Chapter 6 Emission Inventories

This chapter identifies emission source categories in Washington that could be affecting visibility in mandatory Class I Areas in Washington and other states impacted by Washington emissions. The Regional Haze Rule (RHR)[1] requires statewide emission inventories of pollutants that are reasonably anticipated to cause or contribute to visibility impairment in any mandatory Class I Area.

6.1 Emission Inventory Development

Emission inventories play an important role in the identification and evaluation of sources that are reasonably expected to impact visibility. Most of the emissions data prepared and used in this foundational Regional Haze (RH) SIP were originally collected and reported in some form by state, local, and tribal air pollution control programs. Various Western Regional Air Partnership (WRAP) forums compiled these data for use in WRAP modeling and individual state analyses. as follows:

- The Stationary Sources Joint Forum and the Emissions Forum commissioned projects to obtain point source area source emissions.
- The Emissions Forum commissioned projects to obtain mobile source emissions.
- The Dust Emissions Joint Forum and the Modeling Forum commissioned projects to obtain ammonia, dust, and biogenic emissions.
- The Fire Emissions Joint Forum commissioned projects to obtain natural and anthropogenic fire emissions.

The Fire Emissions Joint Forum formed the Natural Background Task Team to develop a methodology to classify fire as either "natural" or "anthropogenic." The resulting policy uses the following three classification criteria[2]:

1. Prescribed fire is an anthropogenic source, except where it is utilized to maintain an ecosystem that is currently in an ecologically functional and fire resilient condition, in which case it is classified as a "natural" source.
2. Wildfire that is suppressed by management action is a "natural" source. Wildfire, when suppression is limited for safety, economic, or resource limitations, remains a "natural" source. Wildfires managed for resource objectives are classified the same as prescribed fires.
3. Native American cultural burning for traditional, religious, and ceremonial purposes is a "natural" source.

The WRAP developed a central regional emissions inventory database to facilitate the data collection efforts. These emissions inventories are available from the WRAP Technical Support

[1] 40 CFR 51.308 (d)(4)(v)
[2] The Natural Background Task Team of the Fire Emissions Joint Forum, *Policy for Categorizing Fire Emissions*, November 15, 2001. http://www.wrapair.org/forums/fejf/documents/nbtt/FirePolicy.pdf

System (TSS) website (http://vista.cira.colostate.edu/TSS/Results/Emissions.aspx). The TSS website has links to numerous references that describe in detail the emissions methods used in developing inventories for the foundation RH SIPs. Appendix G to this RH SIP, Technical Support System Road Map, also contains information on inventories.

Along with the other WRAP states, Washington used the WRAP-developed emission inventories to develop the state's RH SIP as agreed to between Environmental Protection Agency (EPA), the states, and the WRAP.

6.2 Emission Inventory Scenarios

The WRAP focused on the development of the emission inventories for three scenarios:

(1) A base case emission inventory for 2002 for evaluation of model performance (referred to as "Base02")
(2) An inventory representing a typical year's emissions during the 2000-2004 baseline period ("Plan 02")
(3) A projected inventory for 2018 for evaluation of reasonable progress toward achieving the national visibility goal ("Base 18", later "PRP18")

Inventories for all three scenarios went through a series of revisions. Each revision refined the inventory by correcting errors and adding emission inventory improvements and updates. Each version of an inventory series is denoted by the addition of a letter to the inventory name. For example Base02b is the second version of the 2002 Base Case Inventory.

A general overview of the inventories developed for each of the three WRAP scenarios is provided below. Further information on modeling and source apportionment is found in Chapter 7.

6.3 Base Case Inventories

The purpose of the "2002 Base Case" or "Base02" inventory is to represent the actual emissions of pollutants causing or contributing to visibility impairment during calendar year 2002. Accordingly, the Base02 inventory is based on the best available data on actual 2002 emissions.

The WRAP used the Base02a inventory to model visibility for the calendar year 2002 and to evaluate model performance. The ability of the model to provide an adequate representation of air quality that occurred in 2002 would provide confidence that the model can adequately represent revised emissions in projected years. The WRAP decided model performance was acceptable.

The Base02b inventory was developed to correct errors and add emission inventory improvements. The WRAP considers the Base02b inventory to have the best estimates of actual 2002 emissions for all sectors for North America. The WRAP modeled the Base02b inventory to enable comparisons between the 2002 base case and the 2000-2004 typical-year modeling.

6.4 Typical-Year Baseline Inventories

The purpose of the 2000-2004 baseline period planning case emissions scenario is to represent emission patterns based on average or "typical" conditions during the 2000-2004 baseline period rather than emissions for any specific year. The inventory provides a basis for comparison with 2018 projected emissions and gauging reasonable progress. The WRAP refers to the Typical-Year Baseline Inventory as the "Plan02" inventory.

Versions of the Plan02 inventory were used for modeling visibility impairment and determining source apportionment. The WRAP also used the Plan02 inventory to develop information about the source areas of visibility impairing emissions impacting individual Class I Areas.

The WRAP used the third iteration of Plan02 inventory, the Plan02c inventory, to model baseline period visibility. The Plan02c inventory was also used with a different model and a source apportionment tool (discussed in Chapter 7) to identify the source regions and the contributions of major source categories to sulfate and nitrate at the Class I Areas.

The WRAP developed a Plan02d inventory that, among other revisions, included updates to source classification codes and source inventory codes along with source emissions corrections. This inventory was used for updated modeling of baseline period visibility impairment. The Plan02d inventory was also used for an analysis (discussed in Chapter 7) based on emissions and meteorology of potential source areas contributing visibility-impairing pollutants to the mandatory Class I Areas.

6.5 Reasonable Progress Inventories

The year 2018 represents the first milestone date for demonstrating reasonable progress toward the national visibility goal. The WRAP projected emissions to the year 2018 by taking into account growth, "on-the-books" (that is, adopted) controls and regulations, and application of RH strategies. The factors that were considered in projecting the inventory include the following:

- Presumptive Sulfur Dioxide (SO_2) Best Available Retrofit Technology (BART) for Electrical Generating Units (EGUs) in the WRAP region or current controls if lower
- Known BART controls in the WRAP region
- Mobile source controls
    - Heavy Duty Diesel (2007) Engine Standard
    - Tier 2 Tailpipe Standards
    - Large Spark Ignition and Recreational Vehicle Rule
    - Nonroad Diesel Rule
    - Low sulfur fuel requirements for gasoline engines, on-road diesel engines, off-road diesel engines, and locomotives
- Combustion Turbine and Industrial Boiler/Process Heater/Reciprocating Internal Combustion Engine (RICE) Maximum Achievable Control Technology (MACT)
- Post-2002 permits and state/EPA consent agreements

- Reductions in 2000-04 average fire emissions due to Emissions Reduction Techniques in Smoke Management Programs
- Ozone and Coarse Particulate Matter (PM_{10}) SIPs in place in the WRAP region
- State oil and gas emissions control programs

The WRAP did two series of 2018 projected emission inventories. The first series is referred to as "Base18" and the second, superseding series is referred to as "Preliminary Reasonable Progress" or simply "PRP18" inventories.

The second iteration of the Base18 inventory, the Base18b inventory, was modeled with the same model and source apportionment tool as the Plan02c inventory to identify the source regions and the contributions of major source categories to sulfate and nitrate at mandatory Class I Areas in 2018. The results can be compared with the earlier source apportionment modeling performed with the Plan02c inventory.

The WRAP modeled both the first and the second iterations of the PRP18 inventories, the PRP18a and the PRP18b inventories, and used the results to estimate 2018 visibility at mandatory Class I Areas. The PRP18a inventory included presumptive SO_2 BART for EGUs where BART had not been determined. The PRP18b inventory included known or projected BART for EGU and non-EGU sources along with presumptive SO_2 and Nitrogen Oxides (NO_x) BART for EGUs where BART was yet to be determined. These modeling runs were evaluated by various states in determining reasonable progress goals for mandatory Class I Areas and the emission reductions needed to achieve those goals.

The WRAP also developed a special version of the PRP18b inventory reflecting a more accurate inventory for commercial marine shipping off the Pacific coast. This PRP18cmv inventory was modeled to estimate 2018 visibility in mandatory Class I Areas.

The analysis based on emissions and meteorology of potential source areas contributing visibility impairing pollutants to mandatory Class I Areas was rerun with the PRP18a, PRP18b, and PRP18cmv projected 2018 emissions inventories. The results can be compared with the earlier analysis based on the Plan02d inventory. None of the PRP18 inventories include the projected affects of the recently adopted International Maritime Organization (IMO) Emission Control Area for the West Coast of the United States and Canada.

6.6 Emission Inventories for Washington's Regional Haze State Implementation Plan

While the various inventories developed for the three scenarios played a role in the development of the technical analysis for the WRAP region, Washington State's foundational RH SIP focuses on two emission inventories in particular:

- the Typical-Year Baseline Inventory referred to as "Plan02d"
- the inventory projected for 2018 specified by the WRAP as "Preliminary Reasonable Progress emissions inventory 2018 version a", but commonly referred to as "PRP18a".

These two inventories were the most recent, complete, and up-to-date inventories available through TSS when Washington State began doing its own analysis of the WRAP's technical basis for the state's regional haze SIP.

The visibility-impairing emissions examined in both inventories are SO_2, NO_x, Volatile Organic Compounds (VOC), Organic Carbon (OC), Elemental Carbon (EC), Fine Particulate Matter ($PM_{2.5}$), and PM_{10} and Ammonia (NH_3). The emission tables show the primary source categories for each visibility impairing pollutant. The source categories vary by the type of pollutant. Source categories include: point, area, on-road mobile, off-road mobile, anthropogenic fire, natural fire, biogenic, road dust, fugitive dust and windblown dust.

Not included as an "in-state" emission source category is offshore marine vessel emissions, which are considered "regional" emissions. It should also be noted the PRP18a emissions for natural fire (wildfires) is based on historical rates of burning and does not take into account increased burning that may occur due to climate change or natural causes.

The emissions information for Washington is organized by visibility-impairing pollutant. Inventory information for each pollutant is provided by major source categories for both the Plan02d and the PRP18a inventories.

Sulfur Dioxide Emissions

Table 6-1 shows Washington SO_2 emissions for the baseline year and the end of the first planning period.

Table 6-1 Washington Sulfur Dioxide Emission Inventories – 2002 and 2018

Washington Statewide SO_2 Emissions (tons/year)				
Source Category	**Plan02d**	**PRP18a**	**Net Change**	**% Change**
	2002	**2018**	**2018 - 2002**	**(2018-2002) / 2002**
Point	52,885	37,444	-15,441	-29%
Area	7,311	8,667	1357	+19%
On-Road Mobile	5,543	679	-4,864	-88%
Off-Road Mobile	13,913	262	-13,651	-98%
Anthropogenic Fire	1,411	1,043	-368	-26%
Natural Fire	1,641	1,641	0	0%
Total	**82,703**	**49,736**	**-32,967**	**-40%**

Gaseous SO_2 emissions are converted to sulfate particles, generally ammonium sulfate, in the atmosphere. Ammonium sulfate particles grow rapidly in size in the presence of water through water absorption and change from solid particles to solution droplets. The size of ammonium sulfate at high relatively humidity (>70%) makes it disproportionally responsible for visibility impairment compared to inorganic salts that do not take up water molecules.

Baseline year 2002 SO_2 emissions come primarily from point sources, including a coal-fired power plant, oil refineries, primary aluminum plants, pulp and paper mills, and a cement plant.

A 40% statewide reduction in SO_2 emissions is expected by 2018 due to planned controls on existing sources, especially due to on-the books rules for on-road and off-road fuels and a reduction of nearly 19,000 tons from the coal-fired power plant.

Nitrogen Oxides Emissions

Table 6-2 shows Washington NO_x emissions for the baseline year and the end of the first planning period.

Table 6-2 Washington Nitrogen Oxides Emission Inventories – 2002 and 2018

Washington Statewide NO_x Emissions (tons/year)				
Source Category	**Plan02d**	**PRP18a**	**Net Change**	**% Change**
	2002	**2018**	**2018 - 2002**	**(2018-2002) / 2002**
Point	43,355	49,456	6,101	14%
Area	17,587	22,746	5,159	29%
On-Road Mobile	201,991	55,911	-146,080	-72%
Off-Road Mobile	84,710	46,529	-38,181	-45%
Anthropogenic Fire	6,821	4,971	-1,850	-27%
Natural Fire	5,997	5,997	0	0%
Biogenic	17,923	17,923	0	0%
Total	**378,384**	**203,533**	**-174,850**	**-46%**

NO_x emissions are generated during combustion processes from the reaction of oxygen with the nitrogen content of the fuel and at higher temperatures from the reaction of nitrogen and oxygen in the atmosphere. NO_x, similar to sulfur dioxide, reacts in the atmosphere to form nitrate particles such as ammonium nitrate. Like ammonium sulfate, ammonium nitrate particles grow rapidly in the presence of water to reach a size that is disproportionately responsible for visibility impairment.

Baseline year 2002 NO_x emissions come predominantly from on-road mobile sources. Of lesser importance are emissions from off-road mobile sources and point sources.

Point source emissions are projected to increase based on the increased utilization of existing units and new sources established between 2002 and 2008. Overall, NO_x emissions in Washington are expected to decline 46% by 2018, primarily due to significant improvements in on-road and off-road mobile source emissions.

Volatile Organic Compounds Emissions

Table 6-3 shows Washington VOC emissions for the baseline year and the end of the first planning period.

Table 6-3 Washington Volatile Organic Compounds Emission Inventories – 2002 and 2018

Washington Statewide VOC Emissions (tons/year)				
Source Category	**Plan02d**	**PRP18a**	**Net Change**	**% Change**
	2002	**2018**	**2018 - 2002**	**(2018-2002) / 2002**
Point	18,651	26,212	7,561	41%
Area	151,680	253,703	102,023	67%
On-Road Mobile	140,181	50,625	-89,556	-64%
Off-Road Mobile	61,601	38,618	-22,983	-37%
Anthropogenic Fire	14,858	10,532	-4,325	-29%
Natural Fire	13,160	13,160	0	0%
Biogenic	642,736	642,736	0	0%
Total	**1,042,867**	**1,035,587**	**-7,280**	**-1%**

The dominant source of VOC emissions throughout the country is biogenic emissions. These emissions comprise 61% of total Washington VOC emissions in 2002. These are natural emissions mostly from forests, but also agricultural crops and urban vegetation. Among the other sources, most notably, on-road mobile sources, area sources, and off-road mobile sources, contribute to VOC loading in the atmosphere.

Significant VOC increases in area sources are primarily driven by population growth. Specific area sources expected to increase include residential wood combustion and solvent utilization.

Significant VOC reductions from mobile sources in the 2018 inventory are more than offset by increases in area sources due primarily to population growth. Use of solvents in paints, dry cleaning fluid, charcoal lighter fuel, windshield washer fluids, and many home use products shows up in the area source category and is linked to population growth.

From a regional haze perspective, there is less concern with VOCs emitted directly to the atmosphere and more with the formation of secondary organic aerosols. Secondary organic aerosols form after condensation and oxidation. VOCs also play a role in the photochemical production of ozone in the troposphere. Biogenic VOCs are uncontrollable and, therefore, there is a limit to the amount of visibility improvement that can be gained.

VOCs react with NO_x to produce nitrated organic particles that impact visibility in the same series of chemical events that lead to ozone. Thus, strategies to reduce ozone in the atmosphere often lead to visibility improvements.

Organic Carbon Emissions

Table 6-4 shows Washington OC emissions for the baseline year and the end of the first planning period.

Table 6-4 Washington Organic Carbon Emission Inventories – 2002 and 2018

Washington Statewide Organic Carbon Emissions (tons/year)				
Source Category	**Plan02d**	**PRP18a**	**Net Change**	**% Change**
	2002	**2018**	**2018 - 2002**	**(2018-2002) / 2002**
Point	763	941	178	23%
Area	16,577	22,214	5637	34%
On-Road Mobile	1,821	1,533	-287	-16%
Off-Road Mobile	1,948	1,288	-660	-34%
Anthropogenic Fire	10,305	7,349	-2,955	-29%
Natural Fire	17,931	17,931	0	0%
Road Dust	189	202	13	7%
Fugitive Dust	739	992	253	34%
Total	**50,273**	**52,451**	**2,178**	**4%**

OC is primarily the end product of combustion of organic material. Most of these emissions in Washington are from natural (nonanthropogenic) wildfire, which can fluctuate greatly from year to year. For instance, 2003 was an unusually high year for wildfires in Washington. Area sources are the largest anthropogenic contributor to the OC inventory, and these are expected to increase significantly (34%) from 2002 to 2018 mostly due to population increase. A variety of sources contribute to the area source category, but wood stoves are a particularly significant component.

Elemental Carbon Emissions

Table 6-5 shows Washington EC emissions for the baseline year and the end of the first planning period.

Table 6-5 Washington Elemental Carbon Emission Inventories – 2002 and 2018

Washington Statewide Elemental Carbon Emissions (tons/year)				
Source Category	**Plan02d**	**PRP18a**	**Net Change**	**% Change**
	2002	**2018**	**2018 - 2002**	**(2018-2002) / 2002**
Point	144	206	62	43%
Area	2,180	3,005	825	38%
On-Road Mobile	2,003	481	-1,522	-76%
Off-Road Mobile	4,213	1,696	-2,517	-60%
Anthropogenic Fire	780	585	-195	-25%
Natural Fire	3,717	3,717	0	0%
Road Dust	14	15	1	8%
Fugitive Dust	50	67	17	34%
Total	**13,102**	**9,773**	**-3,329**	**-25%**

EC is black carbon, a product of incomplete combustion, which is emitted as soot. It is similar to OC, but EC represents more complete combustion of the fuel that produces carbon. The primary sources of EC are natural fires, off-road and on-road mobile sources, and area sources. Elemental carbon emissions from mobile sources are estimated to decrease significantly by 2018 as new federal mobile source regulations are being implemented. Overall, elemental carbon emissions are estimated to decline by 25% by 2018.

Fine Particulate Matter Emissions

Table 6-6 shows Washington $PM_{2.5}$ emissions for the baseline year and the end of the first planning period.

Table 6-6 Washington Fine Particulate Matter Emission Inventories – 2002 and 2018

Washington Statewide Fine Particulate Matter Emissions (tons/year)				
Source Category	**Plan02d**	**PRP18a**	**Net Change**	**% Change**
	2002	**2018**	**2018 - 2002**	**(2018-2002) / 2002**
Point	2,257	2,625	368	16%
Area	12,708	17,234	4,526	36%
Anthropogenic Fire	3,869	2,691	-1,178	-30%
Natural Fire	1,139	1,139	0	0%
Road Dust	2,819	2,910	91	3%
Fugitive Dust	12,957	17,366	4,408	34%
WB Dust	5,401	5,401	0	0%
Total	**41,151**	**49,366**	**8,216**	**20%**

$PM_{2.5}$ in the emissions inventory includes soil materials and other non-carbon, non-sulfate and non-nitrate particulate matter less than 2.5 microns in size. The primary sources are area and fugitive dust sources (agriculture, mining, construction, and unpaved and paved roads). Even though direct PM tailpipe emissions are relatively small they are accounted for as PM_{10} under mobile sources. Overall, the PM fine emissions show an increase of 20% by 2018.

Coarse Particulate Matter Emissions

Table 6-7 shows Washington PM_{10} emissions for the baseline year and the end of the first planning period. In the WRAP emission inventories PM_{10} is defined as particles between 2.5-10 microns in size and may be referred to as PM_{10}.

Table 6-7 Washington Coarse Particulate Matter Emission Inventories – 2002 and 2018

Washington Statewide Coarse Particulate Matter Emissions (tons/year)				
Source Category	**Plan02d**	**PRP18a**	**Net Change**	**% Change**
	2002	**2018**	**2018 - 2002**	**(2018-2002) / 2002**
Point	6,244	5,742	-502	-8%
Area	2,083	4,117	2,033	98%
On-Road Mobile	1,079	1,089	10	1%
Anthropogenic Fire	806	547	-259	-32%
Natural Fire	3,856	3,856	0	0%
Road Dust	26,044	26,642	598	2%
Fugitive Dust	66,704	105,007	38,303	57%
WB Dust	48,612	48,612	0	0%
Total	**155,430**	**195,613**	**40,184**	**26%**

PM_{10} emissions are significantly greater than $PM_{2.5}$ in Washington. Substantial increases in PM_{10} emissions are seen in fugitive dust and area sources. This is due to the fact that construction and emissions from paved and unpaved roads are tied to population growth and vehicle miles traveled. Overall, PM_{10} emissions are estimated to increase by 26% in 2018.

Ammonia Emissions

Table 6-8 shows Washington NH_3 emissions for the baseline year and the end of the first planning period.

Table 6-8 Washington Ammonia Emission Inventories – 2002 and 2018

Washington Statewide Ammonia (NH_3) Emissions (tons/year)				
Source Category	**Plan02d**	**PRP18a**	**Net Change**	**% Change**
	2002	**2018**	**2018 - 2002**	**(2018-2002) / 2002**
Point	3,863	5,466	1,603	41%
Area	45,218	47,769	2,551	6%
On-Road Mobile	5,211	7,086	1,874	36%
Off-Road Mobile	57	73	15	27%
Anthropogenic Fire	3,439	2,398	-1,040	-30%
Natural Fire	1,265	1,265	0	0%
Total	**59,054**	**64,057**	**5,003**	**8%**

Emission estimates for NH_3 have a high degree of uncertainty associated with them, based on a high variability in emission factors, wide range of activities, and lack of a uniform emission methodology. However, NH_3 emissions are important in that they react with SO_2 and NO_x to form sulfate and nitrate particles which are significant contributors to visibility impairment.

NH_3 emissions come from agricultural related activities, primarily livestock operations and farming fertilizer applications. WRAP has categorized these as either point or area sources.

The area source emission inventories for NH_3 have two components:

1. Emissions reported by the state and
2. Meteorologically driven fugitive emissions based on land use

Washington reported 4,470 tons/year of area source emissions in 2002. In 2018, the state reported portion is estimated to be 7,021 tons/year.

Based upon the work done by the Modeling Forum, WRAP estimated 40,748 tons/year of meteorologically driven fugitive emissions based on land use. This number was held constant in 2002 and 2018. Some of the fugitive emissions may have already been accounted for in the state reported portion resulting in double counting of NH_3 emissions.

Improvements in developing ammonia inventories are needed in the near future to develop more effective RH strategies. Along with an improved emission inventory, a better understanding of the chemistry in forming SO_4 and NO_3 is needed for RH planning.