,946	32,377	5,803	117,126
Blair	36,919	1,844	2,668	41,431
Bradford	16,861	232	1,224	18,317
Bucks	141,951	30,506	5,425	177,882
Butler	**46,271**	**2,523**	**2,215**	**51,009**
Cambria	44,453	3,795	2,882	51,130
Cameron	1,749	35	176	1,960
Carbon	14,431	5,104	990	20,525
Centre	27,786	2,691	1,749	32,226
Chester	99,549	25,911	3,155	128,615
Clarion	11,635	118	471	12,224
Clearfield	24,829	412	1,064	26,305
Clinton	10,141	662	711	11,514
Columbia	16,856	1,328	1,388	19,572
Crawford	24,430	397	1,933	26,760
Cumberland	51,934	10,450	2,792	65,176
Dauphin	52,961	20,195	3,848	77,004
Delaware	93,642	64,529	9,361	167,532
Elk	11,355	79	807	12,241
Erie	70,504	2,955	9,504	82,963
Fayette	41,679	3,094	2,473	47,246
Forest	1,660	8	18	1,686
Franklin	34,720	4,292	2,073	41,085
Fulton	4,084	56	133	4,273
Greene	**10,387**	**481**	**416**	**11,284**
Huntingdon	12,463	331	686	13,480
Indiana	23,215	825	1,232	25,272
Jefferson	14,276	237	729	15,242
Juniata	6,455	355	166	6,976
Lackawanna	53,357	3,328	12,626	69,311
Lancaster	98,364	32,122	7,370	137,856
Lawrence	**28,316**	**799**	**1,489**	**30,604**
Lebanon	27,272	8,647	2,225	38,144
Lehigh	59,753	29,474	5,118	94,345
Luzerne	82,363	15,404	9,435	107,202
Lycoming	31,568	2,812	2,998	37,378
McKean	13,794	158	972	14,924
Mercer	34,859	735	1,817	37,411
Mifflin	12,327	1,788	966	15,081

Table 3. Number of Single and Double-Family Housing Units from 2002 Census

County	# 1-Unit Detached Housing Units	# 1-Unit Attached Housing Units	# 2-Unit Housing Units	Total # of Housing Units
Monroe	40,696	1,726	1,457	43,879
Montgomery	163,211	53,370	9,599	226,180
Montour	4,769	645	346	5,760
Northampton	60,344	19,729	4,755	84,828
Northumberland	21,955	9,280	1,657	32,892
Perry	12,209	733	398	13,340
Philadelphia	48,724	359,877	46,425	455,026
Pike	15,501	395	299	16,195
Potter	5,263	62	281	5,606
Schuylkill	32,695	17,989	2,092	52,776
Snyder	10,263	644	526	11,433
Somerset	22,159	1,236	1,312	24,707
Sullivan	2,165	18	84	2,267
Susquehanna	12,139	180	711	13,030
Tioga	11,076	150	753	11,979
Union	9,341	652	527	10,520
Venango	17,197	227	1,080	18,504
Warren	13,031	239	930	14,200
Washington	**60,711**	**3,891**	**3,187**	**67,789**
Wayne	14,311	249	750	15,310
Westmoreland	**113,694**	**4,839**	**5,997**	**124,530**
Wyoming	7,858	159	412	8,429
York	95,921	20,218	6,102	122,241
Total	**2,724,746**	**860,086**	**235,658**	**3,820,490**

After the model runs, model outputs were processed to develop summer work weekday emissions inventories for NOx, VOC, and CO. In the Pittsburgh area, gasoline RVP values vary by season. A value of 7.8 RVP is used in the summer and part of the time during the fall for most of the nonattainment area. We assumed RVP values of 9.0, 7.8, 8.8, and 9.0 for the spring, summer, autumn, and winter, respectively.

Nonroad equipment refueling, either by portable container or at the gasoline pump, is being accounted for under Pennsylvania's area source inventory. As such, spillage and vapor displacement VOC emission estimates were subtracted from the total VOC emission estimates for all NONROAD model emissions. Therefore, only exhaust, crankcase, and evaporative diurnal components are included in these VOC estimates.

Emissions from nonroad equipment were tabulated in both source classification code and category format. Immaterial rounding errors may exist when comparing the two formats due to different arithmetic operations performed inside and outside the NONROAD model for the two formats.

III. 2002 LOCOMOTIVE EMISSIONS

Much of the locomotive emissions were captured from a 1999 survey conducted by the Department included hydrocarbon (HC) and NO_x for the following locomotive source categories:

2285002006 : Railroad Equipment, Diesel, Line Haul Locomotives: Class I Operations
2285002007: Railroad Equipment, Diesel, Line Haul Locomotives: Class II/III Operations
2285002008: Railroad Equipment, Diesel, Line Haul Locomotives: Passenger Trains (Amtrak)
2285002010: Railroad Equipment, Diesel, Yard Locomotives

All line haul locomotive emissions were grouped into one SCC category in the appendix, 2285002005.

Norfolk Southern and CSX Corporations purchased Conrail. The takeover of Conrail's assets occurred in June 1999. For that reason, it was a very bad time to develop a representative emission inventory for these railroads. Both Conrail and Norfolk Southern suffered major gridlock in Pennsylvania and beyond during 1999. Consequently, fuel consumption and air emissions for these two railroads were greatly reduced in 1999. The Department requested and received 2002 fuel usage from these railroad companies and developed a 2002 emissions inventory for them. Fuel consumption increased 60 percent from 1999 to 2002. Clearly, this was not due to normal economic growth. All other emissions from railroad companies operating in Pennsylvania in 1999 were grown with a growth factor to obtain 2002 emissions.

Estimating Emissions Growth

To estimate 2004, 2009, and 2018 locomotive emissions, the Department projected the 2002 inventory to 2004 and beyond using national fuel consumption information supplied to the Department by the Association of American Railroads in combination with emissions factors developed by EPA and presented on the EPA website in the *Emissions Factors for Locomotives*, EPA420-F-97-051, December 1997, Table 9, Fleet Average Emission Factors For All Locomotives. According to the Association of American Railroads, national railroad annual fuel consumption has grown consistently at about 1.6 percent over the last 15 years. We used the following normalized emission growth factors for locomotive emissions. These numbers compare well with EGAS 5.0 in the near-term. The only differences are that EGAS 5.0 forecasts a slightly larger reduction of NOx emissions in 2018 and a much larger VOC reduction in some future years. VOC emissions from locomotives are typically very small. EGAS 5.0 may be downloaded from http://www.epa.gov/ttn/ecas/egas5.htm.

Table 4. Normalized Growth Factors for Locomotives

Year	Fuel Use Growth	NOx Emission Factors	NOx Emission Growth (Fuel use growth * emission factor)	HC/VOC Emission Factors	HC/VOC Emission Growth (Fuel use growth * emission factor)
2002	1.0000	1.0000	1.0000	1.0000	1.0000
2009	1.1175	0.6765	0.7560	0.8785	0.9817

In the Regulatory Support Document (RSD) for locomotive emission standards, national emissions account for future, phased-in controls that will primarily reduce NO_x and HC emissions as well (EPA, 1997). Emission reductions, which include rule effectiveness and rule penetration, are estimated based on the percent change in emissions from the base year to a given projection year. The Department reduces the 2002 locomotive emissions for NO_x and VOC by the percentages shown in Table 4.

To estimate VOC emissions from HC, the Department applied a VOC/HC conversion factor of 1.005 to the HC emissions. This conversion factor was obtained from EPA's *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and Other Nonroad Components of the National Emission Inventory, Volume I: Methodology* (EPA, 2002).

Estimated annual emissions were divided by 365 to obtain a daily emission estimate which was assumed to be a good estimate for emissions during an average summer day.

IV. AIRCRAFT EMISSIONS

Emissions from commercial aircraft for 2002 are estimated using the Emissions & Dispersion Modeling System (EDMS) 4.20. Commercial aircraft operations were modeled directly by EDMS for Pittsburgh International Airport (PIT) in Allegheny County. A small number of commercial aircraft operations were also modeled by EDMS for Arnold Palmer Regional Airport (LBE) in Westmoreland County. A description of EDMS calculation methods is included for PIT and LBE.

Commercial airport operations data. Airport specific data on operations were found at www.transtats.bts.gov and also the FAA's Terminal Area Forecast found at http://www.apo.data.faa.gov. Operations data on all significantly large regional airports in Pennsylvania could be found at this website, although some of the airports modeled supported very few commercial flights. We used default values in the EDMS model for aircraft engines and service equipment for each aircraft type. Calendar year 2002 was modeled in EDMS and grown to 2004, 2009, and 2018 using operations projection in the Terminal Area Forecast. No specific data is available on the type of aircraft that will be operating out of PIT in 2009 and 2018. This creates a problem for projecting emissions. We expect aircraft design trends to continue toward developing more fuel-efficient engines that produce more NOx. We expect that these types of engines will replace aging models of planes in the fleet. The inventory did not capture those increases. We also expect that older ground support equipment (GSE) will be replaced with lower polluting GSE. The inventory did not necessarily capture all of those possible reductions. Therefore, changes in NOx emissions from these trends are not perfectly captured in the inventory for the Pittsburgh area airports. Overall, operations at PIT have rapidly decreased over the last 10 years as a result of US Airways closing their hub at PIT. The forecasted trend is for operations at PIT to continue to decrease over the next few years before recovering slightly.

Table 5. Normalized Growth Factors for Aircraft Operations				
	2002	2004	2009	2018
Pittsburgh International Airport	1.0000	0.8091	0.5352	0.5729

Mixing height in EDMS. It was determined that a better mixing height than the model's default value could be used in EDMS. Upper air meteorological data available from Sterling Virginia in combination with surface data measurements taken at the Philadelphia International Airport generated 1-hr mixing heights in the meteorological preprocessor model PCRAMMET, EPA, *PCRAMMET* (software), Research Triangle Park, NC, June 1999. All mixing heights between 10 a.m. and 6 p.m. were not considered when generating these averages because an extremely small percentage of flight operations occur between those hours. The average summer mixing height was 4,428 feet for airports in the Eastern Pennsylvania. The default value of 3000 feet was used for all other airports, which includes airports in the Pittsburgh area.

Small airport emission estimation methodology. Small aircraft emissions were calculated by using small airport operation statistics, which can be found at www.airnav.com. An emissions factor for a typical air general aviation single engine, multi-engine, and jet engine aircraft were derived by averaging the emissions factors from a basket of emission factors for common aircraft of each of the three types of aircraft. Emission factors and operational characteristics contained in EDMS were used. The proportion of operations between the three groups of aircraft was determined by examining the number of each aircraft type based at each airport. For military operations at small airports, the type of aircraft and its emission factors are sometimes identifiable. If not, emission factors calculated to represent an "average" military aircraft are used. Growth was estimated using estimates of small airport activity from Federal Aviation Administration's *APO Terminal Area Forecast Detailed Report.* Growth factors were applied to each airport.

V. COMMERCIAL MARINE VESSEL EMISSIONS

The counties of Allegheny, Armstrong, Beaver, Greene, Washington, and Westmoreland contain waterways that are considered part of the Port of Pittsburgh. Commercial Marine Vessels (CMV) navigate these waterways in these counties and the extended region and produce significant air emissions.

All air emissions from CMV traffic in the seven county area of the Port of Pittsburgh were estimated using the methodology outlined in EPA's publication *Commercial Marine Activity for Great Lakes and Inland River Ports in the United States, Final Report*[1]. A comprehensive understanding of the methodology can be achieved by reviewing this document. Additional information was obtained from conversations with tug operators in the port.

The best available EPA methodology for estimating emissions from the Port of Pittsburgh requires that a typical port be chosen to compare to the port to be modeled. A typical port is a port where EPA examined the emissions and operations in detail. A typical port contains all the major elements that can be found in an inland river port to be modeled. The modeler can then more easily compare the port being modeled with known operating characteristics in the typical port to derive trip durations and movements in the modeled port. The typical port that was chosen to compare to Pittsburgh was the Port of St. Louis. The Port of St. Louis was chosen because of the presence of locks and the barge to tug ratio in this port is comparable to the Port of Pittsburgh.

The next step summarized trip data for the modeled port. Trip data is obtained directly from the website of the Waterborne Commerce Statistics Center of the United States Army Corps of Engineers[2]. Trip data under the heading Port of Pittsburgh in that report totals trips for the Monongahela River, Allegheny River, and the Ohio River to the state border with Ohio, along with other trips that occur on the smaller tributaries in the port. The total number of trips used for modeling emissions for the Port of Pittsburgh was obtained here.

Determining Number of Trips for the Modeled Port Ship Types

Next, we separated the number of trips into components of upbound and downbound trips both passing and calling. The number of trips was separated into horsepower bins of various groups of tugboats. The Port of St. Louis was not used in determining the number of trips for three reasons: 1) Pittsburgh has no upbound, passing traffic, 2) tugs in St. Louis generally have more horsepower than tugs in Pittsburgh, and 3) horsepower data is available for all tugs operating in Pittsburgh. Therefore, more accurate and appropriate data was used.

To complete this step, tugs operating in the Port of Pittsburgh were separated in five horsepower bins to allow for easier calculation of fuel usage. Horsepower information was obtained from the Waterborne Commerce Statistics Center website[3]. All upbound traffic is calling (i.e. the boat makes a stop somewhere in the Port of Pittsburgh) since the port is an endpoint for river traffic. Downbound traffic is primarily comprised of tugs and coal barges making calls at the steel-producing facilities and power plants. Some downbound traffic passes on to other ports. No method exists to easily predict the amount of passing downbound traffic. By looking at lock data, one lock being west of the Ohio border and the other one being east, an estimate was made about the number of tugs that pass over the border.

Determining Trip Durations

By using formulas supplied in the *Commercial Marine Activity for Great Lakes and Inland River Ports in the United States*[4], trip times were calculated for tugboats of different horsepower. The time of trips included maneuvering on the river and maneuvering into locks. A total time was obtained for all trips by multiplying the time per trip per horsepower bin by number of trips per horsepower bin. Similarly, the total maneuvering time was estimated by using the formulas supplied below. *Commercial Marine Activity for Great Lakes and Inland River Ports in the United States*[5] states that 1.0 hours is needed for maneuvering into each lock and 0.5 hours for each lock area. There are many more locks in Pittsburgh that are distributed in a more complicated pattern in the port than in the typical port. A method to determine the average number of locks traversed for each horsepower bin was developed. When trips were averaged for both directions for each horsepower bin, it offers a reasonable estimate of trip durations based on power rating. More powerful tugboats traverse more locks than smaller tugboats, which is consistent with the results of the EPA methodology, since larger tugs typically travel longer distances. The EPA methodology states that the average speed of larger tugs is greater.

Tugboats operators informed us that their boats are pushing freight essentially non-stop - except for shift changes and maintenance. Operators in the port strive to achieve an average speed of five miles per hour for 20 hours per operating day or about 100 miles a day including maneuvering time. Using the methodology in *Commercial Marine Activity for Great Lakes and Inland River Ports in the United States*[6] generated a speed greater than five miles per hour, but less than the 20 hours per day average that the tug operators strive to achieve, which reasonably approximates what operators described.

A series of sample calculations are given below for estimating trip times:

Allocation of Cruise Time-in-mode to the Modeled Port[7]

$$\mathbf{MP_{CT} = LP * MP_{RD}/LP_{RD} * LP_{CS}/(LP_{CS} \ {}^{+}/_{-}\ LP_{RC} \ {}^{+}/_{-}\ MP_{RC})}$$

Where:

MP_{CT} = Modeled Port cruise time-in-mode (hr/trip)
LP_{CT} = Like Port cruise time-in-mode.
MP_{RD} = Modeled Port distance along the river
LP_{RD} = Like Port distance along the river
LP_{CS} = Like Port cruise speed. Depends on direction.
LP_{RC} = Like Port river current (added for upbound vessels or subtracted for downbound)
MP_{RC} = Modeled Port river current (subtracted for upbound vessels or added for downbound)

River current in the Port of Pittsburgh ranges from rapid flowing to pooling. An average current of 3.5 miles per hour was chosen after talking with tugboat operators in the port.

Sample Calculation of Downbound Trip

$\mathbf{MP_{CT}}$ **=** 2.7 hours * 120 miles/70 miles * 6.6 mph/(6.6 mph – 2 mph + 3.5 mph)
= 3.77 hours

Average Number of Locks Traversed

$$\mathbf{LT_{HP\ BIN} = MP_{CT\ for\ HP\ BIN} * (LP_{CS} \ {}^{+}/_{-}\ LP_{RC} \ {}^{+}/_{-}\ MP_{RC})/13}$$

Where:

$LT_{HP\ BIN}$ = Locks traversed for each horsepower bin
$MP_{CT\ for\ HP\ BIN}$ = Modeled port cruise time for each type of horsepower

LP_{CS} , LP_{RC} , MP_{RC} = As explained above
13 = Number of locks along typical total length of Pittsburgh waterway

Sample Calculation

$\mathbf{LT_{HP\ BIN}}$ **=** 3.77 hours * (6.6 mph - 2 mph + 3.5 mph) = 30.54 miles/13
= 2.35 locks

Total Maneuver Time[8]

$\mathbf{TMT = LT_{HP\ BIN} * (1.0 + 0.5)}$
Where:
TMT = total maneuver time
1.0 hours = time required to maneuver through a lock
0.5 hours = time required to maneuver to and from a lock

Sample Calculation

TMT = 2.35 locks * (1.0 hours + 0.5 hours)
= 3.52 hours

Estimating Emissions

Determining fuel usage and multiplying by an emission factor determined total emissions. Fuel usage was estimated for each horsepower bin by using information from the study *Shipboard Marine Engines Emission Testing for the United States Coast Guard-Final Report*[9]. Although fuel usage for every horsepower bin was not available in this report, examining the available horsepower data could make a reasonable estimation of the rate of fuel usage. The names of tugs operating in the Port of Pittsburgh area and their horsepower ratings are available from the website of the *Waterborne Commerce Statistics Center* of the United States Army Corps of Engineers[10]. Barges in the Port of Pittsburgh are mostly loaded in the downbound direction and unloaded in the upbound direction. Tugboats were estimated to run at close to maximum power, 75 percent load, for calculating fuel usage, since they push cargo downstream and empty barges upstream against a strong current. The following fuel usage was used for the various horsepower bins:

Table 6. Tugboat Fleet Characterization in the Port of Pittsburgh Based on Horsepower Rating

Horsepower Bin	Number of Tugs in the Port	Percentage of Total Tugs and Trips	Fuel Usage (gal/hr)
0-500	32	33	25
750-1500	51	52	44
1500-3000	9	9	105

3000-5000	4	4	200
5000-8000	2	2	250
Total Tugs	98	100	

Emission factors from tugboats and pushboats are nearly nonexistent. *Commercial Marine Vessels Contributions to Emission Inventories*[11] suggested that 550 lb of NOx are produced per 1000 gallons of fuel used. CMV engines also known as type II marine engines are engineered and perform similarly to locomotive engines. Since some locomotive engines are the same size and operate under similar circumstances as tugboat engines, emission factors of locomotive engines were used at the suggestion of Greg Janssen of EPA[12]. Emission factors of locomotives from the U.S. EPA website, www.epa.gov[13] show NOx emissions at 609 lb per 1000 gallons of fuel. Since these tugs are under load like locomotives, the emission factors of locomotives seem more appropriate than other emission factors available. Other emission factors for hydrocarbons, carbon monoxide, and particulate matter were 23.6 lb, 60.4 lb, and 15.0 lb, respectively, for 1000 gallons of fuel consumed.

Distributing Emissions to the County Level

We used total emissions for the Port of Pittsburgh and apportioned the total to the county level by counting the number of piers, wharves, and docks (PWDs) in each county and calculating the percentage PWDs in the county relative to the port total of PWDs,[14] as shown in Table 6. The total emissions from the port for all pollutants were multiplied by the percentage of PWDs in the county to obtain countywide emissions.

Table 7. Geographic Distribution Piers, Wharves, and Docks in the Port of Pittsburgh by County.

County	Number of Piers, Wharves, and Docks in County	Percentage of Piers, Wharves, and Docks by County
Allegheny	102	53.7
Armstrong	5	2.6
Beaver	34	17.9
Fayette	7	3.7
Greene	11	5.8
Washington	24	12.6
Westmoreland	7	3.7
Total	190	100.0

Example Emission Calculation of Downbound Calling Trips for 0-750 Horsepower Tugboats in the Port:

Total tug trips in the Port of Pittsburgh in 1999 = 28,584
Downbound calling trips in 1999 = 13,850
Number of tugs in the 0-750 horsepower ranges = 32
Total number of tugs in operation in the port = 98

Percentage of tugs and trips (assumed) in the 0-750 horsepower bin = 33
Downbound calling trips in this horsepower bin= (13,850 * 0.33) = 4,571
Like port cruise times for these tugs on downbound calling trips = 2.7 hours
Modeled port cruise time for these tugs on downbound calling trips = 3.77 hours
Average number of locks traversed for these tugs on these trips in modeled ports = 2.35
Modeled port maneuver time = 2.35 * (1.0 hours + 0.5 hours) = 3.52 hours
Total time per trip = 3.77 hours + 3.52 hours = 7.29 hours
Total NOx emissions = 4,571 trips * 7.29 hours/trip * 25 gal/hour * 609 lb NOx/1000 gal of fuel used *1 ton/2000 lb = 253.67 tons/year
NOx Emissions in Allegheny County from 0-750 horsepower bin in downbound direction = 253.67 tons/year * 5.8% = 14.71 tons/year.

Emissions from all horsepower bins and trip types were summed to get an annual emissions estimate for each county in the Port of Pittsburgh. The number of operations and shipping activity are believed to be relatively constant throughout the year. An exception may occur when there is a severe drought. Therefore, annual emissions were divided by 365 days to determine the average emissions per summer day.

Estimating Emissions CMV Growth

Emissions growth is based on two factors: future fuel consumption and future emissions standards. Emissions standards or programs that take place in the future will greatly lower emissions produced by CMV engines. Fuel use growth and future emission reductions used to calculate total future emissions were based upon information contained in the *Final Regulatory Impact Analysis: Control of Emissions from Marine Diesel Engines*.[15]

Fuel use growth for CMV was obtained from Table 5.8 in the regulatory impact analysis, "Baseline Emissions from Category 2 CI Marine Engines Operated in U.S. Waters."[16] An average annual fuel use growth of 0.9 percent was estimated in the table, which led to corresponding baseline emission increases (absent controls) in carbon monoxide (CO), NOx, and VOC. Growth was based upon the number of extra CMV expected to enter service in future years.

In Table 5-14, which is entitled, "Projected NOx Emission Reductions from Category 2 CI Marine Engines Operated in U.S. Waters,"[17] the emission reductions for hydrocarbons were obtained for future years. The hydrocarbon reduction was applied directly to VOC emissions. Emission reductions in NOx were obtained from Table 5-9, "Projected NOx Emission Reductions from Category 2 CI Marine Engines Operated in U.S. Waters."[18] Table 5-9 was used for NOx because it shows emission reductions of Category 2 CI Marine Engines exclusively. Percentage reductions were derived from these two tables for VOC and NOx for use in the future years contained in our inventory. The tables gave reductions for 2010, 2020, and 2030. We interpolated linearly between years to obtain reductions for our inventory's years of 2002, 2004, 2009, and 2018. Table 8 below shows the growth rates in emissions used to estimate emissions in the inventory.

		Table 8. Normalized Growth in Emissions for CMV in the U.S.					
		Normalized Future Emission Factors			Normalized Growth in Emissions (CMV Growth * Normalized Future Emission Factors)		
Year	**CMV Fuel Use Growth**	**CO**	**NOx**	**VOC**	**CO**	**NOx**	**VOC**
2002	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2004	1.0181	1.0000	0.9800	0.9900	1.0181	0.9977	1.0079
2009	1.0647	1.0000	0.9600	0.9800	1.0647	1.0221	1.0434
2018	1.1541	1.0000	0.8700	0.9200	1.1541	1.0041	1.0618

[1] United States Environmental Protection Agency, Office of Mobile Sources, Assessment and Modeling Division, *Commercial Marine Activity for Great Lake and Inland River Ports in the United States, Final Report*, Ann Arbor, Michigan, September 1999.

[2] United States Army Corps of Engineers, Navigation Data Center, Waterborne Statistics Center, *Waterborne Commerce of the United States, Waterways and Harbors on the: Gulf Cost, Mississippi River System and Antilles*, New Orleans, Louisiana, available February, 2004, at http://www.iwr.usace.army.mil/ndc/wcsc/wcsc.htm.

[3] Waterborne Commerce Statistics Center of the United States, United States Army Corps of Engineers, *Vessel Characteristics*, available at the website http://www.iwr.usace.army.mil/ndc/veslchar/veslcharsearch.htm, July 19, 2001.

[4] United States Environmental Protection Agency, Office of Mobile Sources, Assessment and Modeling Division, *Commercial Marine Activity for Great Lake and Inland River Ports in the United States, Final Report*, Ann Arbor, Michigan, September 1999, Section 4.

[5] Ibid., p. 4-9.

[6] Ibid., Section 4

[7] Ibid., p. 4-24.

[8] Ibid., p. 4-9.

[9] Volpe National Transportation Systems Center and United States Coast Guard Headquarters Naval Engineering Division, prepared by Environmental Transportation Consultants, *Shipboard Marine Engines Emission Testing for the United states Coast Guard Final Report*, 1995.

[10] Website of the Waterborne Commerce Statistics Center of the United States, United States Army Corps of Engineers, http://www.iwr.usace.army.mil/ndc/wcsc/wcsc.htm, July 19, 2001.

[11] Booz-Allen & Hamilton Inc, Transportation Consulting Division, 523 West Sixth Street, Suite 616, Los Angeles, CA 90014, *Commercial Marine Vessel Contributions to Emission Inventories*, September 12, 1991.

[12] Email exchange with Greg Janssen of U.S. EPA, Office of Transportation and Air Quality, Assessment and Standards Division, Ann Arbor Michigan, January 24, 2001.

[13] U. S. EPA, Office of Transportation and Air Quality, website at http://www.epa.gov/otaq/locomotv.htm, July 19, 2001.

[14] United States Environmental Protection Agency, Office of Mobile Sources, Assessment and Modeling Division, *Commercial Marine Activity for Great Lake and Inland River Ports in the United States, Final Report*, Ann Arbor, Michigan, September 1999, p. 4-9.

[15] United States Environmental Protection Agency, Office of Mobile Sources, Engines and Compliance Division, *Final Regulatory Analysis: Control of Emissions from Marine Diesel Engines*, November 1999.

[16] Ibid. , p. 109.

[17] Ibid. , p. 115.

[18] Ibid. , p. 110.

APPENDIX F-2

Nonroad Source Emissions

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