Appendices to:

"Review of the Washington State Visibility Protection State Implementation Plan
~ *Final Report* ~"

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Appendix A

2002 Visibility SIP Progress Review Work Plan and the SIP Review Requirements

2002 VISIBILITY SIP PROGRESS REVIEW WORK PLAN April 4, 2002

Background
The visibility State Implementation Plan (SIP) provides for a periodic review (herein referred to as "progress review") of the long-term strategy. The state must provide a report to the public and EPA on progress towards the national visibility goal. The progress review report includes an assessment of the SIP progress review reporting requirements. This is a phase I visibility progress review, not a regional haze progress review.

Based on recommendations contained in Ecology's 1997 progress review (Ecology publication 97-206, April 1997) several revisions to the visibility SIP were submitted to EPA in September 1999 (Ecology publication 99-211, September 1999). Included in the 1999 SIP revision submittal were several changes pertaining to the SIP progress review reporting requirements. Of the 11 original reporting requirements contained in the March 1985 SIP, three were removed, two were combined with other requirements and one requirement was added.

This work plan addresses the revised list of requirements. The revised reporting requirements are:

1. The progress achieved in remedying existing impairment of visibility in any mandatory class I federal area.
2. The ability of the long-term strategy to prevent future impairment of visibility in any mandatory class I federal area.
3. Any change in visibility since last report.
4. Additional measures, including the need for SIP revisions, that may be necessary to assure reasonable progress toward the national visibility goal.
5. The progress achieved in implementing BART and meeting other schedules set forth in the long-term strategy.
6. The impact of any exemption from BART. (new)
7. The need for BART to remedy existing visibility impairment of any integral vista listed in the plan since the last report.

Note: See the end of this work plan for a brief summary of the review requirements that were removed or combined.

Consultation with Federal Land Managers
Ecology is required to consult with Federal Land Managers (FLM) during the progress review process. This draft work plan serves as the initial consultation with the FLM. The FLM have appointed representatives to serve on a progress review work group. In addition, Ecology invited the Washington State Department of Natural Resources and the

Environmental Protection Agency to participate and those agencies have appointed representatives to serve on the work group.

General stakeholders will be informed of the process, timeline, and draft/final reports through the Visibility Improvement Efforts in Washington advisory committee (VIEW). A draft progress review report will be released for review by the FLM and other interested parties near the end of this process.

Timeline

- January 2002 - Develop draft work plan.
- March 25, 2002 - Meet with FLM and EPA to finalize work plan.
- May 31, 2002 - Complete technical assessments and provide draft write-ups to Frank Van Haren.
- July 15, 2002 - Complete FLM progress review draft report and release to FLM, EPA and VIEW committee.
- August 30, 2002 - Deadline for comments on FLM progress review draft.
- October 15, 2002 - Complete progress review final report and release to FLM, EPA, VIEW and the public.

WORK PLAN

This work plan is divided into two parts. Part I covers SIP review requirements 1 – 4, that entail certain technical analyses. Part II covers SIP review requirements 5 – 7, that are more policy oriented or do not entail any specific sort of technical analysis.

PART I – SIP Review Requirements 1 through 4

The following is a description of the analysis that Ecology deems necessary to satisfy the reporting requirements.

1. The progress achieved in remedying existing impairment of visibility in any mandatory Class I federal area.

This is essentially an assessment and documentation of progress made to date. This assessment will be made using available class I area visibility aerosol monitoring data from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network and source emission data as described below. Trends in these data will be presented for the periods noted below.

a) Monitoring Data Analysis

Analysis will be limited to class I area monitoring sites having a minimum of three years of consecutive data available for developing fine mass and light extinction budgets, and five consecutive years for trends analysis.

IMPROVE aerosol data from Mt. Rainier National Park (Tahoma Woods) and Alpine Lakes Wilderness (Snoqualmie Pass) will be used for all analysis, unless otherwise noted.

These two sites are long-term (3+ years), year-round IMPROVE sites which have complete suites of aerosol data.

Since the draft work plan was released it has been discovered that data completeness for the Alpine Lakes site is significantly low. Essentially, only two years of data from the historical data set meet the completeness criteria outlined in the "Draft Guidance for Tracking Progress Under the Regional Haze Rule", USEPA, 9/27/01. That criteria is no less than 75% per year, 50% for any season and no more than 10 consecutive missing days in any season. Even after eligible data substitutions were made only the years 1997 and 1998 met the completeness criteria. Only those two years will be used in the analysis for Alpine Lakes.

Note: Four additional class I area IMPROVE sites have recently been established, but to date no data from these sites is available for analysis. Therefore, analysis will be limited to Mt. Rainier and Alpine Lakes. However, we will include a map and description of the expanded network.

Analysis to be conducted is as follows:

i) Fine Mass and Light Extinction Budgets. Annual and seasonal averages, best case (average of the best 20%) and worst case (average of the worst 20%) fine mass and light extinction will be reconstructed from the aerosol data using standard IMPROVE methodology as described in "Spatial and Seasonal Patterns and Temporal Variability of Haze and its Constituents in the United States: Report III", Malm et al, CIRA, CSU, May 2000. In addition, other applicable methods from the "Draft Guidance for Tracking Progress Under the Regional Haze Rule", USEPA, 9/27/01, will be used where appropriate (for instance, we will use the newly developed monthly f(rh) correction factors for calculating light extinction from aerosol species mass). The most recent overlapping three years of data from each site will be used (approximately 12/96 – 11/99). Due to data completeness problems at Alpine Lakes, the period 12/96 – 11/98 will be used for analysis of data from this site.

ii) Fine Mass and Light Extinction Trends. Only sites with at least five consecutive years of data will be used for trend analysis; therefore, only Mt. Rainier will be used. Years meeting the minimum data completeness requirement during the period 12/01/88 through 11/30/99 will be used for trend analysis at Mt. Rainier.

iii) If time allows, data from nearby out of state class I areas will be analyzed. Probable sites for this analysis are the Three Sisters Wilderness in Oregon and Glacier National Park in Montana. Analysis will be limited to light extinction budgets and trends for the worst case days.

b) Emission Source Data Analysis

An emission inventory will be developed on a year-round, state wide, county level for the years 1985 and 1996. This data will be used to determine if there has been any emission changes (decrease or increase) between 1985 and 1996. This information in conjunction with monitoring data will serve as the measure of progress to date.

Data will be presented in a tabular format by source category and season, and by source category and county. The following source and pollutant categories will be examined:

Source Category	Pollutants
onroad mobile	SO_2, NOx, $PM_{10}/PM_{2.5}$, VOC
road dust, paved and unpaved	$PM_{10}/PM_{2.5}$
nonroad (excluding aircraft, locomotives)	SO_2, NOx, $PM_{10}/PM_{2.5}$, VOC
ships	SO_2, NOx, $PM_{10}/PM_{2.5}$, VOC
locomotives	SO_2, NOx, $PM_{10}/PM_{2.5}$, VOC
prescribed burning	SO_2, NOx, $PM_{10}/PM_{2.5}$, VOC
architectural coatings	VOC
consumer/commercial solvents	VOC
point sources	SO_2, NOx, $PM_{10}/PM_{2.5}$, VOC
woodstoves/fireplaces	SO_2, NOx, $PM_{10}/PM_{2.5}$, VOC
agricultural dust	$PM_{10}/PM_{2.5}$
agricultural burning	$PM_{10}/PM_{2.5}$, VOC
livestock	NH_3
fertilizer application	NH_3
biogenics	VOC, NOx
soils	NH_3

2. The ability of the long-term strategy to prevent future impairment of visibility in any mandatory Class I federal area.

a) The primary mechanism for assessing the ability of the long-term strategy to prevent future impairment is the analysis of emission projections for the year 2018, which will then be compared to 1996 levels. Changes in the emission levels between these two years will be the primary measure of future progress. The same source categories and pollutants as described in review requirement 1 will be used.

b) Provide a general discussion of the anticipated effect of other ongoing air quality programs on visibility. This will include a discussion of such programs like Reasonably Available Control Technology, Smoke Management, Prevention of Significant Deterioration, New Source Review, Best Available Control Technology, Best Available Retrofit Technology, efforts to maintain the ozone and particulate matter standards, regional haze SIP development, national programs for reducing mobile emissions and any other programs that will reduce visibility impairing emissions.

3. Any change in visibility since the last report.

Same as review requirement 1. Because the period of available data since the last report is only two years instead of three, and because a minimum of five years is needed to ascertain trends, reviewing any change since the last report is, by itself, of limited value. However, the two additional years since the last report will be added to the trend analysis described in review requirement 1. The trend analysis will suffice to satisfy this review requirement.

4. Additional measures, including the need for SIP revisions, that may be necessary to assure reasonable progress toward the national visibility goal.

If the progress demonstrations conducted under review requirements 1 and 2 indicate reasonable progress has not been made or, more importantly, will not be made in the future, then additional control measures may need to be developed. Control measure development should be done during the SIP ***revision*** phase of the review/revision couplet. However, to begin that process the state needs to know what source categories and source regions are contributing to visibility impairment in class I areas. This necessitates that some level of modeling analysis be conducted concurrently with the progress demonstrations. Analysis to be conducted is as follows:

a) Trajectory analysis of the worst case days at Mt. Rainier and Alpine Lakes will be conducted to identify potential source regions.

b) Trajectories will be developed for additional class I federal areas on a seasonal and annual basis.

c) If time allows, emissions projections for each county will be conducted in an attempt to identify counties where potential future problems may be anticipated. Projections will be made for the year 2018. This information combined with trajectory analysis will help focus attention on regions and sources that may have the potential to contribute to future visibility impairment in class I areas.

d) We will provide a summary of activities, progress and any results from work being conducted by the Pacific Northwest Regional Technical Center.

e) We will provide a summary of the results of the recent cumulative impact analysis conducted by the Bonneville Power Administration.

PART II – SIP Review Requirements 5 through 7

The following is a description of requirements 5 through 7 and the work necessary, if any, to satisfy these requirements.

5. The progress achieved in implementing BART and meeting other schedules set forth in the long-term strategy.

a) No BART determinations have been made. However, emission controls being placed on the Centralia Power Plant are considered to be better than BART. An overview of the process that led to these emission controls will be provided and progress in installing the control technology will be reported.

b) States are required to develop a list of BART eligible sources for the upcoming Regional Haze SIP. Although the development of the list is **not** a requirement for this Phase 1 SIP progress review, Ecology will begin developing the list and will report on progress to date.

6. The impact of any exemption from BART.
No exemptions from BART have been granted. No work is necessary for this review requirement.

7. The need for BART to remedy existing visibility impairment of any integral vista listed in the plan since the last report.
The FLM did not formally list any integral vistas or finalize its proposed list by the federal deadline of December 31, 1985. The state proposed removing the list of integral vistas in their 9/99 SIP revision submittal (see discussion below). In fact, for the same reason the list of integral vistas was removed, the state will propose removing this requirement in its next SIP revision. No work is necessary for this review requirement.

SIP REVIEW REQUIREMENTS THAT WERE REMOVED OR COMBINED WITH OTHER REQUIREMENTS PER THE 9/99 SIP REVISION SUBMITTAL

The following SIP progress review requirements were removed or combined with others as part of the visibility SIP revision submitted to EPA in September 1999. EPA is still reviewing that submittal.

Review of additional proposed integral vistas, if any, and adoption into the SIP of those meeting the selection requirement (old requirement 7, removed).
Since the deadline for selecting integral vistas under the federal visibility regulations is past, no additional integral vistas can be proposed. Because the Assistant Secretary, Fish and Wildlife and Parks, Department of the Interior (the delegated FLM for the NPS and FWS) chose not to finalize the original proposed list, but rather rely on existing coordination procedures (through other air quality programs like NSR and PSD), the state determined that the proposed list should be removed from the SIP. Removal of the old proposed list and the removal of this SIP review requirement were recommended in the state's 9/99 SIP revision submittal.

Review of projected impacts to visibility in any class I area from any proposed new major stationary source or major modification (old requirement 8, removed).
Review of projected impacts to visibility from new major stationary sources or major modifications is conducted on an ongoing, case-by-case basis under the NSR/PSD program. Ecology, in its April 1997 SIP Review Final Report - section 8.6, concluded that SIP review requirements 8 and 9 (described as H and I in that report) derive from 40 CFR 51.306(d) and were mistakenly included by the authors of the original SIP as part of

40 CFR 51.306(c) SIP review requirements. The state proposed in its 9/99 SIP revision submittal that this requirement be removed.

Review of impacts any new major stationary source or major modification may have on visibility in any class I area (old requirement 9, removed).
Same as review requirement 8.

Progress in decreasing impacts from prescribed forestry burning, including rescheduling, utilization and emission reduction programs (old requirement 10, now combined with requirements 1 and 2).
Changes in emissions from prescribed burning will be assessed through the emission source data analysis conducted as part of SIP review requirements 1 and 2. A general discussion of barriers and incentives to utilization will be assessed and discussed under SIP review requirement 2 as part of the Smoke Management discussion.

Discussion of incentives such as tax credits and low-cost loans to promote utilization, and legal aid to change or modify blocking legislation (old requirement 11, now combined with requirement 2).
At the time of the original visibility SIP, one barrier to increased utilization of forest slash was a lack of a profitable market for biomass. Tax credits, low-cost loans and revised legislation were recognized as means to promote these types of markets. Although barriers to utilization still exist, they are not limited to the lack of tax credits, low-cost loans and legal aid to change blocking legislation (see section 5.4.1 of the April 1997 SIP Review Final Report). In the state's 9/99 SIP revision submittal, it was recommended that this requirement be removed and that an overall assessment and discussion of barriers and incentives to utilization be conducted under SIP review requirement 2.

Appendix B

Emissions Inventory Details and Methodology

May 2002

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1 Introduction

A statewide emissions inventory was constructed to support a review of the Visibility SIP in 1999. Major sources of the following visibility impairing pollutants were addressed: primary particulate matter (PM_{10} and $PM_{2.5}$), sulfur dioxide (SO_2), nitrogen oxides (NOx), volatile organic compounds (VOC), and ammonia (NH_3). Estimates were made by county and month for the years 1985, 1996, and 2010. 1985 was the base year of the original Visibility SIP; 1996 was the year of the most current emissions inventory, and 2010 was a future projection.

For this SIP review, 1985 and 1996 were retained as the original base year and most current year of emissions, respectively. The projection year was changed to 2018 in an effort to align the SIP review effort with requirements of the upcoming regional haze SIP. Time did not allow a complete update of the emissions inventory. Many sources were not updated, except to update the projection year from 2010 to 2018. In some cases, this produced inconsistencies in underlying data, such as using different land cover datasets, or different meteorological stations to define county meteorological parameters. These inconsistencies are not expected to influence statewide emissions greatly. A more comprehensive update of the emissions inventory will be done for the upcoming regional haze SIP.

The updates and improvements made to the inventory for this review were:

- Added carbon monoxide to the reported pollutants
- The onroad mobile inventory for VOC, NOx and CO was recalculated using EPA's latest model (MOBILE6) for all inventory years.
- Onroad PM/SO_2/NH_3 inventories for 1996 and 2018 prepared by Environ under contract to the Western Regional Air Partnership (WRAP) for regional haze SIP inventory development were substituted for those prepared for the 1999 SIP review.
- Nonroad inventories for 1996 and 2018 prepared by Environ under contract to the Western Regional Air Partnership (WRAP) for regional haze SIP inventory development were substituted for those prepared for the 1999 SIP review. The WRAP inventory also included additional nonroad sources such as aircraft.
- Ship emissions for the Columbia and Snake Rivers were added based on a special study done through and for the Northwest Regional Technical Center
- Locomotives and agricultural burning emissions estimates were added.
- An error in 1985 paved road dust emissions was corrected
- Woodstove projection to 2018 was based on a new survey
- Ammonia emission rates from soil and livestock operations were updated
- Minor updates and corrections throughout the documentation

Sources and pollutants included in the inventory are shown in Table 1-1 below.

Table 1-1: Sources and Pollutants Inventoried

Source Category	**Pollutants**
Onroad Mobile Sources	**SO_2, NOx, PM_{10}/$PM_{2.5}$, VOC, CO, NH_3**
Road Dust, Paved and Unpaved	**PM_{10}/$PM_{2.5}$**
Nonroad Mobile Sources (nonroad equipment and vehicles, aircraft, marine vessels)	**SO_2, NOx, PM_{10}/$PM_{2.5}$, VOC, CO, NH_3**
Nonroad Mobile Sources (locomotives)	**SO_2, NOx, PM_{10}/$PM_{2.5}$, VOC, CO**
Prescribed Burning	**SO_2, NOx, PM_{10}/$PM_{2.5}$, VOC, CO**
Agricultural Field Burning	**SO_2, NOx, PM_{10}/$PM_{2.5}$, VOC, CO**
Solvent Usage (architectural coatings and consumer/commercial solvents)	**VOC**
Point Sources	**SO_2, NOx, PM_{10}/$PM_{2.5}$, VOC, CO**
Woodstoves/Fireplaces	**SO_2, NOx, PM_{10}/$PM_{2.5}$, VOC, CO**
Agricultural Dust (tilling and windblown)	**PM_{10}/$PM_{2.5}$**
Livestock	**NH_3**
Fertilizer Application	**NH_3**
Biogenics	**VOC, NOx**
Soils	**NH_3**

The remainder of the inventory documentation is divided into two sections: emissions estimation methods, and emissions summaries.

2 Emissions Estimation Methods

To estimate emissions, seven basic tasks were completed for each source category. The six tasks were: 1) estimate the 1996 activity level, 2) adjust/allocate the 1996 activity (or emissions) temporally, 3) allocate the 1996 activity (or emissions) spatially, 4) estimate 1996 emission rates per the activity, 5) estimate 1985 emission rates, 6) estimate 2018 emission rates, and 7) provide qualitative observations. The tasks are described below for each source category.

2.1 Onroad Mobile Sources

Onroad mobile source emissions are those generated by operating vehicles on public roadways. Emissions from fuel combustion and evaporation, and brake and tire wear were estimated.

Activity Level

The activity measurement for onroad mobile sources is the number of miles driven. The units are typically given in average daily vehicle miles traveled (ADVMT). ADVMT is normally estimated from traffic counts collected over a sampling area, or through use of travel demand models, which simulate vehicle travel patterns based on demographic and economic parameters. Travel demand models are validated with traffic counts. For this inventory, ADVMT was estimated through use of the national Department of Transportation's Highway Performance Monitoring System (HPMS) as obtained from the Washington State Department of Transportation (WSDOT).[1] HPMS is a system of traffic counts collected over several sampling areas. Roads are classified into one of twelve functional classifications (e.g. interstate, arterial, collector). There are sampling areas for several large urban areas, rural areas and small urban areas. The ADVMT calculated for each of the sampling areas is valid over the entire area for each functional classification. More detailed data is available for areas with local transportation planning departments, but for consistency, HPMS was used for all areas.

Temporal Adjustments

WSDOT provided monthly ADVMT adjustment factors for the 1990 carbon monoxide and ozone nonattainment area base year inventory efforts.[2] The factors were compared to similar data for 1994[3] and showed very little change. The WSDOT adjustment factors were multiplied by the ADVMT estimates and the number of days per month to estimate total monthly VMT.

Table 2-1: WSDOT Monthly VMT Adjustment Factors

Month	Adjustment		Month	adjustment
Jan	0.896		Jul	1.072
Feb	0.922		Aug	1.096
Mar	0.982		Sep	1.029
Apr	1.009		Oct	1.004
May	1.019		Nov	0.963
Jun	1.061		Dec	0.951

Spatial Adjustments

ADVMT estimates by county were required, but the HPMS sampling areas did not coincide with county boundaries. WSDOT makes estimates of county ADVMT by functional classification from HPMS,[4, 5] although they caution that they do not carry the same validity that the HMPS data by sampling area does. The WSDOT estimates were used in this inventory.

Table 2-2: 1996 County ADVMT in thousands

County	ADVMT		County	ADVMT
Adams	1,099		Lewis	2,455
Asotin	315		Lincoln	894
Benton	3,456		Mason	1,032
Chelan	2,235		Okanogan	1,187
Clallam	1,315		Pacific	538
Clark	6,648		Pend Oreille	389
Columbia	211		Pierce	14,254
Cowlitz	3,576		San Juan	44
Douglas	1,007		Skagit	3,099
Ferry	535		Skamania	223
Franklin	1,284		Snohomish	13,171
Garfield	159		Spokane	7,803
Grant	2,373		Stevens	934
Grays Harbor	1,419		Thurston	4,666
Island	1,270		Wahkiakum	95
Jefferson	733		Walla Walla	1,208
King	39,885		Whatcom	3,822
Kitsap	4,011		Whitman	1,058
Kittitas	2,493		Yakima	4,453
Klickitat	958		***STATE TOTAL***	***136,307***

Emission Rates - VOC, NOx and CO

The Environmental Protection Agency's (EPA) MOBILE model (version 6) was used to generate emission rates for NOx, CO, and VOC in grams per mile. EPA used data collected from different categories of vehicles under different operating conditions to develop the model. The model is continuously updated as new information is gathered. The model may be tailored to account for local conditions. Local parameters were used for speed, inspection and maintenance (I/M) programs, fuel specifications, meteorological parameters, and vehicle fleet characteristics. The MOBILE6 input parameters are described in reference 6 for all of the inventory years. Specific considerations for this review are detailed below.

Speed

Speeds were chosen to correspond to the HPMS facility and vehicle types as described in reference 6.

Inspection and Maintenance (I/M) Program

Vehicle Inspection and Maintenance (I/M) programs are operated in the Puget Sound, Spokane and Vancouver regions. The programs began in different years for each area, and experienced various changes over the years. Vehicle Inspection and Maintenance (I/M) program parameters for MOBILE6 are described in reference 6.

MOBILE6 emission rates in grams per mile for each of the I/M areas are combined with estimates of VMT to calculate emissions. The I/M program areas are defined by zip codes, and do not encompass entire counties. ADVMT subject to the I/M program for each applicable county is listed in the table below. The percentages were taken from local transportation planning agency link-level data.[7, 8, 9]

Table 2-3: I/M Program ADVMT Percentages

Program	Clark	King	Pierce	Snohomish	Spokane
no I/M program	34	11	20	29	27
I/M start year 1982-85	n/a	69	n/a	28	73
I/M start year 1993	66	20	80	42	0

A further adjustment was made to the I/M ADVMT to account for travel inside of the I/M area from vehicles registered outside of the testing area. Percentages of outside VMT for each I/M area are: 17.1% (King, Pierce, Snohomish), 22.5% (Spokane), and 28.5% (Clark).[10, 11]

Fuel Specifications

Reid vapor pressure (RVP), oxygenated fuel programs, and fuel sulfur content are fully described in reference 6.

Meteorological Parameters

Average meteorological parameters by month and county were established for general emissions inventory work as described in reference 6. The parameters included minimum daily temperature, maximum daily temperature, and daily humidity.

Vehicle Fleet Characteristics

Vehicle fleet characteristics include VMT fractions by vehicle type, vehicle fleet age distribution, and diesel sales fractions. All are described in reference 6.

Month and Year of Evaluation

The MOBILE model can calculate emission factors that represent a January 1 or July 1 registration distribution. Jan-Mar was modeled as a January 1 distribution; Apr-Dec was modeled as July 1.

Special Consideration for Buses in the PART5 Model

Bus emission factors were calculated for both transit and central business district travel. They were applied to ADVMT per NET guidance: all rural, urban interstates, and urban freeway/expressways were modeled as transit; all other VMT was assumed central business district.

Emission Rates - PM_{10}, $PM_{2.5}$, SO_2 and NH_3

During the writing of this report, MOBILE6.1 became available in draft form. MOBILE6.1 allows calculation of PM_{10}, $PM_{2.5}$ and SO_2 emission rates. It does not represent a major update to the current PM/ SO_2 model, PART5, but it does include updates to reflect new particulate regulations that came into effect since the PART5 model was released.[12]

Time did not allow use of the draft MOBILE6.1 to calculate PM_{10}, $PM_{2.5}$ and SO_2 emission rates; however, emissions estimates calculated using information in MOBILE6.1 were available for each county and season from the Western Regional Air Partnership (WRAP). The WRAP calculated estimates for regional haze modeling in the western states. The WRAP also made estimates of NH_3 that were incorporated into this inventory.

1985 Methodology

The methods used to estimate emissions for 1985 were the same as for 1996, except for PM_{10}, $PM_{2.5}$, SO_2 and NH_3. Emission rates for PM_{10}, $PM_{2.5}$ and SO_2 were generated with the EPA model PART5[13] because the WRAP did not estimate emissions for 1985. Estimates of NH_3 were calculated by multiplying 1996 WRAP NH_3 emissions by the ratio of 1985 VMT to 1996 VMT.

ADVMT was back cast to 1985 using WSDOT information.[14] It was approximately 70% of the 1996 ADVMT.

2018 Methodology

The methods used to estimate emissions for 2018 were the same as for 1996. King, Kitsap, Pierce and Snohomish Counties' ADVMT were projected to increase by 40% from 1996. Clark County ADVMT was projected to increase by 69%, Spokane County by 57% and Thurston County by 77%. All other counties' ADVMT were assumed to increase by 42%. The projections were made using a combination of local transportation planning agency and WSDOT ADVMT projection information.[15, 16, 17, 18, 19]

For I/M, it was assumed that tailpipe testing was no longer in operation. Only on-board diagnostic (OBD) testing was modeled.

Observations

MOBILE6 is new, and produces results that differ significantly from previous versions of the model. Every attempt was made to use as much local data as possible in the model. Results obtained were similar to those modeled by Environ under contract to the Western Regional Air Partnership for Regional Haze SIP development. Comparison to MOBILE5b showed results similar to those shown in reference 20.

PM and SO_2 estimates were made by WRAP for 1996/2018 and by Ecology for 1985. Differences in methods and county ADVMT allocations will result in difference in the emissions estimates, so care should be taken in comparisons.

2.2 Paved Road Dust

Dust emissions are generated as vehicles pass along the roadways and disturb the layer of loose material on or near the road surface. This material contains particulate matter from soil, brake and tire wear, exhaust, and other substances. Since emissions from exhaust and brake and tire wear were calculated under the onroad mobile source category, they were subtracted from the paved road dust totals to avoid double-counting of emissions.

Activity Level, Temporal Adjustments, Spatial Adjustments

The measure of activity, and temporal and spatial adjustments for paved road dust emissions calculations are identical to those discussed under the category "Onroad Mobile Sources."

Emission Rates

A study prepared for WSDOT examined paved road dust PM_{10} emissions using a tracer technique and compared the results to the AP42 (PART5) equation.[21, 22] The study found that for unsanded paved roads, a better prediction of emissions could be obtained using an equation dependent on humidity levels. Paved road dust emissions in g/mi were estimated according to the study formula:

$2.83584 - 0.036H$ where H = % relative humidity, $10\% < H < 70\%$

$PM_{2.5}$ was estimated by multiplying PM_{10} emissions by 0.25, the ratio of $PM_{2.5}$ to PM_{10}, given in table 4.8-1 of the NET documentation.[23]

Humidity can vary greatly, even within the same hour. Long-term relative humidity for SeaTac, Yakima, Quillayute, and Spokane were used for the calculations. County assignments are shown below.[24] Values are shown in the table below. All values over 70% were set to 70% in the dust calculation.

SeaTac AP: Clark, Cowlitz, Island, King, Kitsap, Lewis, Pierce, San Juan, Skagit, Snohomish, Thurston, Whatcom
Quillayute: Clallam, Grays Harbor, Jefferson, Mason, Pacific, Skamania, Wahkiakum
Yakima AP: Adams, Benton, Douglas, Franklin, Grant, Lincoln, Yakima
Spokane AP: Asotin, Chelan, Columbia, Ferry, Garfield, Kittitas, Klickitat, Okanogan, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman

Table 2-4: Relative Humidity, (10am, 4 pm averages)

Month	Yakima	Spokane	SeaTac	Quillayute
Jan	75	82	77	87
Feb	65	75	72	82
Mar	48	62	68	77
Apr	38	51	65	72
May	35	46	61	70
Jun	35	43	60	71
Jul	31	35	57	70
Aug	34	36	59	72
Sep	38	43	65	72
Oct	49	57	73	80
Nov	68	80	78	87
Dec	78	85	79	89

1985 and 2018 Methodology

No changes were made to the methodology to estimate emissions for 1985 or 2018. ADVMT estimates were the same as those used in the category "Onroad Mobile Sources."

Observations

The method used was developed in Spokane. Application to the wetter climate west of the Cascades may not be appropriate. Several of the monthly humidity values exceed the equation's upper boundary. The significance of changing these values to 70% has not been determined. All that can be concluded is that the emissions estimates are an upper boundary with respect to the equation.

There are different methods being employed in Washington to estimate emissions from paved roads. Particulate matter state implementation plans for Spokane, Puget Sound areas, and Thurston County all used different methods for calculating emissions from paved roads. The methods include the method used here, use of CMB-source apportionment information, and some measurement data. All agree that the current EPA equation provides an estimate that is too high. Current efforts by EPA and the Western Regional Air Partnership should be examined in the future.

2.3 Unpaved Road Dust

Dust emissions are generated as vehicles pass along unpaved roadways and disturb the layer of loose material on or near the road surface. This material contains particulate matter from soil, brake and tire wear, exhaust, and other substances. Emissions from exhaust, brake and tire wear are only a minute portion of the total particulate emissions from unpaved roads, so effort was not made to subtract them from the unpaved road dust totals.

Activity Level

Similar to onroad mobile sources and paved road dust, the measure of activity for unpaved road dust emissions calculations is ADMVT. Travel over unpaved roads is included in HPMS ADVMT estimates, but cannot be separated from the paved road travel. Several agencies were contacted to obtain ADVMT on unpaved roads. The County Road Administration Board (CRAB) provided roadway mileage and ADVMT estimates for each county for three surface types: unimproved, graded and drained, and gravel.[25] For this study, the unimproved and graded types were combined and classified as "dirt" to match the emission factor equation below. WSDOT provided estimates of city jurisdiction roadway mileage for each county for two surface types: dirt and gravel.[26] The CRAB data was used to develop an ADVMT per lane-mile factor. The factor was multiplied by the WSDOT city lane-mileage data in order to estimate ADVMT.

Total ADVMT for both county and city jurisdictions are shown in the table below. Because ADVMT over unpaved roads was included in HPMS, it is essentially being double counted under paved roads; however, unpaved ADVMT is only 0.8% of the total ADVMT, so it will not be a serious error.

Table 2-5: ADVMT by Surface Type – County and City Jurisdiction

County	Gravel	Dirt		County	Gravel	Dirt
Adams	41,002	2,206		Lewis	4,684	160
Asotin	8,169	630		Lincoln	49,195	2,266
Benton	7,535	1,704		Mason	6,418	325
Chelan	4,113	2,174		Okanogan	28,644	3,300
Clallam	2,481	15		Pacific	4,374	92
Clark	7,153	303		Pend Oreille	20,572	2,754
Columbia	4,169	583		Pierce	6,309	632
Cowlitz	555	394		San Juan	1,927	75
Douglas	79,978	33,211		Skagit	4,746	180
Ferry	21,756	9,922		Skamania	2,227	313
Franklin	30,784	534		Snohomish	8,297	471
Garfield	15,178	1,763		Spokane	164,878	16,592
Grant	66,954	8,527		Stevens	54,712	1,940
Grays Harbor	8,606	566		Thurston	5,634	17
Island	617	145		Wahkiakum	2,604	190
Jefferson	6,187	2,124		Walla Walla	12,642	1,713
King	75,642	1,326		Whatcom	8,634	950
Kitsap	1,658	1,221		Whitman	106,430	39,980
Kittitas	3,438	852		Yakima	83,856	1,175
Klickitat	22,147	2,138		***STATE TOTAL***	***984,907***	***143,463***

ADVMT was distributed to twelve vehicle classes as identified in the PART5 model.

Table 2-6: PART5 1996 ADVMT Mix

Vehicle Type	%ADVMT	Vehicle Type	%ADVMT
Gasoline car	63.2	Light diesel truck	0.1
Light gasoline truck1	17.6	Diesel truck2B	1.2
Light gasoline truck2	8.9	Light heavy duty diesel truck	0.1
Heavy duty gasoline truck	2.7	Med. heavy duty diesel truck	1.5
Motorcycle	0.5	Heavy heavy duty diesel truck	3.5
Diesel car	0.4	Bus	0.4

Temporal Adjustments

The monthly adjustments used for the category "Onroad Mobile Sources" were also used to make monthly adjustments to travel over unpaved roads

Spatial Adjustments

Spatial adjustments were not necessary since the ADVMT was available by county.

Emission Rates

Unpaved road dust was estimated according to the equation in AP42.[22] The equation assumes that emissions occur on days where the rainfall is below 0.01 inches when taken as an annual average. The NET guidance assumed that the equation was also valid on a monthly basis.[23] The approach taken here was to develop emission factors for an individual day where rainfall is below 0.01 inches. The resulting factors were multiplied by each month's total number of days where rainfall was less than 0.01 inches. This basically follows the NET assumption that the equation is valid on a monthly basis. The AP42 equation is shown below, minus the rainfall adjustment.

$$E = k\,(5.9)\,(s/12)\,(S/30)\,(W/3)^{0.7}\,(w/4)^{0.05}$$

where E is the emission factor in lbs/mi
k = particle size multiplier (1 = TSP, 0.36 = PM_{10}, 0.054 = $PM_{2.5}$*)
s = silt content of surface (%) (dirt = 12%, gravel = 8.9%, AP42)
S = mean speed (mph)
W = mean vehicle weight (tons)
w = mean number of wheels
* PM25 fraction from NET guidance, table 4.8-1[23]

Emission factors were calculated for each vehicle type using vehicle weight and number of wheels from the PART5 User's Manual.[27] It was assumed that most unpaved roads are classified as rural collectors.[28] The NET recommended speeds for urban and rural local roads were averaged and used for all calculations (25 mph).[23]

Table 2-7: Vehicle Weight in Pounds and Number of Wheels

Vehicle	weight	wheels		vehicle	weight	wheels
Gasoline car	2500	4		Light diesel truck	6000	4
Light gasoline truck1	5500	4		Diesel truck2B	9000	4
Light gasoline truck2	9000	4		Light heavy duty diesel truck	15000	6
Heavy duty gasoline truck	20000	6		Med. heavy duty diesel truck	35000	6
Motorcycle	1000	2		Heavy heavy duty diesel truck	55000	18
Diesel car	2500	4		Bus	55000	4

Days of precipitation greater than 0.01 inches by month were obtained for four meteorological stations for 1996: SeaTac AP, Spokane AP, Yakima AP, and Aberdeen/Hoquiam.[29, 30] Analysis of precipitation maps and long-term averages suggested that estimates for some eastern and central Washington counties could be improved by using additional stations.[31] While long-term averages were available, 1996 was not easily available for the additional stations.

To estimate 1996 values for the additional stations, the number of days per month in 1996 greater than or equal to 0.01 inches of precipitation for Spokane and Yakima were compared to their long-term averages to develop a ratio of 1996 data to long-term average data. The ratios were multiplied by the long-term averages of the additional stations to derive an estimate of 1996 data. The Spokane station was used with other eastern Washington areas; Yakima was used with other central Washington areas. County assignments to rainfall areas, and number of days greater than or equal to 0.01 inches are listed below.

Emissions were calculated by multiplying the emission factors by ADVMT per vehicle type and number of days of precipitation greater than or equal to 0.01 inches.

Primary Meteorological Stations:

SeaTac AP: Clark, Cowlitz, Island, King, Kitsap, Lewis, Pierce, San Juan, Skagit, Snohomish, Thurston, Whatcom
Aberdeen: Clallam, Grays Harbor, Jefferson, Mason, Pacific, Skamania, Wahkiakum
Yakima AP: Adams, Benton, Douglas, Franklin, Grant, Lincoln, Yakima
Spokane AP: Pend Oreille, Spokane, Stevens, Whitman

Additional Stations:

Walla Walla/Pendleton: Asotin, Columbia, Garfield, Walla Walla
Cle Elum: Chelan, Kittitas
Mt. Adams/Dallesport: Klickitat
Republic/Winthrop: Ferry, Okanogan

Table 2-8: 1996 Days of Precipitation Greater Than or Equal to 0.01 Inches

Station(s)	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	year
Aberdeen	30	14	20	24	23	12	6	10	16	22	24	28	229
SeaTac	26	16	20	23	19	6	8	11	16	19	24	25	213
Spokane	24	16	14	20	15	10	5	8	13	18	18	21	182
Yakima	13	13	10	9	14	4	4	1	12	14	15	19	128
Walla Walla-Pendleton	22	16	14	20	13	9	3	7	12	19	17	19	170
Cle Elum	21	22	18	17	19	6	5	1	19	27	27	31	214
Mt Adams-Dallesport	19	20	17	13	16	4	4	1	15	22	25	27	184

Republic-Winthrop	17	12	9	13	13	10	5	8	12	14	14	16	144

1985 Methodology

Historical ADVMT for 1985 was not obtained. Unpaved road dust emissions for both 1985 and 2010 were held to the same level as in 1996. There was more traffic in 1996, but paving programs may have reduced or eliminated any corresponding increase in unpaved road travel.

2018 Methodology

Unpaved road dust was held to the same level as in 1996. While traffic is projected to increase, paving programs may reduce or eliminate any corresponding increase in unpaved road travel.

Observations

More recent methodologies should be explored in future efforts. On-going work for regional haze SIPs has generated information which should be examined.

Future efforts should also include unpaved roads near Class I areas. Some roads near Class I areas were not inventoried. The Western Regional Air Partnership has done work in this area. It should be examined for future efforts.

2.4 Nonroad Mobile Sources

In the last Visibility SIP Review, emissions were estimated using EPA's 1990 Nonroad study. The study is now more than 10 years old. EPA has developed a nonroad source emissions model (NONROAD) that has been available in draft form for several years. Because each county, year and season must be run separately in NONROAD, running the model for the requirements of this inventory would have been impractical. The source code has been released and could perhaps be altered to allow multiple scenarios, but this has not yet been done. Another source of estimates from NONROAD was available. The NONROAD model was used by the WRAP to calculate emissions for each county and season for regional haze modeling in the western states. WRAP estimated emissions for 1996 and 2018. They also included estimates for NH_3, which is not calculated in the draft NONROAD model. The WRAP inventories were used in this Visibility SIP Review inventory.

Temporal Adjustments

The WRAP seasonal inventories represented tons per seasonal weekday. They were adjusted to an average day using day-of-week allocation factors for individual source categories. The allocation factors were taken from a variety of sources.[32, 33, 34]

Spatial Adjustments

One adjustment was made to the WRAP inventory. It appears that the statewide total recreational boats are allocated to the county level by using county water surface area. The statewide totals were reallocated to counties based on county boating registration data, since this was thought to be a better representation of the spatial distribution of boats. Table below shows 1996 county estimates of population and boating registrations, respectively.[35, 36]

Table 2-9: County Population and Boat Registration Estimates, 1996

County	population	boats		County	population	boats
Adams	15,400	481		Lewis	66,700	2,235
Asotin	19,600	445		Lincoln	9,800	853
Benton	131,000	5,957		Mason	46,700	3,707
Chelan	61,300	3,244		Okanogan	37,500	1,283
Clallam	65,000	3,757		Pacific	21,100	1,020
Clark	303,500	9,330		Pend Oreille	11,100	592
Columbia	4,200	171		Pierce	665,200	21,449
Cowlitz	90,800	4,017		San Juan	12,400	1,859
Douglas	30,400	1,504		Skagit	95,500	6,143
Ferry	7,200	262		Skamania	9,800	281
Franklin	43,700	1,587		Snohomish	538,100	22,813
Garfield	2,400	126		Spokane	406,500	10,536
Grant	66,400	3,120		Stevens	36,600	2,213
Grays Harbor	68,200	3,005		Thurston	193,100	8,599
Island	70,300	4,025		Wahkiakum	3,800	286
Jefferson	25,700	1,892		Walla Walla	53,400	1,286
King	1,628,800	45,120		Whatcom	152,800	6,473
Kitsap	224,700	9,306		Whitman	41,000	761
Kittitas	30,800	973		Yakima	207,600	5,826
Klickitat	18,700	484		***STATE TOTAL***	***5,516,800***	***197,021***

1985 Methodology

The WRAP did not calculate emissions for 1985. Two statewide runs of NONROAD were made for 1985 and 1996: one with summer conditions and one with winter conditions. Emissions ratios of 1985 to 1996 were calculated for each pollutant using the sum of all nonroad sources. The ratio was multiplied by 1996 emissions to estimate 1985 emissions. Ammonia was not estimated by NONROAD. Ammonia emissions for 1985 were estimated from the 1996 emissions estimates using the 1985 to 1996 NOx ratio.

2018 Methodology

WRAP calculated emissions for 2018. They were utilized with the 1996 spatial adjustment to recreational boats listed above. The county spatial distribution for boats was assumed to be the same as in 1996.

Observations

A careful examination of NONROAD should be performed in the future to evaluate assumptions about equipment populations and spatial distribution. Results differed significantly from the prior 1990 Nonroad Study by EPA. The NONROAD model has not been finalized, and at this time it is expected that updates to the model will result in lower NOx emissions for 2018.

2.5 Ships

Two separate sources of information were used to estimates emissions from ships: one for emissions occurring on the Columbia and Snake River systems, and one for Puget Sound, Strait of Juan de Fuca and other coastal waterways.

For the Sound, Strait, and coastal waterways, emissions inventories prepared by the WRAP were used for this SIP Review inventory. The WRAP calculated emissions for each county and season for regional haze modeling in the western states. WRAP estimated emissions of all criteria pollutants and ammonia for 1996 and 2018. WRAP inventories for counties where the Columbia or Snake River was the predominant waterway were not used. The remainder of this section is a description of the ship emissions inventory over the river systems.

Activity Level and Emission Rates

A special project was undertaken through the Northwest Regional Technical Center (NWRTC) Demonstration Project to conduct an emissions inventory for ships (Corbett, 2001).[37] The main focus of the inventory was on ships traveling on the Columbia, Snake and Willamette Rivers. Emissions of NOx, SOx and PM were estimated for 1999 based on a bottom-up fuel consumption approach. PM_{10} and $PM_{2.5}$ were estimated using a particle size distribution.[38] Upper and lower bounds were established for the estimates. The estimates were provided by river segment consistent with segments reported in the US Army Corps of Engineers Waterborne Commerce publication. It was assumed that emissions in 1999 would be similar to those in 1996.

Temporal Adjustments and Spatial Adjustments

Emissions from ships were assumed to be uniform year-round.

For the Sound, Strait and coastal waters, the WRAP data was provided by county so no spatial adjustments were necessary. Emissions from ships on the rivers were assigned to counties using simple GIS methods. For this SIP Review, all emissions from ships on the Columbia River were assigned to Washington. Where the rivers passed between two Washington counties, one-half of the emissions were assigned to each county.

Observations

The river inventory only inventoried PM, SOx and NOx. In the future, other pollutants should be added.

1985 Methodology

Neither the WRAP nor Corbett reports back-cast emissions to 1985. Emissions were assumed to be the same as in 1996.

2018 Methodology

The WRAP projected emissions to 2018, and their estimates were used for this inventory for the Sound, Strait and coastal waters. The Corbett report did not project emissions for the river traffic. The WRAP ship emissions projection factors were used to project emissions from ships on the rivers.

2.6 Locomotives

A special project was undertaken through the Northwest Regional Technical Center (NWRTC) Demonstration Project to conduct an emissions inventory for locomotives for calendar year 1996. The Oregon Department of Environmental Quality (ODEQ) conducted the work for the three state region of ID, OR and WA. Emissions were calculated for line haul and switch yard locomotives on Class 1 and Class 2/3 railroads for each county in the region. Detailed methodology may be found in the NWRTC Demonstration Project documentation and ODEQ documentation.[39, 40] The methodology was based on EPA guidance.[41] A short description of the methodology is presented below.

Activity Level

Activity level is measured in gallons of diesel consumed by line haul and switch yard locomotives. The majority of the activity takes place on Class 1 railroads. Three Class 1 railroads operate in Washington: Burlington Northern Santa Fe (BNSF), Union Pacific (UP), and Amtrak. BNSF and UP provided fuel consumption. Amtrak fuel consumption was not available and was estimated using trip information with Amtrak locomotive fuel consumption rates.

Fuel consumption from Class 2 and 3 railroads was estimated using a combination of individual railroad data, EPA information, and other sources.

Temporal Adjustments

Locomotives were assumed to operate uniformly year-round per EPA guidance.[33]

Spatial Adjustments

Most of the activity information was obtained by county; therefore, no spatial adjustments were necessary. Where activity was not available by county, track mileage and trip information was used to assign activity to counties.

Emission Rates

Emissions rates were taken from EPA documents and staff.

1985 and 2010 Methodology

The inventory did not project or back-cast emissions. Emissions were assumed identical for all inventory years.

2.7 Point Sources

Point sources were defined to be all stationary sources classified as either air operating permit sources or synthetic minor sources. Air operating permit sources are sources with the potential to emit at levels greater than or equal to 100 tons per year of total suspended particulate (TSP), PM_{10}, SO_2, NOx, VOC, or CO. Synthetic minor sources are major sources that opt out of the Air Operating Permit Program by accepting federally enforceable emissions limits that ensure emissions below major source thresholds.

Two additions were made to the source list: Centralia Mining and Rayonier. Centralia Mining has emissions above major source thresholds for PM_{10}, but it is not an operating permit or synthetic minor source because of the fugitive nature of its emissions. Rayonier was not classified as an operating permit source since it was in the process of shutting down. Because it still operated in 1996, its emissions were retained for this inventory.

Point sources meeting the above criteria were selected from the 1996 Washington Emissions Data System (WEDS), the annual air emissions inventory database.

Activity Level and Emission Rates

Point source activity is reported in WEDS. Activity is measured by process throughput as defined by source classification category (SCC) code. Examples of activity measures are amount of fuel burned, and ton of product produced. Emissions may be estimated using direct source measurement (stack testing, continuous emissions monitoring), material balance, published emission factors (emissions rates per activity), or professional judgment.

The majority of total PM, SO_2 and NOx emissions were estimated through direct measurement in 1996. VOC emissions were estimated mainly by use of emission factors. PM_{10} is normally not measured, but is calculated from published particle size distributions applied to total particulate measurements.

WEDS does not include emissions estimates for $PM_{2.5}$. $PM_{2.5}$ emissions were estimated using a computer look-up program distributed by the EPA, called PM Calculator.[42] The program uses the combination of source classification category (SCC) code and primary/secondary control equipment codes to estimate both PM_{10} and $PM_{2.5}$ emissions. The program makes use of particle size distributions by SCC code and control equipment efficiencies at each of several particle size classes.

Temporal Adjustments

All point sources were assumed to operate uniformly throughout the year.

Spatial Adjustments

No spatial adjustments were necessary. All sources were identified by county, and more specifically, by geographic coordinates.

1985 Methodology

The operating permit program did not exist in 1985. The source list for 1985 was selected from the 1985 WEDS. The list consisted of the intersection of the 1996 list and the complete 1985 inventory database, plus all other sources at or above the major source thresholds. Feedlots were originally selected, but were eliminated from consideration due to a recent change in emission factors that if applied to the 1985 data, would result in 1985 emissions less than 100 tons.

1n 1985, there were no $PM_{2.5}$ estimates, and incomplete PM_{10} estimates. The PM Calculator was used to calculate both PM_{10} and $PM_{2.5}$ as percentages of total PM for all sources.

A change was made to the NOx emissions estimates for the Centralia Power Plant. In 1985, NOx was estimated using emission factors for coal-fired boilers. From 1992 on, emissions were made using actual source test data. Source-specific NOx factors were calculated from 1992-95 source test data and applied to the 1985 coal usage.

2018 Methodology

The source list and emissions for 2018 were assumed to be the same as that used for 1996, with a few exceptions. One major change, several deletions and some general additions were made to the 2018 inventory. The major change occurred in the Centralia Power Plant which is now meeting emissions limits of 10,000 tons per year of SO_2 and 16,000 tons per year of NOx as part of a regulatory order establishing Reasonably Available Control Technology (RACT). This is a major reduction in emissions.

Between 1996 and 2018 sources may start up or shut down. Resources did not allow a comprehensive query of local air agencies on changes between 1996 and the writing of this report (2002), or to assess future changes. Only a few known changes are accounted for in this report. Four source closures:

Rayonier in Port Angeles, Vanalco in Vancouver, American Silicon Technologies in Rock Island, and Georgia Pacific pulping operations in Bellingham. These were large sources in their respective counties.

Emissions increases from source additions were not treated individually. Through the Prevention of Significant Deterioration program, large new or modified emissions sources may be permitted. Specific information is available for a few new sources; however, the information is based on allowable rather than actual emissions and cannot be directly compared with the 1996 inventory which is based on actual emissions. It is also unknown the extent of additional changes that may occur through the year 2018. Most of the recent permitting work has been in gas turbines for power generation and gas compressors. It is estimated that power needs may increase by an average of 120 megawatts per year from 2002 to 2018. Based on current permits, this could increase emissions as shown in the table below. The estimates are consistent with known new permitting. Because source locations are not known, the emissions increase was added as a single statewide source. It is counted in the statewide summaries, but not in the county summaries.

Table 2-10: Projected Point Source Emissions Increases

Pollutant	T/megawatt-yr	**Total tons increase 2018**
NOx	0.25	**480**
CO	0.16	**310**
SO_2	0.12	**230**
VOC	0.27	**520**
PM	**0.36**	**690**

Observations

A word of explanation is appropriate concerning the comparability of 1985 and 1996 emissions estimates. Differences may be due to decreased operation or improvements in controlling emissions, or they may instead reflect a change in calculation method or updated emission factors. During the ten-year interval, air quality issues such as ozone formation put increasing emphasis on improving VOC, and to a lesser extent, NOx factors. PM_{10} replaced TSP as the national particulate measure, also resulting in efforts that improved factors. Only a careful, source by source study could reveal the source of actual differences.

Point sources, as a group, are the largest source of SO_2. The SO_2 inventory was affected significantly by the closing of the Asarco facility, and to a lesser extent, by the cessation of the rotary cement kiln operations of Columbia Cement (now Tilbury Cement). Asarco was in the process of shutting down during 1985, and although emissions were greatly reduced from pre-1985 levels, they were still quite large (> 12,000 tons); emissions were zero in 1996. The cement kiln reduction was about 2200 tons.

There are inconsistencies in the way source test particulate matter is reported (filterable vs. filterable + condensible). The differences may be quite large for individual sources. Solutions to this go beyond inventory efforts since different regulating authorities have different particulate reporting requirements.

A project is underway to obtain allowable emissions for all large sources in Washington. When the project is complete, projections may be made using permitted emissions levels.

2.8 Prescribed Burning

Prescribed burning includes logging debris burns and forest health burns. Prescribed burning is done by the Department of Natural Resources (DNR), U.S. Forest Service (USFS), Bureau of Indian Affairs (BIA), and private industry. DNR permits and tracks all burns, except those done by the BIA. Using models developed by the USFS, DNR estimates the tons burned and resulting air emissions.

Activity Level and Emission Rates

DNR enters information on each permitted burn in the USFS models. Some of the information required includes: location, date, ownership, elevation, moisture, species, duff depth, tons of material and/or acres, burn type (broadcast, pile, underburn, etc.). The models calculate fuel consumption and emissions for each burn. The emission factors used in the model were developed for the Pacific Northwest by the USFS.

DNR provided the entire 1996 burn permit database, which was queried for emissions by county.[43] Emissions were estimated for PM_{10}, $PM_{2.5}$, non-methane HC, and CO.

Emissions of SO_2 and NOx were estimated using ratios of NOx to CO and SO_2 to CO from the 1985 NAPAP inventory as described in the NET documentation.[23] The ratios were calculated using the NET database totals for CO, NOx and SO_2 (231,286 tons, 8,260 tons, and 310 tons, respectively). The calculated ratios were 0.035714 for NOx and 0.001339 for SO_2.[44]

Temporal Adjustments

Because the date of each burn was included in the database, monthly emissions were calculated by summing the emissions for all burns occurring in each individual month.

Spatial Adjustments

No spatial adjustments were necessary. All burns were identified both by county, and section-township-range.

1985 Methodology

DNR's current database tracking system was not in place in 1985. Information on tons of material burned during 1985 was available by county in DNR's annual smoke management report.[45] The report included aggregated information on monthly activity for eastern and western Washington. The monthly activity was converted to a monthly percentage distribution for the east and west sides of the state. Each county was labeled as either east or west, and its burning activity was assumed to follow the percentage distribution.

2018 Methodology

Burning by the US Forest Service in eastern Washington is expected to increase in the future, primarily for forest health. Estimates by forest are shown in Table 2-11 below. Emissions estimates for burns by the US Forest Service or other federal agency in the forests shown below, and in other eastern Washington locations were increased by the projection factors. USFS and DNR staff believed that there would be little or no increase in burning in western Washington or on state or private lands; therefore 2018 western Washington emissions were assumed to be equal to 1996 emissions.[46, 47] Because future emissions could not be spatially defined at the county level, the assumption was made that 2018 emissions would occur in the same areas as in 1996.

Table 2-11 Prescribed Burning Projection Factors

Forest	**Projection Factor**
Colville	**8.6**
Okanogan	**4.0**
Umatilla	**2.3**
Wenatchee	**5.6**

Observations

As a result of the 1991 Clean Air Washington Act, a two-phase emissions reduction goal was set for prescribed burning. The first target was a 20% reduction by 1994; the second target was a 50% reduction by 2000. Both targets were met. Large decreases in emissions were observed between 1985 and 1996.

It is difficult to predict future prescribed burning activity. Private land activity is not expected to change significantly. This is not the case with burning on USFS lands. Compliance with the Endangered Species Act has resulted in less tree cutting, and virtually no clear cutting on USFS land. This translates into decreased burning. With the recent listing of some salmon species as endangered species, prediction of prescribed burning becomes even more difficult. The decrease in burning on USFS land in eastern Washington over the past several years has led to buildups of material that may pose a threat to forest health due to increased wildfire and disease risk. Plans to alleviate the risk by increasing prescribed burning are being discussed. Increased prescribed burning will be dependent on public reaction, funding, and weather conditions.

Several groups are addressing outdoor burning issues. Among these groups are the Western States Air Resources Council (WESTAR), the Western Governors' Association, and the Western Regional Air Partnership Fire Emissions Joint Forum.

2.9 Agricultural Field Burning

Agricultural field burning emissions were calculated for cereal grains including wheat, barley and oats. Field burning was not tracked by season in 1996. Seasonal tracking began in 1997. For this inventory, 1998 was chosen for the baseline since it is the base year for future agricultural field burning targets, and 1996 data was not available by season.

Activity Level

Acres permitted for burning are tracked by the Department of Ecology. Table shows the number acres permitted in 1998 by county and season.[48, 49] It was assumed that all acres permitted for burning were actually burned.

Table 2-12: Acres Permitted, 1998

county	crop	spring	**fall**
Adams	wheat	692	**5,184**
Asotin	wheat	0	**3,255**
Benton	wheat	0	**1,026**
Columbia	wheat	28,253	**19,444**
Douglas	wheat	0	**6,142**
Franklin	wheat	0	**7,303**
Garfield	wheat	2,293	**6,807**
Grant	wheat	0	**1,511**
Lincoln	wheat	6,000	**10,663**
Stevens	wheat	0	**73**
Walla Walla	wheat	6,458	**17,476**
Whitman	wheat	26,665	**80,701**
total		70,361	159,585

Emission Rates

Emission rates were taken from EPA's AP42 and are shown in Table 2-13 below.[50] Emission rates are given in pounds of pollutant per ton of residue burned. A loading factor of 5 tons of residue per acre was assumed. The loading factor was part of a memorandum of understanding between the Wheat

Growers Association and Ecology. It is noted that the loading factor is more than twice the loading factor in AP42.

PM_{10} and $PM_{2.5}$ were estimated from total particulate using information from the Air Resources Board in California.[51]

Table 2-13: Emission Rates in Pounds Per Ton Residue Burned

crop	TSP	PM_{10}	$PM_{2.5}$	VOC as NMTOC	**CO**
barley	22	22	21	15	**157**
oats	44	43	41	26	**137**
wheat	**22**	**22**	**21**	**13**	**128**

Spatial and Temporal Adjustments

Burning is tracked by county and season, so no spatial or temporal adjustments were necessary

1985 Methodology

Information was not available for 1985. The values calculated for 1998 were used for 1985.

2018 Methodology

In a 1999 agreement among Ecology, the state Department of Agriculture and the Washington Association of Wheat Growers, the wheat growers committed to reduce field burning by at least half by 2006. The 1998 calendar year was used as the baseline year for the agreement. It was assumed that emissions in 2018 would be 50% of those calculated for 1998.

Observations

In the future the residue loading factor of 5 tons per acre should be re-evaluated.

2.10 Architectural Surface Coating

Architectural surface coating operations consist of applying a thin layer of coating such as paint, paint primer, varnish, or lacquer to architectural surfaces, and the use of solvents as thinners and for cleanup. Architectural surface coating was addressed in the EPA-STAPPA/ALAPCO Emission Inventory Improvement Program (EIIP).

The EIIP per-capita factor method for estimating emissions from architectural surface coating was used in this inventory.[52]

Activity Level and Emission Rates

The activity level is measured by per capita coating usage. Per capita coating usage was determined by dividing the national quantities of water and solvent based architectural coatings by the US population for the given year. National coating usage and population were taken from US Census information.[53, 54] VOC emission rates in pounds per gallon of coating applied were taken from the EIIP. The information is shown in the table below.

Table 2-14: Architectural Surface Coating Usage and Emission Rates

Coating Base	US gal (1000s)	US '96 Pop (1000s)	gal/person	VOC lbs/gal
Solvent	143,114	265,284	0.54	3.87
Water	490,025	265,284	1.85	0.74

The usage rate and VOC rate were combined with 1996 county population estimates to estimate emissions (see Table 2-9: County Population and Boat Registration Estimates, 1996).

Temporal Adjustments

Monthly adjustment factors were derived from 1996 quarterly gross income figures for Washington businesses in standard industrial classification (SIC) 523: Paint, Glass and Wallpaper Stores.[55] Quarterly activity levels were assigned the same percentages as the quarterly income data, and each month in the quarter was assigned one-third of the quarterly activity. The revenue data compared well with EPA summer seasonal adjustment factors: 29% and 33%, respectively. [56]

Table 2-15: 1996 Gross Income in SIC 523

Quarter	Income	Annual (Month)
1	60,124,670	19.9% (6.6%)
2	81,869,608	27.1% (9.0%)
*3	90,828,947	30.1% (10.0%)
4	69,145,570	22.9% (7.6%)

* Q3 not available; calculated from Q1,2,4 and CY total

Spatial Adjustments

The calculation methods consisted of multiplying a per capita emission rate by population. Population was available by county, so emissions could be assigned to each county.

1985 Methodology

The methodology used to calculate emissions for 1985 was the same as that used for 1996. Paint usage data was not readily available for 1985; the nearest year to 1985 that was available was 1991.[57] Therefore, 1991 data was used to develop emission factors per person. The resulting emission factors were multiplied by 1985 population.[58] Seasonal adjustments were the same as those used for the 1996 inventory.

2018 Methodology

Maximum achievable control technology (MACT) standards were promulgated for architectural coatings. The final rules were published in the Federal Register on September 11, 1998.[59] EPA estimated that the MACT standard would reduce emissions by 20%; therefore, the emission factors for 2018 were reduced by 20%. The emission factors were multiplied by 2018 projected population.[60] Seasonal adjustments were the same as those used for the 1996 inventory.

Observations

The MACT standard's estimated 20% reduction in VOC emissions was applied equally to the emission factors for both water and solvent based coatings in order to ensure a 20% reduction in the overall emission rate. In reality, the reductions for water and solvent based coatings will differ; hence, the 2018 calculated emission rates are valid only for combined architectural coatings and not individual coating types.

2.11 Consumer and Commercial Products

This category addresses non-industrial solvents that are used in commercial or consumer applications. The solvents may serve as propellants, aid in product drying through evaporation, or act as co-solvents and cleaning agents.

Activity Level and Emission Rates

The EIIP recommended method for calculating emissions is to multiply national per capita emission rates by local population data (see Table 2-9: County Population and Boat Registration Estimates, 1996). The table below details consumer and commercial products and their VOC emission rates.[61]

Table 2-16: Per Capita VOC Emission Factors

Product Category	lbs VOC/person
personal care products	2.32
household products	0.79
automotive aftermarket products	1.36
adhesives and sealants	0.57
* FIFRA regulated products	1.78
coatings and related products	0.95
miscellaneous products	0.07
TOTAL	***7.84***

* Federal Insecticide, Fungicide and Rodenticide Act

Temporal Adjustments

All but FIFRA products are assumed to be used uniformly throughout the year (8.3% of annual activity per month).[61] Monthly adjustment factors for the FIRFA products were derived from 1996 quarterly gross income figures for Washington businesses in standard industrial classification (SIC) 526: Nursery and Garden Supplies.[55] Quarterly activity levels were assigned the same percentages as the quarterly income data, and each month in the quarter was assigned one-third of the quarterly activity. Fourth quarter income was originally $96,790,314. It was set to equal first quarter income of $60,887,406 because it was thought to be high due to Christmas sales (not chemical sales).

Table 2-17: 1996 Gross Income SIC 526

Quarter	Income	Annual (Month)
1	60,887,406	19.3% (6.4%)
2	116,741,398	37.0% (12.3%)
*3	76,619,684	24.3% (8.1%)
**4	60,887,802	19.3% (6.4%)

* Q3 not available; calculated from Q1,2,4 and CY
** re-set to Q1 levels

Spatial Adjustments

The calculation methods consisted of multiplying a per capita emission rate by population. Population was available by county, so emissions could be assigned to each county.

1985 Methodology

The emission factors calculated for 1996 were multiplied by 1985 population.[58] Seasonal adjustments were the same as those used for the 1996 inventory.

2018 Methodology

Maximum achievable control technology (MACT) standards were promulgated for consumer products. The final rules were published in the Federal Register on September 11, 1998.[59] EPA estimated that the MACT standard would reduce emissions by 20%; therefore, the emission factors for 2018 were reduced by 20%. The emission factors were multiplied by 2018 projected population.[60] Seasonal adjustments were the same as those used for the 1996 inventory.

Observations

The MACT standard's estimated 20% reduction in VOC emissions was applied equally to all of the consumer product emission factors in order to ensure a 20% reduction in the overall emission rate. In reality, the reductions for individual products will differ; hence, the 2018 calculated emission rates are valid only for combined consumer/commercial products and not individual products.

2.12 Residential Wood Combustion

Residential wood combustion includes wood burning in woodstoves, fireplaces and home central furnaces.

Activity Level

The measure of residential wood combustion activity is the amount of wood burned. Several steps are necessary to arrive at an estimate of the amount of wood burned. A survey of wood burning device use conducted in 1990 was combined with more recent wood burning device sales records to estimate the amount of burning activity. Details are given below.

Survey Year Activity Level

In 1990, the Bonneville Power Administration (BPA) conducted a telephone survey of wood heating habits during the 89-90 winter season.[62] They surveyed 2078 households. The BPA survey was used to develop number of households using each type of device (Central Furnace, Certified (Phase I) and Non-certified Inserts and Woodstoves, and Fireplaces) and how much wood was burned in each device type. Areas specifically over-sampled by the survey were Puget Sound, Olympic, Spokane and Yakima. BPA provided the survey and database of responses to Ecology for use in residential wood combustion calculations.

Equipment Usage

The following table summarizes the survey results for each of the four main areas sampled in percent of households utilizing equipment. For households identifying more than one type of wood burning device, only the device identified as the one used most frequently was recorded for this inventory.

Table 2-18: Percent of Households Using Wood Burning Device

Equipment Type	Olympic	Puget Sound	Spokane	Yakima
Central Furnace	1.31	1.27	1.26	0.83
Fireplace	9.18	21.39	15.97	10.83
Non-Certified Insert	12.26	9.92	10	9.21
Certified Insert	2.16	1.75	1.76	1.63
Non-Certified Woodstove	29.82	11.89	10	16.29
Certified Woodstove	5.26	2.1	1.76	2.88

Amount of Wood Burned - Pellets and Presto Logs

The BPA survey gathered information on pellets, presto logs and cords of wood burned. Pellets used were given in number of 40 lb. bags used, and presto logs as number of logs burned. A presto log manufacturer in Spokane estimated the weight of a log as 8 lbs. Because of the small amount burned in comparison to cord wood, no distinction was made between the four geographic areas.

Table 2-19: Pellets and Presto Logs – lbs. burned per device

Equipment Type	lbs burned
Central Furnace	9
Fireplace	119
Non-Certified Insert	100
Certified Insert	635
Non-Certified Woodstove	88
Certified Woodstove	344

Amount of Wood Burned - Cord Wood

A cord contains 128 ft^3 (4' x 4' x 8'). The solid volume may range from 60-100 ft^3. An average solid volume of 85 ft^3 was used in this inventory.[63, 64] The weight of a cord of wood varies with moisture content and species type. It was assumed that moisture content was 20% (legal moisture limit).[65] Species type was defined using several sources. In a 1985 survey done by Market Trends, Inc.,[66] species burned were identified for western and eastern Washington. The survey was used to identify species for western Washington, but Ecology, Department of Natural Resources (DNR), and US Forest Service (USFS) staff all agreed that the species allocations for eastern Washington had changed somewhat, so their recommendations were used.[67] A further refinement was made for the Yakima area based on a USFS Study of the Naches area.[68] Results are shown in the table below along with estimated weight of a cord of wood in pounds for western and eastern Washington.[63]

Table 2-20: Wood Species Weight and Percent Use by Area

Species	lb/cord	WWA	EWA	Yakima
Alder	2,540	56		
Apple	4,400			37
Cedar	2,060	4		
Cottonwood	2,160	4		
Douglas Fir	2,970	16.5	25	15.75
Hemlock	2,700	16.5		
Larch	3,330		25	9.45
Lodgepole Pine	2,610		25	3.15
Madrona	4,320	1		
Oak	3,680	1		
Ponderosa Pine	2,240		25	15.75
Silver Fir	2,654			15.75
Willow	2,540			3.15

Table 2-21: Average Wood Weight per Cord

Area	lbs/cord
Olympic	2,607
Puget Sound	2,607
Spokane	2,788
Yakima	3,343

The BPA survey provided information on the number of cords burned per device as shown below. Because of the low number of central furnaces, cords burned shown are the statewide average. Within each major geographic region, the average amount burned in all stoves and inserts was used for both certified and non-certified devices due to the lower number of certified equipment used.

Table 2-22: Number of Cords Burned

Equipment Type	Olympic	Puget Sound	Spokane	Yakima
Central Furnace	2.27	2.27	2.27	2.27
Fireplace	1.75	0.45	0.48	0.57
Non-Certified Insert	3.15	1.56	1.60	2.12
Certified Insert	3.15	1.56	1.60	2.12
Non-Certified Woodstove	2.66	2.36	2.71	2.70
Certified Woodstove	2.66	2.36	2.71	2.70

Using the information above, the total pounds burned by area and device type were calculated.

Table 2-23: Total Pounds Burned per Device

Equipment Type	Olympic	Puget Sound	Spokane	Yakima
Central Furnace	5,927	5,927	6,338	7,597
Fireplace	4,673	1,284	1,449	2,016
Non-Certified Insert	8,312	4,167	4,561	7,187
Certified Insert	8,847	4,702	5,096	7,722
Non-Certified Woodstove	7,022	6,240	7,643	9,114
Certified Woodstove	7,279	6,497	7,900	9,371

Calculation of 1996 Activity Level

Since the 1990 BPA survey, the Dept. of Revenue (DOR) has tracked the number of sales of new stoves and inserts.[69] The BPA survey information was combined with the DOR sales data to determine 1996 wood burning activity. Replacement and new installation rates were calculated from the DOR and BPA data. The rates calculated were 67% new installations and 33% replacements. All new sales were assumed to have met Phase II certification. 1996 County allocations of new sales were based on county household growth[35] and expected usage rates.

Table 2-24: Wood Burning Devices - New Sales by Fiscal Year

FY	new sales	flag		FY	new sales	flag
1990	36,212	*		1994	22,162	**
1991	29,535	*		1995	16,933	**
1992	13,434	*		1996	16,342	**
1992	10,111	**		1997	7,933	**
1993	22,222	**				

* does not include fireplaces, ** includes fireplaces

Table 2-25: Percent of Households Using Wood Burning Device, 1996

Equipment Type	Oly	Pug Snd	Spk	Yak	PS-Oly	Spk-Yak
Central Furnace	1.1	1.1	1.1	0.7	1.1	0.9
Fireplace (1990 and older)	7.4	17.8	13.8	9.1	11.5	10.8
Fireplace (post 1990)	1.9	4.1	1.3	1.2	3.6	2.1
Non-Certified Insert	9.7	8.2	8.6	7.7	8.2	7.7
Certified Insert, Phase I	1.9	1.6	1.6	1.4	1.6	1.5
Certified Insert, Phase II	2.9	2.2	1.0	1.2	3.1	1.7
Non-Certified Woodstove	23.6	9.7	8.6	13.6	15.3	10.4
Certified Woodstove, Phase I	4.6	1.9	1.6	2.5	3.1	2.0
Certified Woodstove, Phase II	7.4	2.9	1.1	2.2	6.1	2.5
TOTAL DEVICES	***60.5***	***49.5***	***38.6***	***39.8***	***53.6***	***39.5***

Temporal Adjustments

Long-term average heating degree days from Quillayute, SeaTac, Spokane and Yakima were used to determine monthly activity.[24] Monthly heating degree days were divided by the annual total to determine the fraction of activity occurring in each month. County assignments are shown below.

SeaTac AP	Clark, Cowlitz, Island, King, Kitsap, Lewis, Pierce, Skagit, Skamania, Snohomish, Thurston
Quillayute	Aberdeen: Clallam, Grays Harbor, Jefferson, Mason, Pacific, San Juan, Wahkiakum, Whatcom
Yakima AP	Benton, Douglas, Franklin, Grant, Kittitas, Klickitat, Walla Walla, Yakima
Spokane AP	Adams, Asotin, Chelan, Columbia, Ferry, Garfield, Lincoln, Okanogan, Pend Oreille, Spokane, Stevens, Whitman

Table 2-26: Monthly Heating Degree Day Percentages

Month	Quillayute	SeaTac	Spokane	Yakima
Jan	13	16	19	18
Feb	11	12	14	13
Mar	11	12	13	11
Apr	10	10	1	8
May	7	6	6	4
Jun	5	3	2	2
Jul	3	1	0	0
Aug	3	1	1	1
Sep	4	3	2	3
Oct	8	8	9	8
Nov	11	12	14	13
Dec	13	15	19	18

Spatial Adjustments

The number of households for each county[35,58,60,70] was used with wood burning rates to spatially allocate wood burning activity. Each county was assigned wood burning activity rates based on one of the survey geographic groups. Two additional groups were made by averaging (not a weighted average) the following groups: Puget Sound-Olympic, and Spokane-Yakima. Counties assignments are shown below.

Puget Sound	King, Kitsap, Pierce, Snohomish, Thurston
Olympic	Clallam, Grays Harbor, Jefferson, Mason, Pacific, Wahkiakum
PS-Oly	Clark, Cowlitz, Island, Lewis, San Juan, Skagit, Whatcom
Yak-Spk	Adams, Franklin, Grant, Klickitat, Okanogan, Skamania
Yakima	Benton, Chelan, Douglas, Kittitas, Yakima
Spokane	Asotin, Columbia, Ferry, Garfield, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman

Table 2-27: Number of Households by County, 1996

County	households		County	households
Adams	5,238		Lewis	25,654
Asotin	7,935		Lincoln	4,033
Benton	49,434		Mason	18,532
Chelan	24,618		Okanogan	14,479
Clallam	27,083		Pacific	8,979
Clark	114,098		Pend Oreille	4,269
Columbia	1,721		Pierce	253,893
Cowlitz	35,469		San Juan	5,511
Douglas	11,343		Skagit	37,451
Ferry	2,667		Skamania	3,643
Franklin	14,422		Snohomish	200,784
Garfield	1,004		Spokane	164,575
Grant	24,234		Stevens	13,407
Grays Harbor	27,500		Thurston	75,725
Island	26,935		Wahkiakum	1,532
Jefferson	11,126		Walla Walla	21,360
King	678,667		Whatcom	60,395
Kitsap	84,792		Whitman	17,155
Kittitas	13,219		Yakima	74,143
Klickitat	7,083		***STATE***	***2,174,108***

Emission Rates

Emission factors in pounds of pollutant per ton of wood burned were taken from AP42. [71] Certified stoves and inserts were assumed to be 50% catalytic and 50% non-catalytic. Estimates of $PM_{2.5}$ were made using information from AP42 and the California Air Resources Board.[71, 38]

Table 2-28: Emission Factors in Pounds per Ton Burned

Equipment Type	PM_{10}	$PM_{2.5}$	SO_2	NOx	VOC
Central Furnace	30.6	32.2	0.4	2.8	53
Fireplace	34.6	29.2	0.4	2.6	*229
Non-Certified Insert	30.6	32.2	0.4	2.8	53
Certified Insert, Phase I	19.8	20.8	0.4	2	13.5
Certified Insert, Phase II	15.4	16.2	0.4	2	13.5
Non-Certified Woodstove	30.6	32.2	0.4	2.8	53
Certified Woodstove, Phase I	19.8	20.8	0.4	2	13.5
Certified Woodstove, Phase II	15.4	16.2	0.4	2	13.5

* verified by EPA

Final Emissions Calculations

Emissions for each wood burning device and pollutant were calculated according to the following equation:

(1996 households) x (1996 fraction device usage) x (tons burned/device) x (pollutant lbs/T) x (T/2000 lbs) x (monthly heating degree day fraction)

1985 Methodology

The methodology used to calculate emissions for 1985 was similar to that used for the 1996 inventory. The BPA survey values for usage of woodstoves and inserts were used directly, except all equipment was assumed to be uncertified, since certification programs had not yet begun. The burn rates, species types, emission factors, and seasonal adjustments used in the 1996 inventory were also used to calculate 1985 emissions.

2018 Methodology

The methodology used to calculate emissions for 2018 was similar, but not identical to that used for the 1996 inventory. In 2001, Washington State University under contract to the Idaho Department of Environmental Quality conducted a telephone survey of wood heating and outdoor burning habits in Idaho, Oregon and Washington.[72] The survey included questions to assess the number of households using each type of device (Central Furnace, Certified (Phase I, Phase II) and Non-certified Inserts and Woodstoves, and Fireplaces); how much wood was burned per device; and seasonal, daily and hourly usage rates. In Washington, the survey defined four geographic groups in Washington: 1) incorporated cities, 2) non-city western WA, 3) non-city eastern WA with forest lands, and 4) non-city eastern WA without forest lands. The new survey compared well with the previous survey. This new survey was used to project emissions to 2018.

It was assumed that all inserts and woodstoves were certified to Phase II standards. Emission factors were the same as those used for 1996. Weight of a cord of wood was assumed to be 2,607 lbs. west of the Cascades and 2788 lbs. east of the Cascades. Projected population was used with estimates of persons per occupied housing units to project the number of households in 2018.[60, 73, 74]

Observations

Because different surveys were used to calculate the 1985/1996 and 2018 inventories, care should be taken when comparing emissions estimates, particularly at the county level. Generally, the 2001 survey showed little change in amount of burning taking place in Washington. Future fuel costs and availability make projections of woodstove use uncertain.

2.13 Agricultural Windblown Dust

Agricultural dust emissions are generated when the soil surface is disturbed by either tilling or wind. A major research effort to develop a quantifiable methodology to predict the hazards and controls of PM from agricultural fields in the Columbia Plateau began in 1993. The effort is a cooperative effort among Ecology, EPA, U.S. Department of Agriculture, Washington State University and the University of Idaho. The research effort was divided into three phases, two of which are completed.

Completed work includes prediction of soil erodibility using soil sand, clay and organic carbon content, and prediction of soil loss using surface residue and soil roughness. A model is being developed to predict wind erosion from agricultural fields; it has been employed to model a few high wind events. While the study is not complete, the findings used here to make some very general estimates of emissions from agricultural dust in Washington are the most comprehensive available. The methods used here draw on work done early in the study. All assumptions and equations used will be stated below.

The windblown dust season is generally September through November, after harvest when fields are relatively bare and dry. This was the season used for this inventory. The Columbia Plateau study area covers most of eastern Washington, where 95% of the 1996 acres harvested were located. Because information necessary for calculations was not readily available for western Washington and the acres harvested were only 5% of the state total, emissions estimates were not made for western Washington.[75]

Activity Level

The activity level is defined by the soil type and vegetative cover for agricultural lands. WSU provided land use and soil class data on a one-kilometer basis for the Columbia Plateau study modeling domain (includes most of eastern Washington). Three agricultural land use types were identified: irrigated cropland, non-irrigated cropland, and rangeland. Soils were defined by one of several different soil classes.

Temporal Adjustments

As stated above, only the fall (Sept. – Nov.) was selected for emissions calculations.

Spatial Adjustments

The one-kilometer spatial information discussed under the activity level was assigned to counties using GIS tools.

Emission Rates

Dust Flux Equation

An estimate of emission rates was made using a dust flux equation that was employed during the initial modeling work for the Columbia Plateau study.[76] The equation describes the emission flux (F) of dust (defined as PM_{10}) in terms of wind friction velocity, and a threshold friction velocity (u_{*t}) which incorporates the effects of soil type, soil moisture, soil texture, and vegetative cover. The equation is:

$F = Cu_*^3 a_g(u_* - u_{*t})$ where

- F is the dust flux in g/m^2-sec
- C is an empirical dust constant (approximately 1 x mg sec^3 m^{-6}). C was determined for each wind event by calibrating the modeled values against observations.
- a_g is a constant to correct for the use of hourly averaged winds compared to the nonlinear effect of near-instantaneous gusts upon dust production (1.20).
- u_{*t} is the threshold friction velocity for the given soil and land use type. Values for u_{*t} are shown in Table 2-29: Threshold Friction Velocities
- u_* is the friction velocity and was calculated using the equation from the CALMET[77] meteorological data model:

  $u_* = (U * 0.4)/\ln(10/z_0)$ where:

  - U is the wind speed at 10 meters above the surface in m/sec.
  - z_0 is the surface roughness height. The surface roughness height was assumed to be 0.05 meters, which is the value given in MM5 (Mesoscale Model 5)[78] for agricultural lands during the non-growing season.

Thirty soil samples were taken in the Columbia Plateau, most of which were classified as silt-loams; therefore, the value of s in the equation was set to the silt content of silt-loam (52%).[79, 23] The ratio of $PM_{2.5}$ to PM_{10} was approximately 20% during windy periods in the discussion surrounding Figure 3 in reference 76. This is nearly identical with preliminary analysis of Columbia Plateau soil sample data, which showed a strong correlation between PM_{10} and $PM_{2.5}$, with $PM_{2.5}$ comprising nearly 20% of the PM_{10} emissions.[79]

Table 2-29: Threshold Friction Velocities (m/sec)

Soil Type	Irrigated Bare	* Dryland Fallow	* Dryland Residue	Rangeland
L1, D	0.40	0.40	1.20	1.03
L2	0.54	0.40	1.48	1.32
L3	0.63	0.40	1.56	1.44
L4	0.74	0.74	1.60	1.54
L5	0.80	0.80	1.60	1.6

* dryland areas were assumed to be 50% fallow and 50% residue due to crop rotation practices.[76]

The Columbia Plateau Study showed that cumulative precipitation had a large effect on dust generation; wind erosion was much greater during extended dry periods. Two wind events were modeled for the study: one in September 1993, and the other in November 1993. Rainfall was measured near the center of the modeling domain. There had been little rain before the September event, but by November the cumulated rainfall from Sept. 1 totaled 3.5 mm. The constant C in the dust flux equation was calculated to be about six times higher in the September event than in November (9.6 vs 1.5).

Application of the Dust Flux Equation

Daily precipitation was obtained from the National Climatic Data Center's Internet homepage for the Hanford Reservation meteorological station, which is near the center of the modeling domain.[80] Precipitation for 1996 showed no significant rainfall until September 14 at the Hanford site. It rained 21 mm on the 14th and continued raining most of the week. October saw 12 days of rain, and more rain came in November. Given the results of the Columbia Plateau study, it was decided to focus only on the dry period of September 1-13. It is noted that PM_{10} air monitoring data for 1996 showed no exceedances of the standard during September through November.

Hourly wind speeds during September 1-13, 1996 were obtained from the University of Washington for Spokane International Airport and the Hanford Reservation meteorological stations. The frequency of winds at each speed were averaged for the two stations and used in the friction velocity equation. The equation yielded dust emissions for wind speeds greater than 5.6 m/sec. The value of C (9.6) calculated by WSU in the Columbia Plateau study for the dry September event was used to calculate emissions for the September 1-13, 1996 period. A summary of wind speeds and resulting emissions for eastern Washington may be seen in the table below.

Table 2-30: Total Hours and PM_{10} Emissions by Wind Speed (m/sec), Sept. 1-13, 1996

m/sec	hours	PM_{10} Tons		m/sec	hours	PM_{10} Tons
0.0	10.6	0		6.2	13.7	1,097
0.5	1.1	0		6.7	6.4	1,035
1.0	4.0	0		7.2	3.2	876
1.5	21.0	0		7.7	3.7	1,618
2.1	34.4	0		8.2	5.0	3,203
2.6	34.3	0		8.7	1.1	969
3.1	32.0	0		9.3	3.4	4,137
3.6	31.3	0		9.8	0.5	821
4.1	25.4	0		10.3	1.1	2,302
4.6	30.4	0		11.3	0.6	2,028
5.1	31.9	0		11.8	0.6	2,553
5.7	16.4	415				

1985 and 2018 Methodology

Control measures that have been employed or will be employed in the future are not readily quantifiable at this time. Meteorological conditions, and therefore dust emissions, may vary significantly from year to year. For comparative purposes, the emissions rates were held constant for the three evaluation years.

Observations

Windblow dust is very dependent on meteorological conditions during periods when fields are bare and dry.

2.14 Agricultural Tilling Operations

Please see the introductory statements under the category "Agricultural Windblown Dust."

Activity Level

Acres planted are the measure of activity for tilling; however, they were not readily available. The Washington State Department of Agriculture publishes information on acres harvested for various crop types.[75] The acres harvested were used to determine activity.

Table 2-31: 1996 Acres Harvested

crop	acres		crop	acres
alfalfa	481,600		lettuce	950
alfalfa seed	11,800		oats	8,200
barley	429,900		onions	12,600
carrots-fresh	1,800		Other grass seed	4,700
carrots-processing	6,350		peppermint	28,500
corn-grain	117,200		potatoes	160,500
corn-silage	41,900		spearmint	9,300
dry beans	20,000		spring wheat	376,700
green peas	42,200		sweet corn	77,400
hay	301,800		winter wheat	2,344,700
Kentucky Bluegrass seed	36,100			

Spatial Adjustments

No spatial adjustments were necessary as the acres harvested was available by county.

Emission Rates

EPA has provided an equation for calculating emissions from tilling operations in the NET documentation.[23] The equation is essentially the same as in earlier guidance[81] except that a particle size multiplier for $PM_{2.5}$, and silt content for major soil types were provided. A default number of tillings per acre was also given. The equation is:

$E = (c)(k)(s^{0.6})(p)(a)$

where E = PM emissions in pounds

c = constant 4.8 lbs/acre-pass

k = particle size multiplier (TSP = 1, PM_{10} = 0.21, PM25 = 0.042)

s = silt content of surface soil (52%) (% mass of particles smaller than 75 um in diameter)

p = number of tillings (passes) per year (default = 3)

a = number of acres planted

As for windblown dust, $PM_{2.5}$ was assumed to be 20% of the PM_{10}.

Temporal Adjustments

The tillings were assumed to occur during the normal planting seasons: in September, October and November for winter wheat, and in March, April and May for all other crops.[82]

1985 and 2018 Methodology

Historical information was not readily available. Agricultural tilling emissions for 1985 and 2018 were assumed to be the same as in 1996.

Observations

During the Columbia Plateau project, investigators had little confidence in the current tilling emissions equation. It is also noted that the current equation has no soil moisture adjustment.

2.15 Livestock and Poultry Waste

Ammonia emissions from livestock and poultry wastes were estimated. Methodology and emission factors from a study done for the Northwest Regional Technical Center Demonstration Project were used to estimate emissions.[83]

Activity Level – Non-milk Cows

The Washington State Department of Agriculture publishes information on number of head of several livestock animals by county.[84] The statistics are kept for beef cows, hogs/pigs, sheep/lambs, horses/ponies, and broilers. Statistics are also kept on milk cows, but a different method was used to determine milk cow activity (see below). The numbers published represented number of animals on farms at any given time, except for broilers. Broilers were given as the annual total. Broilers are only kept an average of eight weeks.[85] Assuming uniform distribution over the year, the number of broilers at any given time was calculated by multiplying the total broilers by 8/52.

Activity Level – Milk Cows

Dairy waste is a water quality concern addressed by the Dept. of Ecology. An EPA grant study was done by the Soil Conservation Service addressing dairy concerns. The study provided information on location and number of cows for each farm.[86] The precise spatial allocation will be helpful in other analyses. The total number of cows was about 15% lower than that reported by the Washington Department of Agriculture.

Temporal Adjustments

No information was available to make monthly adjustments, so emissions were considered uniform throughout the year.

Spatial Adjustments

Non-milk cow information was available by county. Milk cow information was assigned to counties based on geographic coordinates.

Emission Rates

As stated above, the emission factors recommended in the NWRTC study were used to estimate ammonia emissions. The factors are shown below:

Table 2-32: Livestock Emission Factors

Livestock	kg NH_3/head-yr
Beef Cows	12.3
Milk Cows	24.6
Hogs/Pigs	6.39
Sheep/Lambs	1.34
Horses/Ponies	8
Broilers	0.28

1985 Methodology

The methodology for estimating emissions in 1985 was almost identical to that used for the base year 1996 inventory above. The information on number of head was not readily available by county for 1985. County totals were estimated by multiplying the state totals for 1985 (or the nearest year to 1985 that was available)[87, 88] by the ratio of 1996 county head to 1996 state head. In general, beef, hogs/pigs, and sheep/lamb production decreased from 1985 to 1996. Milk cow and broiler production increased.

2018 Methodology

Broiler production had shown a fairly steady increase since 1935, but in the last three years, production slightly decreased. Milk production increased until 1995, and then leveled during 1996-97. For all livestock animals, it was assumed that emissions in 2018 would be the same as in 1996.

Observations

Recommendations for future work are described in reference 83.

2.16 Biogenic Sources

Biogenic emissions are natural emissions that result from biological activity. For this inventory, emissions from vegetation (the predominant biogenic source of VOC) and soil microbial activity (NOx emissions), were addressed.

Much of the information here was excerpted from work done by Washington State University for an ozone formation study conducted for the Dept. of Ecology.[89]

Biogenic emissions were calculated for isoprene, terpenes, other VOCs and nitrogen oxide. For each of these compound classes, the following formulation was used to calculate the emission flux (mass/area/time) for a given land use of vegetation class:

$$F = Fs \times CL \times CT$$

where Fs is the class specific emission flux for the specified compound class at 30°C and 1000 μmol/m2/sec PAR (photosynthetically active radiation), CL is a light correction factor, and CT is a temperature correction factor. To perform the emissions calculations, the standard emission factors and correction factors were combined with vegetation species distributions. Each is discussed below.

Activity Level

Activity data for biogenic sources is the area of land covered by each of several major vegetative species groups.

Western Washington Counties

Recent US Forest Service tree inventory data were obtained for western Washington, and these data were used to determine the distribution of forest species within Washington and northwestern Oregon. These data included tree inventory information for approximately 2,000 plots within the state. For each plot the data included number of trees, species types, tree sizes, and crown area. Plots represented approximately 3 mi. x 3 mi. areas. The information from the plots was used to determine the species distributions for each grid where a plot occurred and to determine the fraction of the grid area accounted for by the total crown area.

The plot data was combined with land use data obtained from the National Research council of Canada. These data were the dominant land use type in each grid for the land use types.

To combine the land use and species plot data, for each grid with a plot, the species distribution was used directly and the balance of the land area within the grid was represented by the land use type. These plot data were then interpolated using an inverse distance squared routine where the existing land use type in a grid was modified according to the interpolation results for that grid. For example, given a grid with land use type equal to rangeland, the areal contribution of species from nearby plots was calculated and the rangeland area was reduced proportionally.

County totals for each species were calculated using grid to county assignments.

Eastern Washington

Species distributions for each county were taken from the land use file available in PC-BEIS2. One adjustment was made to the species assignments. Cover type wcnf (W Coniferous Forest - AVHRR, Guen) was replaced with state-defined type ewaf (eastern WA forest). Ewaf was defined as a mixture of 25% each of Ponderosa Pine, Lodgepole Pine, Douglas Fir, and tamarack (larch), which more accurately represents eastern Washington forests.

Table 2-33: Vegetative Species Distribution

Eastern Washington			Western Washington	
Species	percent		Species	percent
EWA forest (Ecology defined)	39		grassland	44
misc crops	23		Douglas fir	15
grass	15		conif. forest	14
wheat	8		western hemlock	9
woodland/cropland (AVHRR, Guen)	4		red alder	6
western Woodland (AVHRR, Guen)	3		western red cedar	3
barley	2		mixed ag & forest	2
hay	2		pacific silver fir	2
scrub	2		bigleaf maple	2
hardwood forest (AVHRR, Guen)	1		all other species	4
BEIS urban (.2 grass/.2 forest)	1			
all other species	1			

Emission Rates

Emission factors for isoprene, terpenes, other volatile organic compounds and nitrogen oxide from the Biogenic Emission Inventory System 2 (BEIS2) are given below for standard conditions of 30°C and 1000 μmol/m2/sec PAR.[90] Only the major species and land use types for eastern and western Washington are shown in the table. Emission factors for western Washington were defined using the BEIS2 factors as a basis for assignments.[91]

The emission factors for the category "Eastern WA Forest" were calculated using the emission factors for fir and pine and larch (25% fir, 50% pine, 25% larch).

An adjustment was made to the NO factors. The standard factors given in BEIS2 represent conditions where the soil temperature is 30°C, not the ambient air temperature; however, corrections for variations in temperature are based on air temperature. Therefore, adjustments were made to standardize the factors to 30°C air temperature using the air temperature to soil temperature equations in the PC-BEIS2 manual.[90]

Table 2-34: Emission Factors at Standard Conditions in μg/m^{2}hr

Eastern Washington					Western Washington				
Species	Isop	Terp	OVOC	NO	Species	Isop	Terp	OVOC	NO
barley	7.6	19	11.4	256.7	bigleaf maple	42.5	680	693.7	4.2
EWA forest	92.8	1880.6	1514.7	4.5	conif. forest	524.2	1672	1781.2	4.2
grass	56.2	140.5	84.3	52.9	Douglas fir	170	2720	2775	4.2
hardwood forest	8730	436	882	4.2	grassland	37.8	94.5	56.7	52.9
hay	37.8	94.5	56.7	12	mixed ag & forest	265.9	845.5	896.3	8.1
misc crops	7.6	19	11.4	12.8	pacific silver fir	170	5100	2775	4.2
scrub	37.8	94.5	56.7	52.9	red alder	42.5	42.5	693.7	4.2
urban (.2 grass/.2 forest)	408.6	161.9	200.5	12.5	western hemlock	79.3	158.7	1295	4.2
woodland/cropland	2550	663	2053	8.7	western red cedar	170	1020	2775	4.2
wheat	15	6	9	192.5					
western woodland	525	250	360	4.2					

Temporal Adjustments

Corrections to Standard Emission Factors

Corrections for light and temperature were made to the standard emission factors using a model developed by Dr. Brian Lamb of WSU.[92] In the model, microclimate solar radiation levels and leaf temperatures are estimated as a function of height within the canopy using a simple forest canopy model and leaf energy balance. During daylight hours, the effects are to attenuate solar radiation downward through the canopy, and to decrease leaf temperatures due to shading in the lower sections of the canopy. In the BEIS2 model, solar radiation is attenuated through the canopy, but leaf temperatures are assumed to equal above canopy temperatures.

The model requires several spatial, temporal and meteorological inputs. Latitude, longitude, time zone, year, month, hour, and cloud cover combine with the canopy type (conifer, deciduous, none) to calculate the light correction factors. The factor is calculated based on eight different layers throughout the forest canopy. Only isoprene emissions are affected by light.

Hourly temperature, wind speed, relative humidity, and cloud cover are used to calculate the temperature correction factors. All of the emissions are affected by temperature.

One set of values were used for latitude, longitude, time zone, and day of month. The values were 47.5° lat, 121° long, time zone 8 - Pacific Standard Time, and the fifteenth of each month.

Meteorological information was taken from six different stations depending on data availability. The table below shows the stations used for each parameter by meteorological area.

Table 2-35: Meteorological Station Parameters

Area	Temperature	Humidity	Cloud Cover	Wind Speed
Aberdeen	Aberdeen	Quillayute	Quillayute	Portland
Portland	Portland	SeaTac	Portland	Portland
SeaTac	SeaTac	SeaTac	SeaTac	SeaTac
Spokane	Spokane	Spokane	Spokane	Spokane
Yakima	Yakima	Yakima	Yakima	Yakima

Each county was assigned to one of the five areas as follows:

SeaTac AP: Island, King, Kitsap, Lewis, Pierce, Skagit, Snohomish, Thurston
Aberdeen: Clallam, Grays Harbor, Jefferson, Mason, Pacific, San Juan, Wahkiakum, Whatcom
Portland AP: Clark, Cowlitz, Skamania
Yakima AP: Benton, Douglas, Franklin, Grant, Kittitas, Klickitat, Walla Walla, Yakima
Spokane AP: Adams, Asotin, Chelan, Columbia, Ferry, Garfield, Lincoln, Okanogan, Pend Oreille, Spokane, Stevens, Whitman

Hourly information was not readily available for humidity, cloud cover or wind speed. Long-term monthly averages were used for those parameters.[24]

The fraction of cloud cover (c) reduces solar radiation according to the equation:

$$1 - (0.75 \times c^{3.4})$$

Cloud cover was classified as either clear, partly cloudy, or cloudy. Cloud cover is expressed as a fraction from 0 to 1. Clear was defined to be 0 to 0.15, partly cloudy as 0.15 to 0.85, and cloudy as 0.85 to 1. The value of c was calculated for each value between 0 and 1 in 0.01 increments. The average value of c using ranges 0.00 to 0.15, 0.16 to 0.85, and 0.86 to 1.00 for each of the three cloud cover classifications (clear, partly cloudy, cloudy) occurred at cloud covers 0.09, 0.58 and 0.93, respectively. These values were used with long-term monthly percentage of days classified as clear, partly cloudy, and cloudy to calculate monthly effects of cloud cover.

Temperatures were taken from the five different meteorological stations.[29, 30] Hourly temperatures were calculated from the monthly maximum and minimum by fitting a cosine curve where the minimum temperature was assumed to occur at 3 am (pst) and the maximum at 3 pm (pst).

Other Adjustments

Emissions from deciduous trees were set to zero during November to March. VOC emissions from individual agricultural crops were set to zero during months when the crop was not growing.[82] The base NO emission rates were developed considering fertilizer use for the various crop types. The NO emission rate for individual agricultural crops was set to the lowest individual crop emission rate (12 $\mu g/m^2$-hr) from October to February to account for the reduced use of fertilizer during the non-growing season.[93] No adjustment was made to wheat since most of the wheat grown in Washington is winter wheat.

Spatial Adjustments

Spatial adjustments were not necessary. Information for eastern Washington was available by county. In western Washington, the grid information was assigned to counties using geographic coordinates.

1985 and 2018 Methodology

Both the 1985 and 2018 inventories were assumed identical to the 1996 inventory.

Observations

While some land use/species distribution changes have occurred since 1985, and more will occur between 1996 and 2010, the changes are fairly small when compared to the entire state landscape. Differences in meteorology may have a greater effect on state biogenic emissions than changes in land use/species distribution. Meteorology plays an important role in biogenic emissions. A historical study of biogenic emissions was completed by holding land use/species distribution constant and calculating emissions based on daily meteorological differences in temperature and light conditions for summers between 1975 and 1996.[94] The highest emissions were 25% higher than the lowest emissions.

Improvements to the biogenic emissions estimation models are on-going. Recent ozone modeling efforts with Dr. Brian Lamb of Washington State University (contributor to the BEIS model) greatly improved Washington's biogenic inventory for western Washington. A future enhancement would be to obtain more specific land use/species distributions in eastern Washington.

2.17 Soil Ammonia Emissions

Ammonia emissions occur naturally from soil due to the bacterial processes of nitrogen fixation and ammonification. Methodology and emission factors from a study done for the Northwest Regional Technical Center Demonstration Project were used to estimate emissions.[83] Ammonia emissions from soil were estimated based on land use/cover type.

Activity Level and Emission Rates

Emission rates were developed for several land cover classes in the Multi-resolution Land Characteristics, National Land Cover Data (MRLC). The MRLC is land cover data resolved to 30 meters over the USA.[95] Table 2-36 below shows total land area and emission rates for land cover classes where emission rates were available. The emission rates for agricultural lands are presented for periods of fertilizer application (spring, fall) and for all other times; however the emission rates for fertilization were not used in this inventory. Resources did not allow obtaining local fertilizer application practices or schedules. Instead, emissions calculated for the 1999 Visibility SIP Review based on fertilizer use records were used. Future inventories may make use of the fertilizer ammonia emission rates shown in Table 2-36.

Table 2-36: Statewide Land Area and Ammonia Emission Rates

Land Cover	Area (km^2)	Emission Rates (lb- NH_3/km^2-day)	
		Other periods	Fertilizer Application
Forest land	84,758	0	0
Agriculture, pasture/hay	7,258	0.37	63.61
Agriculture, row crops	1,127	0.37	88.66
Agriculture, small grains	11,452	0.37	88.66
Urban/recreational grasses	152	0.37	0.37

Temporal Adjustments and Spatial Adjustments

Emissions were assumed uniform all year. GIS methods were used to assign land cover and land use types to each county.

1985 and 2018 Methodology

Emissions were assumed identical to 1996.

Observations

Emission rates in this report differ significantly from those used in the 1999 Visibility SIP Review. Research done through the Northwest Regional Technical Center cited that semi-natural ecosystems act as ammonia sinks, and that the most significant ammonia emissions are associated with intensive agricultural ecosystems. The research and recommendations for future work are described in reference 83.

2.18 Fertilizer Application

Nitrogen fertilizers are widely used in Washington. Most of the nitrogen fertilizers can decompose to release ammonia after they are applied to croplands. Ammonia emissions from fertilizer application were estimated using methodology and emission factors from a study done for the EPA.[96]

Activity Level

The amount of fertilizer purchased in Washington was available from the Dept. of Agriculture for individual fertilizer types.[97] Amounts are shown in Table 2-37.

Temporal Adjustments

Fertilizer use takes place primarily in the spring and fall. One-half of the annual emissions were assumed to be emitted in the spring and the other half in the fall.

Spatial Adjustments

Because the information was only available at the state level, the emissions calculated were distributed to all agricultural land in the state equally. Agricultural land cover data was available in a geographic information system (GIS) format for Washington.[98] The land cover file was intersected with a 5-km grid file over the state and land covers were assigned to each grid. If a grid had more than one land cover type, each cover was assigned 1/nth of the grid where n = the number of land cover types assigned to the grid. Each grid was mapped to a county, and county totals were determined by summing all the grids for each county.

Emission Rates

Emission rates are shown in the table below. Chemical composition (and therefore the nitrogen content) of the fertilizers was obtained from chemical references.[99, 100] The "other" category emissions were calculated by assuming the average emission rate per ton of fertilizer for all the nitrogen fertilizer types.

Table 2-37: Fertilizer Applied and Ammonia Released

name	formula	tons	%N	N tons	kg NH_3 /1000 kg N	NH_3 tons
ammonia, anhydrous	NH_3	75,318	82	62,027	12	744
ammonia, aqua	NH_40H	145,992	40	58,397	12	701
ammonium nitrate	NH_4NO_3	66,180	35	23,163	25	579
ammonium polysulfide	(20% N)	12,631	20	2,526		0
ammonium sulfate	$(NH_4)_2SO_4$	51,183	21	10,857	97	1,053
ammonium thiosulfate	$(NH_4)_2S_2O_3$	40,143	19	7,595	30	228
nitrogen solution < 28% N	(28% N)	8,307	28	2,326	30	70
nitrogen solution < 32% N	(32% N)	137,396	32	43,967	30	1,319
urea	$CO(NH_2)_2$	60,540	47	28,252	182	5,142
other		51,167				864
ammonium metaphosphate	NH_4PO_3	3,467	14	500	48	24
diammonium phosphate	$(NH_4)_2HPO_4$	10,611	21	2,251	48	108
ammonium polyphosphate	$(NH_4)_3P2O_7$	2,252	18	415	48	20
monoammonium phosphate	$NH_4H_2PO_4$	58,132	12	7,077	48	340
liquid amm polyphosphate	$(NH_4)_3P2O_7$	40,297	18	7,423	48	356

1985 Methodology

Fertilizer sales in Washington during 1985 were not obtained. National fertilizer statistics (available to 1993) show little change in total nitrogen consumption from 1985 to 1993; therefore emissions in 1985 will be assumed equal to those in 1996. There is evidence that the proportions of specific types of fertilizers used may have changed since 1985.[100] On irrigated cropland, urea has become more popular because it is less expensive than other types of fertilizer.[101]

2018 Methodology

For this inventory, 2018 emissions from fertilizer application were assumed equal to the 1996 values. As state above, urea has become more popular for irrigated cropland, but projections of its use and effect on usage of other fertilizer types were not available.

Observations

Except for the temporal variation, this category was not updated from the 1999 Visibility SIP Review. Land use assumptions were based on a different dataset than the dataset used to allocate natural soil ammonia emissions. Recommendations for future work are described in reference 83.

3 Emissions Summaries

Several emissions summaries are presented in this section. Abbreviations for individual source categories are: AGB (agricultural field burning), ARCH (architectural surface coating), BIO (biogenics), BOAT (recreational boats), CONS (consumer/commercial solvents), DNR (prescribed burning), FERT (fertilizer application), LIVE (non-dairy livestock), MILK (dairy cattle), NRM (nonroad mobile), ORM (onroad mobile), PAV (paved road dust), PNT (point sources), RR (railroad locomotives), SHIP (ships), SOIL (soil), TILL (agricultural tilling), UNPV (unpaved road dust), WIND (agricultural windblown dust), WSFP (woodstoves/fireplaces).

Summaries presented in sections 3.1, 3.2, and 3.3 are summarized into major categories of sources. The major categories include the following sources:

Agricultural Field Burning:	AGB
Agricultural Fugitive Dust:	TILL, WIND
Area Source Solvents:	ARCH, CONS
Fertilizer Application	FERT
Livestock Wastes:	LIVE, MILK
Natural Sources:	BIO, SOIL
Nonroad Mobile Sources:	NRM, RR, SHIP
Onroad Mobile Sources:	ORM
Prescribed Burning:	DNR
Point Sources:	PNT
Road Dust:	PAV, UNPV
Woodstoves and Fireplaces:	WSFP

3.1 Annual Source Contribution to Emissions

The following tables show major source category percent contribution to emissions in 1985, 1996, and 2018 for each visibility-impairing pollutant by major source category (nd = no data).

Table 3-1: 1985 Source Contributions in Tons

Major Category	PM_{10}	$PM_{2.5}$	SO_2	NOx	VOC	CO	NH_3
Agricultural Field Burning	12,647	12,072	nd	nd	7,473	73,583	nd
Agricultural Fugitive Dust	90,304	18,332	0	0	0	0	0
Area Source Solvents	0	0	0	0	23,851	0	0
Fertilizer Application	0	0	0	0	0	0	11,548
Livestock Wastes	0	0	0	0	0	0	12,088
Natural Sources	0	0	0	21,447	636,008	0	1,350
Nonroad Mobile Sources	11,956	11,024	23,719	148,506	80,579	523,384	360
Onroad Mobile Sources	5,993	4,665	8,869	240,638	238,329	2,690,347	2,317
Point Sources	24,787	18,370	139,716	57,290	30,514	343,749	nd
Prescribed Burning	15,636	14,335	170	4,528	8,232	126,785	nd
Road Dust	168,606	24,461	0	0	0	0	0
Woodstoves and Fireplaces	28,030	27,350	360	2,494	69,838	210,364	nd

total	357,959	130,609	172,833	474,902	1,094,824	3,968,212	27,663

Table 3-2: 1996 Source Contributions in Tons

Major Category	PM_{10}	$PM_{2.5}$	SO_2	NOx	VOC	CO	NH_3
Agricultural Field Burning	12,647	12,072	nd	nd	7,473	73,583	nd
Agricultural Fugitive Dust	90,304	18,332	0	0	0	0	0
Area Source Solvents	0	0	0	0	31,031	0	0
Fertilizer Application	0	0	0	0	0	0	11,548
Livestock Wastes	0	0	0	0	0	0	12,744
Natural Sources	0	0	0	21,447	636,008	0	1,350
Nonroad Mobile Sources	12,781	11,784	28,268	159,811	115,181	726,604	421
Onroad Mobile Sources	6,298	5,553	5,141	208,291	193,243	2,347,829	3,329
Point Sources	12,587	9,379	120,811	55,624	20,711	174,414	nd
Prescribed Burning	5,957	5,487	66	1,760	3,171	49,293	nd
Road Dust	178,325	26,244	0	0	0	0	0
Woodstoves and Fireplaces	31,603	30,739	460	2,936	76,618	234,986	nd
total	350,502	119,590	154,746	449,869	1,083,436	3,606,709	29,392

Table 3-3: 2018 Source Contributions in Tons

Major Category	PM_{10}	$PM_{2.5}$	SO_2	NOx	VOC	CO	NH_3
Agricultural Field Burning	6,324	6,036	nd	nd	3,737	36,791	nd
Agricultural Fugitive Dust	90,304	18,332	0	0	0	0	0
Area Source Solvents	0	0	0	0	33,402	0	0
Fertilizer Application	0	0	0	0	0	0	11,548
Livestock Wastes	0	0	0	0	0	0	12,744
Natural Sources	0	0	0	21,447	636,008	0	1,350
Nonroad Mobile Sources	12,813	11,805	33,672	138,648	68,154	949,093	599
Onroad Mobile Sources	2,100	2,002	663	52,462	64,857	1,071,566	5,946
Point Sources	13,876	11,160	49,220	52,508	20,881	156,168	nd
Prescribed Burning	9,082	8,282	98	2,614	4,410	73,191	nd
Road Dust	190,373	27,831	0	0	0	0	0
Woodstoves and Fireplaces	39,093	35,807	751	5,688	156,438	299,584	nd
total	363,964	121,256	84,404	273,367	987,885	2,586,394	32,187

3.2 Seasonal Contribution to Emissions: All Sources, 1996

The following tables show major source category percent contribution to emissions in 1996 for each visibility-impairing pollutant by major source category.

Table 3-4: 1996 Source Percent Contributions: All Sources, Spring

Major Category	PM_{10}	$PM_{2.5}$	SO_2	NOx	VOC	CO	NH_3
Agricultural Field Burning	4	11	0	0	1	2	0
Agricultural Fugitive Dust	35	22	0	0	0	0	0
Area Source Solvents	0	0	0	0	3	0	0
Fertilizer Application	0	0	0	0	0	0	56
Livestock Wastes	0	0	0	0	0	0	31
Natural Sources	0	0	0	5	53	0	3
Nonroad Mobile Sources	3	9	18	35	11	18	1
Onroad Mobile Sources	2	4	3	47	21	68	8
Point Sources	3	7	78	12	2	5	0
Prescribed Burning	1	3	0	0	0	1	0
Road Dust	43	19	0	0	0	0	0
Woodstoves and Fireplaces	9	25	0	1	8	7	0

Table 3-5: 1996 Source Percent Contributions: All Sources, Summer

Major Category	PM_{10}	$PM_{2.5}$	SO_2	NOx	VOC	CO	NH_3
Agricultural Field Burning	0	0	0	0	0	0	0
Agricultural Fugitive Dust	0	0	0	0	0	0	0
Area Source Solvents	0	0	0	0	2	0	0
Fertilizer Application	0	0	0	0	0	0	0
Livestock Wastes	0	0	0	0	0	0	70
Natural Sources	0	0	0	7	76	0	7
Nonroad Mobile Sources	6	20	23	40	10	34	3
Onroad Mobile Sources	2	7	4	41	11	59	19
Point Sources	4	11	74	11	1	5	0
Prescribed Burning	1	3	0	0	0	1	0
Road Dust	86	52	0	0	0	0	0
Woodstoves and Fireplaces	2	8	0	0	1	1	0

Table 3-6: 1996 Source Percent Contributions: All Sources, Fall

Major Category	PM_{10}	$PM_{2.5}$	SO_2	NOx	VOC	CO	NH_3
Agricultural Field Burning	7	20	0	0	2	5	0
Agricultural Fugitive Dust	46	26	0	0	0	0	0
Area Source Solvents	0	0	0	0	3	0	0
Fertilizer Application	0	0	0	0	0	0	56
Livestock Wastes	0	0	0	0	0	0	31
Natural Sources	0	0	0	4	53	0	3
Nonroad Mobile Sources	3	7	18	35	11	18	1
Onroad Mobile Sources	1	3	3	46	21	64	8
Point Sources	3	6	78	13	2	5	0
Prescribed Burning	3	8	0	1	1	3	0
Road Dust	31	13	0	0	0	0	0
Woodstoves and Fireplaces	6	17	0	1	7	6	0

Table 3-7: 1996 Source Percent Contributions: All Sources, Winter

Major Category	PM_{10}	$PM_{2.5}$	SO_2	NOx	VOC	CO	NH_3
Agricultural Field Burning	0	0	0	0	0	0	0
Agricultural Fugitive Dust	0	0	0	0	0	0	0
Area Source Solvents	0	0	0	0	5	0	0
Fertilizer Application	0	0	0	0	0	0	0
Livestock Wastes	0	0	0	0	0	0	73
Natural Sources	0	0	0	3	28	0	8
Nonroad Mobile Sources	4	8	14	30	13	11	1
Onroad Mobile Sources	3	6	3	51	28	71	18
Point Sources	7	10	83	14	3	5	0
Prescribed Burning	1	2	0	0	0	0	0
Road Dust	56	16	0	0	0	0	0
Woodstoves and Fireplaces	29	58	1	1	22	13	0

3.3 Seasonal Contribution to Emissions: w/o Dust and Natural Sources, 1996

The following tables show major source category percent contribution to emissions in 1996 for each visibility-impairing pollutant by major source category. The tables are the same as those in section 3.2 except agricultural fugitive dust, road dust, soil ammonia emissions, and biogenic emissions were excluded.

Table 3-8: 1996 Source % Contributions: w/o Dust and Natural Sources, Spring

Major Category	PM_{10}	$PM_{2.5}$	SO_2	NOx	VOC	CO	NH_3
Agricultural Field Burning	18	19	0	0	2	2	0
Area Source Solvents	0	0	0	0	7	0	0
Fertilizer Application	0	0	0	0	0	0	58
Livestock Wastes	0	0	0	0	0	0	32
Nonroad Mobile Sources	15	15	18	37	23	18	1
Onroad Mobile Sources	8	7	3	50	45	68	8
Point Sources	15	12	78	13	4	5	0
Prescribed Burning	5	5	0	0	0	1	0
Woodstoves and Fireplaces	40	42	0	1	18	7	0

Table 3-9: 1996 Source % Contributions: w/o Dust and Natural Sources, Summer

Major Category	PM_{10}	$PM_{2.5}$	SO_2	NOx	VOC	CO	NH_3
Agricultural Field Burning	0	0	0	0	0	0	0
Area Source Solvents	0	0	0	0	8	0	0
Fertilizer Application	0	0	0	0	0	0	0
Livestock Wastes	0	0	0	0	0	0	76
Nonroad Mobile Sources	39	41	23	43	39	34	4
Onroad Mobile Sources	14	14	4	44	44	59	21
Point Sources	27	23	74	12	5	5	0
Prescribed Burning	6	6	0	0	0	1	0
Woodstoves and Fireplaces	15	16	0	0	4	1	0

Table 3-10: 1996 Source % Contributions: w/o Dust and Natural Sources, Fall

Major Category	PM_{10}	PM_{25}	SO_2	NOx	VOC	CO	NH_3
Agricultural Field Burning	32	33	0	0	4	5	0
Area Source Solvents	0	0	0	0	7	0	0
Fertilizer Application	0	0	0	0	0	0	58
Livestock Wastes	0	0	0	0	0	0	32
Nonroad Mobile Sources	11	11	18	37	22	18	1
Onroad Mobile Sources	6	5	3	48	45	64	8
Point Sources	11	9	78	13	4	5	0
Prescribed Burning	13	13	0	1	2	3	0
Woodstoves and Fireplaces	27	28	0	1	16	6	0

Table 3-11: 1996 Source % Contributions: w/o Dust and Natural Sources, Winter

Major Category	PM_{10}	PM_{25}	SO_2	NOx	VOC	CO	NH_3
Agricultural Field Burning	0	0	0	0	0	0	0
Area Source Solvents	0	0	0	0	7	0	0
Fertilizer Application	0	0	0	0	0	0	0
Livestock Wastes	0	0	0	0	0	0	79
Nonroad Mobile Sources	10	10	14	31	18	11	2
Onroad Mobile Sources	7	7	3	53	39	71	20
Point Sources	15	12	83	14	5	5	0
Prescribed Burning	2	2	0	0	0	0	0
Woodstoves and Fireplaces	66	69	1	1	31	13	0

3.4 County Summary Tables, 1996

Annual emissions summary tables for 1996 are shown on the following pages for each inventoried pollutant by individual source category.

Table 3-12: County PM_{10} Emissions Estimates, 1996

County	AGB	BOAT	DNR	NRM	ORM	PAV	PNT	RR	SHIP	TILL	UNPV	WIND	WSFP	total
Adams	323	2	2	84	71	447	82	61	0	6,232	6,664	1,539	80	15,587
Asotin	179	2	13	19	17	100	0	0	0	458	1,125	123	95	2,131
Benton	56	23	0	189	169	1,401	61	79	9	3,689	1,490	2,059	904	10,129
Chelan	0	13	86	93	130	711	143	67	0	32	700	33	450	2,459
Clallam	0	15	247	178	72	105	243	0	611	83	221	0	774	2,548
Clark	0	36	185	395	290	999	1,140	37	38	255	745	0	2,196	6,316
Columbia	2,623	1	78	22	14	67	0	0	1	1,921	618	253	22	5,620
Cowlitz	0	16	280	493	202	539	1,400	30	69	66	107	0	734	3,937
Douglas	338	6	0	57	57	409	992	14	0	3,982	18,906	911	219	25,891
Ferry	0	1	75	51	35	170	27	1	0	203	4,971	0	33	5,566
Franklin	402	6	0	112	63	521	60	57	3	4,480	4,774	2,054	217	12,748
Garfield	501	0	229	26	10	51	0	0	2	2,330	2,190	318	13	5,669
Grant	83	12	0	238	142	964	74	56	0	8,984	11,889	3,576	350	26,368
Grays Harbor	0	12	473	362	81	114	671	0	42	275	829	0	815	3,675
Island	0	16	162	72	76	192	15	0	4	78	80	0	555	1,250
Jefferson	0	7	97	33	43	59	222	0	106	18	801	0	301	1,688
King	0	175	40	2,331	1,549	5,984	570	72	336	48	7,626	0	8,417	27,147
Kitsap	0	36	36	144	180	602	99	0	142	0	325	0	985	2,549
Kittitas	0	4	194	56	158	794	0	4	0	868	456	302	246	3,082
Klickitat	0	2	156	61	62	305	561	60	15	1,923	2,956	487	106	6,695
Lewis	0	9	287	348	127	370	1,242	22	0	475	483	0	525	3,888
Lincoln	916	3	2	99	58	364	0	80	0	8,447	7,918	1,324	48	19,260
Mason	0	14	202	161	61	83	161	0	3	29	607	0	503	1,825
Okanogan	0	5	466	121	77	378	73	1	0	682	4,682	236	224	6,944
Pacific	0	4	170	59	35	43	32	0	38	55	398	0	254	1,089
Pend Oreille	0	2	258	17	25	124	1	2	0	410	2,861	0	48	3,749
Pierce	0	83	318	804	571	2,137	788	63	32	117	705	0	3,042	8,661
San Juan	0	7	72	37	3	7	0	0	34	50	200	0	113	523
Skagit	0	24	213	172	166	467	449	22	27	716	491	0	750	3,496
Skamania	0	1	63	15	15	18	0	26	8	0	235	0	54	434
Snohomish	0	89	325	786	551	1,977	89	73	21	311	880	0	2,409	7,510
Spokane	0	41	380	422	332	2,474	1,548	119	0	4,268	22,060	22	1,966	33,632
Stevens	4	9	268	170	60	298	299	5	0	1,212	6,754	0	154	9,233
Thurston	0	33	210	256	218	701	2	20	0	167	557	0	881	3,046
Wahkiakum	0	1	132	21	6	8	0	0	60	34	253	0	41	556
Walla Walla	1,316	5	1	107	64	384	365	7	3	5,236	1,865	1,835	260	11,448
Whatcom	0	25	181	249	204	575	795	35	26	733	976	0	1,199	4,998
Whitman	5,905	3	0	182	64	337	41	1	4	11,828	18,889	660	212	38,127
Yakima	0	23	57	314	241	1,807	342	6	0	2,437	12,948	1,444	1,408	21,027
total	12,647	764	5,957	9,359	6,298	27,086	12,587	1,022	1,636	73,130	151,239	17,174	31,603	350,502

Table 3-13: County $PM_{2.5}$ Emissions Estimates, 1996

County	AGB	BOAT	DNR	NRM	ORM	PAV	PNT	RR	SHIP	TILL	UNPV	WIND	WSFP	total
Adams	308	2	2	77	64	85	42	56	0	1,270	1,000	308	78	3,291
Asotin	171	2	12	17	15	17	0	0	0	93	169	25	93	614
Benton	54	21	0	174	149	264	33	73	8	751	224	412	891	3,054
Chelan	0	12	78	86	117	125	102	62	0	7	105	7	443	1,142
Clallam	0	13	227	164	64	0	181	0	562	17	33	0	758	2,020
Clark	0	33	170	363	254	94	683	34	37	52	112	0	2,128	3,961
Columbia	2,504	1	69	20	12	12	0	0	1	391	93	51	21	3,174
Cowlitz	0	14	258	454	181	51	1,209	28	68	13	16	0	713	3,005
Douglas	322	5	0	53	51	78	865	13	0	811	2,836	182	215	5,432
Ferry	0	1	68	47	31	30	20	1	0	41	746	0	32	1,017
Franklin	383	6	0	103	55	98	29	52	3	913	716	411	212	2,982
Garfield	478	0	226	24	9	9	0	0	2	475	328	64	13	1,628
Grant	79	11	0	224	128	183	61	52	0	1,830	1,783	715	343	5,409
Grays Harbor	0	11	437	334	72	0	568	0	39	56	124	0	799	2,440
Island	0	14	150	66	69	18	10	0	4	16	12	0	538	897
Jefferson	0	7	89	31	39	0	178	0	98	4	120	0	295	860
King	0	161	37	2,145	1,345	556	409	66	309	10	1,144	0	8,160	14,341
Kitsap	0	33	33	133	159	56	30	0	131	0	49	0	954	1,577
Kittitas	0	3	179	51	142	139	0	4	0	177	68	60	243	1,067
Klickitat	0	2	146	56	56	54	467	56	15	392	443	97	104	1,888
Lewis	0	8	265	321	113	35	667	20	0	97	72	0	510	2,108
Lincoln	875	3	2	91	52	69	0	74	0	1,721	1,188	265	47	4,387
Mason	0	13	186	153	54	0	107	0	3	6	91	0	493	1,106
Okanogan	0	5	420	112	69	67	28	1	0	139	702	47	219	1,808
Pacific	0	4	157	55	32	0	15	0	37	11	60	0	249	618
Pend Oreille	0	2	235	16	23	22	1	2	0	83	429	0	47	859
Pierce	0	77	294	740	498	198	563	58	30	24	106	0	2,948	5,533
San Juan	0	7	67	34	3	1	0	0	32	10	30	0	109	291
Skagit	0	22	196	158	148	44	390	21	25	146	74	0	727	1,950
Skamania	0	1	58	14	13	0	0	24	8	0	35	0	52	206
Snohomish	0	81	299	725	481	184	80	67	20	63	132	0	2,332	4,466
Spokane	0	38	350	389	291	430	1,271	110	0	869	3,309	4	1,917	8,977
Stevens	4	8	245	157	54	52	208	4	0	247	1,013	0	150	2,142
Thurston	0	31	194	235	192	66	2	19	0	34	84	0	853	1,709
Wahkiakum	0	1	122	19	6	0	0	0	58	7	38	0	40	291
Walla Walla	1,257	5	0	98	57	67	249	7	3	1,067	280	367	254	3,710
Whatcom	0	23	167	229	182	54	598	32	24	149	146	0	1,163	2,767
Whitman	5,637	3	0	167	58	59	17	1	4	2,409	2,833	132	207	11,528
Yakima	0	21	51	290	215	341	295	5	0	496	1,942	289	1,387	5,334
total	12,072	703	5,487	8,622	5,553	3,558	9,379	940	1,519	14,897	22,686	3,435	30,739	119,590

Table 3-14: County SO_2 Emissions Estimates, 1996

County Name	BOAT	DNR	NRM	ORM	PNT	RR	SHIP	WSFP	**total**
Adams	1	0	204	45	0	147	0	1	**399**
Asotin	1	0	37	12	0	0	6	1	**57**
Benton	12	0	350	133	460	193	139	13	**1,300**
Chelan	6	1	133	88	3,356	161	0	6	**3,752**
Clallam	8	3	178	51	1,357	0	4,504	12	**6,113**
Clark	19	2	679	246	2,428	87	428	34	**3,923**
Columbia	0	1	52	9	0	0	14	0	**75**
Cowlitz	8	3	385	142	2,329	74	734	10	**3,686**
Douglas	3	0	135	40	725	35	0	3	**941**
Ferry	1	1	42	22	1	2	0	0	**69**
Franklin	3	0	221	49	5	133	44	3	**458**
Garfield	0	3	63	6	0	0	31	0	**104**
Grant	6	0	389	95	1	136	0	5	**632**
Grays Harbor	6	5	276	56	692	0	248	12	**1,295**
Island	8	2	134	51	16	0	19	8	**238**
Jefferson	4	1	45	29	400	0	784	5	**1,267**
King	90	0	3,777	1,457	713	156	1,716	120	**8,030**
Kitsap	19	0	234	151	124	0	949	15	**1,491**
Kittitas	2	2	86	103	0	10	0	4	**207**
Klickitat	1	2	86	39	597	147	244	1	**1,117**
Lewis	4	3	261	96	78,282	52	0	7	**78,706**
Lincoln	2	0	241	36	0	196	0	1	**476**
Mason	7	2	93	41	14	0	17	8	**183**
Okanogan	3	5	121	48	0	2	0	3	**182**
Pacific	2	2	56	22	16	0	399	4	**500**
Pend Oreille	1	3	24	16	0	5	0	1	**49**
Pierce	43	3	1,148	521	2,771	142	182	44	**4,855**
San Juan	4	1	47	2	0	0	222	2	**277**
Skagit	12	2	215	121	9,686	54	151	11	**10,255**
Skamania	1	1	21	9	0	65	129	1	**226**
Snohomish	46	4	1,070	484	508	174	101	36	**2,422**
Spokane	21	4	710	287	6,422	287	0	28	**7,759**
Stevens	4	3	154	38	12	12	0	2	**225**
Thurston	17	2	353	178	1	50	1	13	**616**
Wahkiakum	1	1	17	4	0	0	632	1	**655**
Walla Walla	3	0	238	47	2,002	18	50	4	**2,361**
Whatcom	13	2	331	149	7,718	84	157	18	**8,472**
Whitman	2	0	436	42	165	2	50	3	**700**
Yakima	12	1	444	175	10	13	0	20	**674**
total	**393**	**66**	**13,486**	**5,141**	**120,811**	**2,437**	**11,950**	**460**	**154,746**

Table 3-15: County NOx Emissions Estimates, 1996

County	BIO	BOAT	DNR	NRM	ORM	PNT	RR	SHIP	WSFP	total
Adams	1,353	3	1	1,187	1,963	165	2,444	0	7	**7,124**
Asotin	286	3	4	178	479	0	0	15	9	**973**
Benton	1,073	38	0	1,716	5,406	3,169	3,191	382	85	**15,060**
Chelan	260	21	24	609	3,640	50	2,691	0	42	**7,336**
Clallam	528	24	72	794	2,101	1,084	0	5,120	74	**9,797**
Clark	255	60	58	3,023	9,801	1,943	1,501	917	209	**17,766**
Columbia	334	1	21	295	348	0	1	35	2	**1,038**
Cowlitz	403	26	93	1,810	5,887	5,329	1,226	1,480	67	**16,321**
Douglas	1,163	10	0	742	1,637	0	581	0	21	**4,154**
Ferry	145	2	22	201	859	5	31	0	3	**1,268**
Franklin	722	10	0	1,195	2,014	101	2,280	112	20	**6,455**
Garfield	355	1	78	357	269	0	0	77	1	**1,137**
Grant	1,505	20	0	2,115	3,942	503	2,258	0	33	**10,377**
Grays Harbor	512	19	139	1,286	2,331	914	0	5,198	75	**10,473**
Island	40	26	48	569	2,015	47	0	34	52	**2,830**
Jefferson	412	12	28	199	1,198	522	0	796	29	**3,197**
King	586	291	12	18,288	57,907	4,821	2,856	28,559	774	**114,093**
Kitsap	147	60	10	956	6,018	212	0	1,768	92	**9,263**
Kittitas	413	6	57	411	4,617	18	164	0	23	**5,709**
Klickitat	488	3	46	452	1,573	152	2,435	669	10	**5,827**
Lewis	672	14	85	1,223	4,005	18,782	872	0	48	**25,702**
Lincoln	1,623	6	1	1,400	1,517	0	3,243	0	4	**7,794**
Mason	302	24	59	424	1,695	149	0	554	48	**3,255**
Okanogan	756	8	130	594	2,017	4	36	0	21	**3,565**
Pacific	261	7	50	254	906	85	0	796	24	**2,382**
Pend Oreille	53	4	73	111	657	18	86	0	4	**1,007**
Pierce	468	138	93	5,009	20,718	2,914	2,521	776	282	**32,920**
San Juan	56	12	21	206	68	0	0	243	11	**617**
Skagit	378	40	62	992	4,953	3,371	899	302	70	**11,068**
Skamania	387	2	19	93	388	17	1,068	356	5	**2,333**
Snohomish	487	147	99	4,891	19,437	1,727	2,949	231	226	**30,194**
Spokane	530	68	111	3,451	12,058	1,166	4,803	0	180	**22,367**
Stevens	164	14	75	745	1,600	1,277	192	0	14	**4,083**
Thurston	251	55	62	1,526	7,362	41	825	7	83	**10,212**
Wahkiakum	71	2	39	80	166	0	0	1,274	4	**1,635**
Walla Walla	875	8	0	1,291	1,919	1,739	294	129	24	**6,279**
Whatcom	343	42	53	1,527	5,927	4,924	1,400	2,614	112	**16,942**
Whitman	1,792	5	0	2,499	1,735	262	37	126	19	**6,474**
Yakima	997	38	16	2,155	7,159	113	232	0	130	**10,839**
total	**21,447**	**1,271**	**1,760**	**64,854**	**208,291**	**55,624**	**41,116**	**52,570**	**2,936**	**449,869**

Table 3-16: County VOC Emissions Estimates, 1996

County	AGB	ARCH	BIO	BOAT	CONS	DNR	NRM	ORM	PNT	RR	SHIP	WSFP	**total**
Adams	191	26	2,432	49	60	1	236	1,674	53	92	0	175	**4,989**
Asotin	106	34	1,398	45	77	7	133	513	0	0	0	227	**2,540**
Benton	33	225	4,185	607	511	0	1,741	5,346	79	119	0	1,851	**14,699**
Chelan	0	105	42,727	331	239	37	1,011	3,406	165	103	0	922	**49,048**
Clallam	0	112	19,360	383	254	139	2,199	1,937	247	0	172	1,687	**26,491**
Clark	0	522	6,625	951	1,185	95	2,966	9,427	948	61	0	5,468	**28,248**
Columbia	1,550	7	5,362	17	16	32	90	344	0	0	0	52	**7,471**
Cowlitz	0	156	14,832	410	355	138	6,654	5,096	2,529	46	0	1,835	**32,051**
Douglas	200	52	2,002	153	119	0	202	1,673	5	22	0	439	**4,867**
Ferry	0	12	34,381	27	28	36	651	875	1	1	0	77	**36,090**
Franklin	237	75	8,283	162	171	0	395	2,020	1,524	91	0	473	**13,430**
Garfield	296	4	2,235	13	9	111	61	251	0	0	0	31	**3,010**
Grant	49	114	14,971	318	259	0	1,024	3,695	39	85	0	764	**21,318**
Grays Harbor	0	117	13,816	306	266	267	5,139	2,060	262	0	271	1,798	**24,302**
Island	0	121	1,076	410	274	91	458	1,880	55	0	4	1,384	**5,754**
Jefferson	0	44	19,632	193	100	54	378	1,089	48	0	25	652	**22,215**
King	0	2,802	23,581	4,601	6,359	23	20,904	53,428	2,007	129	1,574	21,378	**136,786**
Kitsap	0	387	4,244	949	877	20	1,520	6,008	153	0	93	2,499	**16,749**
Kittitas	0	53	32,897	99	120	109	707	3,496	0	6	0	503	**37,991**
Klickitat	0	32	18,495	49	73	88	571	1,468	195	91	0	234	**21,296**
Lewis	0	115	25,450	228	260	157	4,825	3,518	282	33	0	1,312	**36,180**
Lincoln	542	17	1,440	87	38	1	338	1,414	0	121	0	115	**4,112**
Mason	0	80	10,981	378	182	114	1,528	1,504	251	0	29	1,096	**16,143**
Okanogan	0	65	61,735	131	146	200	1,584	1,859	43	2	0	490	**66,256**
Pacific	0	36	5,811	104	82	96	919	769	81	0	0	560	**8,458**
Pend Oreille	0	19	24,941	60	43	131	209	635	45	3	0	113	**26,200**
Pierce	0	1,144	16,280	2,187	2,597	179	8,207	19,700	994	108	38	7,721	**59,156**
San Juan	0	21	2,553	190	48	41	384	78	0	0	15	280	**3,610**
Skagit	0	164	18,804	626	373	120	1,910	4,403	2,814	33	20	1,869	**31,137**
Skamania	0	17	28,485	29	38	32	133	351	0	40	0	117	**29,241**
Snohomish	0	926	22,892	2,326	2,101	173	8,117	17,754	1,409	116	21	6,108	**61,944**
Spokane	0	699	13,277	1,074	1,587	214	3,725	11,080	1,278	183	0	4,678	**37,796**
Stevens	2	63	40,864	226	143	142	2,248	1,436	518	7	0	366	**46,014**
Thurston	0	332	7,158	877	754	118	3,083	6,866	440	31	0	2,234	**21,893**
Wahkiakum	0	7	2,090	29	15	74	279	133	0	0	0	91	**2,718**
Walla Walla	778	92	3,864	131	208	0	415	1,868	984	11	0	619	**8,971**
Whatcom	0	263	24,661	660	597	102	2,781	5,555	2,110	54	135	2,990	**39,907**
Whitman	3,489	71	274	78	160	0	476	1,665	30	1	0	507	**6,752**
Yakima	0	357	51,917	594	811	28	2,893	6,966	1,122	10	0	2,905	**67,603**
total	**7,473**	**9,491**	**636,008**	**20,090**	**21,539**	**3,171**	**91,095**	**193,243**	**20,711**	**1,598**	**2,398**	**76,618**	**1,083,436**

Table 3-17: County CO Emissions Estimates, 1996

County	AGB	BOAT	DNR	NRM	ORM	PNT	RR	SHIP	WSFP	total
Adams	1,880	102	17	1,559	22,360	40	241	0	590	**26,790**
Asotin	1,042	94	103	910	6,022	0	0	0	707	**8,878**
Benton	328	1,262	0	17,736	66,749	190	314	0	6,721	**93,301**
Chelan	0	687	678	7,479	44,485	820	266	0	3,342	**57,757**
Clallam	0	796	2,023	10,733	24,310	1,222	0	553	5,781	**45,418**
Clark	0	1,976	1,628	26,403	110,531	20,477	150	0	16,402	**177,567**
Columbia	15,263	36	578	557	4,114	0	0	0	159	**20,707**
Cowlitz	0	851	2,608	25,719	69,088	27,501	121	0	5,444	**131,332**
Douglas	1,965	319	0	1,557	20,189	463	57	0	1,639	**26,190**
Ferry	0	55	624	2,215	10,694	91	3	0	243	**13,926**
Franklin	2,337	336	0	3,689	24,827	26	227	0	1,614	**33,057**
Garfield	2,912	27	2,192	370	3,097	0	0	0	96	**8,694**
Grant	484	661	0	7,959	47,305	66	223	0	2,608	**59,305**
Grays Harbor	0	637	3,885	20,832	27,243	1,179	0	632	6,047	**60,454**
Island	0	853	1,332	4,263	23,422	32	0	177	4,138	**34,217**
Jefferson	0	401	792	3,074	13,635	1,733	0	95	2,258	**21,987**
King	0	9,558	329	210,579	618,083	4,049	289	9,170	62,497	**914,552**
Kitsap	0	1,971	291	15,693	74,366	116	0	1,537	7,333	**101,307**
Kittitas	0	206	1,592	4,442	51,730	5	16	0	1,834	**59,826**
Klickitat	0	103	1,277	2,508	18,974	19,927	240	0	789	**43,817**
Lewis	0	473	2,392	19,049	47,510	2,180	86	0	3,896	**75,586**
Lincoln	5,332	181	17	2,148	17,919	0	319	0	356	**26,272**
Mason	0	785	1,657	6,883	19,639	370	0	61	3,754	**33,149**
Okanogan	0	272	3,628	7,433	23,856	540	4	0	1,660	**37,393**
Pacific	0	216	1,393	4,482	10,124	99	0	0	1,887	**18,201**
Pend Oreille	0	125	2,050	1,057	7,881	3	9	0	356	**11,481**
Pierce	0	4,543	2,613	62,453	230,180	17,309	253	271	22,619	**340,243**
San Juan	0	394	593	3,046	839	0	0	488	843	**6,203**
Skagit	0	1,301	1,747	11,077	57,895	2,987	89	499	5,588	**81,182**
Skamania	0	60	532	833	4,368	1	105	0	398	**6,297**
Snohomish	0	4,832	2,770	62,208	208,610	738	293	749	17,946	**298,146**
Spokane	0	2,232	3,115	34,655	124,715	29,189	475	0	14,569	**208,949**
Stevens	23	469	2,108	8,337	18,728	4,632	19	0	1,142	**35,458**
Thurston	0	1,821	1,723	26,535	89,913	7	81	1	6,568	**126,649**
Wahkiakum	0	61	1,081	1,174	1,798	0	0	0	304	**4,418**
Walla Walla	7,659	272	4	3,822	23,170	1,573	29	0	1,932	**38,461**
Whatcom	0	1,371	1,482	20,054	70,919	34,543	138	292	8,923	**137,724**
Whitman	34,357	161	0	3,748	20,447	204	4	0	1,568	**60,488**
Yakima	0	1,234	439	19,001	88,093	2,102	23	0	10,433	**121,326**
total	**73,583**	**41,734**	**49,293**	**666,272**	**2,347,829**	**174,414**	**4,072**	**14,526**	**234,986**	**3,606,709**

Table 3-18: County NH_3 Emissions Estimates, 1996

County	BOAT	FERT	LIVE	MILK	NRM	ORM	SHIP	SOIL	**total**
Adams	0	533	154	55	3	26	0	97	**867**
Asotin	0	161	40	0	1	7	0	13	**222**
Benton	1	417	114	60	7	84	0	66	**749**
Chelan	0	211	27	0	3	52	0	1	**295**
Clallam	1	164	35	15	3	31	8	8	**264**
Clark	1	173	302	139	16	164	0	18	**814**
Columbia	0	176	56	0	1	5	0	43	**280**
Cowlitz	1	125	166	28	9	86	0	5	**419**
Douglas	0	595	91	0	2	24	0	40	**752**
Ferry	0	292	111	0	1	12	0	6	**422**
Franklin	0	399	224	141	4	31	0	95	**894**
Garfield	0	185	56	0	1	4	0	33	**278**
Grant	0	804	362	242	6	56	0	134	**1,604**
Grays Harbor	0	158	33	131	6	34	8	8	**378**
Island	1	101	22	61	2	30	0	6	**222**
Jefferson	0	83	17	17	1	17	1	1	**138**
King	6	176	89	406	114	994	44	12	**1,842**
Kitsap	1	60	21	0	5	98	3	1	**188**
Kittitas	0	208	295	18	2	60	0	22	**605**
Klickitat	0	438	193	41	1	22	0	27	**722**
Lewis	0	330	708	271	6	59	0	28	**1,403**
Lincoln	0	693	291	2	3	21	0	87	**1,098**
Mason	0	104	15	1	2	24	1	2	**149**
Okanogan	0	688	456	0	2	27	0	19	**1,192**
Pacific	0	113	32	47	1	12	0	3	**209**
Pend Oreille	0	185	49	3	0	9	0	8	**254**
Pierce	3	202	151	181	25	353	1	11	**928**
San Juan	0	89	31	0	1	1	0	4	**126**
Skagit	1	190	271	512	5	74	0	23	**1,076**
Skamania	0	27	6	0	0	5	0	1	**39**
Snohomish	3	202	337	475	33	325	0	16	**1,392**
Spokane	1	557	211	70	19	192	0	79	**1,129**
Stevens	0	580	235	51	3	21	0	31	**923**
Thurston	1	196	274	318	8	114	0	16	**928**
Wahkiakum	0	51	18	34	0	2	0	4	**109**
Walla Walla	0	414	69	1	4	29	0	91	**608**
Whatcom	1	211	217	1,477	9	92	4	28	**2,039**
Whitman	0	732	254	6	5	25	0	205	**1,226**
Yakima	1	527	583	1,327	10	106	0	57	**2,610**
total	**26**	**11,548**	**6,614**	**6,130**	**322**	**3,329**	**72**	**1,350**	**29,392**

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Appendix C

Federal Land Manager Comments on Washington State's Draft Visibility SIP Review

US Forest Service Comments

File Code: 2580-3
Date: September 19, 2002

Ms. Mary Burg
Air Program Director
WA State Dept of Ecology
P.O. Box 47600
Olympia, WA 98504-7600

RE: Washington Visibility State Implementation Plan Review

Dear Ms. Burg:

The Forest Service has reviewed the document "Review of the Washington State Visibility Protection State Implementation Plan" and would like to comment about both the Washington Visibility protection program in general, and the contents of the document specifically.

First we would like to again raise our foremost concern with visibility protection in Washington State and that is the lack of cumulative effects analysis for assessing visibility impacts from pollution sources. This issue has been troubling us for a number of years and last year we voiced those concerns to you in a letter dated November of 2001.

Cumulative effects analysis is legally and scientifically critical to the process of properly assessing visibility impacts to Class I areas. It is fundamental to the success of the FLAG recommendations and for compliance with federal PSD requirements for increment tracking. While we are pleased that Ecology has formally recognized these facts in the Visibility SIP Review Draft we are concerned with the number of years the state has been permitting new sources without doing cumulative effects analysis and the lost opportunities for visibility protection that have resulted.

The WDOE Visibility SIP depends to a large extent on other air regulatory programs to provide visibility benefit. The PSD permitting program is one example. The PSD and NSR programs focus primarily on NAAQS protection while allowing incremental deterioration in visibility from each and every additional source that receives a permit. The PSD program is successful in the application of BACT and in calling attention to and highlighting Class I protection issues. However PSD allows pollutant loadings to continue to increase without regard to existing pollutant amounts or visibility conditions. Effective visibility protection and improvement requires airshed emission decreases, something PSD does not do.

Washington Department of Ecology's partial implementation of the FLAG recommendations has been beneficial, but the recommendations call for the use of cumulative effects analysis when existing, or predicted future, Class I pollutant loadings exceed reasonable levels (i.e. greater than a 10% change in extinction from all increment consuming sources). Currently, the impact of each proposed source is assessed in a vacuum with no consideration of existing visibility impairment. Class I and Class II increment tracking, another PSD program requirement, also depends on implementation of cumulative effects analysis.

Is Ecology intending to step forward and fulfill your responsibility for cumulative effects analysis? We recommend an aggressive effort to get a cumulative effects process integrated into the PSD/NSR and visibility protection programs as soon as possible. Cumulative modeling analysis tools are currently being developed by EPA Region 10 to assist states that have not developed this capability on their own. In addition, we recommend formal commitment to integrating the FLAG visibility recommendations into your PSD permitting process by writing it into the Washington Visibility SIP.

In reviewing the July 2002 document, we also would like to make note of the following:

- There was a nitrate sampling protocol change made in the IMPROVE monitoring systems in 1996 resulting in discontinuity of data collected before 1996 and after. It appears that the WDOE analysis did not follow the IMPROVE committee recommendations for dealing with this problem. Can you justify or explain your approach?
- Three Sisters Wilderness in Oregon is generally one of the cleanest sites in the country whereas Table 1.7 on page 55 shows it to be dirtier on best and median days than the other three areas it's compared to. Can you please double-check your calculations?
- IMPROVE and EPA are now using calendar quarters (JFM, AMJ, JAS, OND) rather than seasons for analysis. We recommend that the next time IMPROVE data is analyzed WDOE does the same.

Thank you for the opportunity to comment on the Washington Visibility Protection SIP. We appreciate the close working relationship of our two agencies and look forward for more opportunities to work together to protect Washington's Class I areas for the benefit of current and future generations.

Sincerely,

JOHN PHIPPS
Forest Supervisor

National Park Service Comments

September 20, 2002

N3615(2350)

Mary E. Burg
Air Quality Program Manager
Department of Ecology
P.O. Box 47600
Olympia, Washington 98504-7600

Dear Ms. Burg:

The National Park Service (NPS) appreciates the opportunity to provide these comments on the Federal Land Manager (FLM) Draft Report for the Review of Washington State Visibility Protection State Implementation Plan, July 2002. It is apparent that much time and effort was expended by the Department of Ecology's (DOE) Air Quality Program in assessing the visibility situation in Washington's Class I areas, and we are pleased to see the State focus more on the haze impacts that affect the important visual resources of these special areas. In our view, the July draft report represents an appropriate transition to begin addressing local and regional haze for purposes of improving the current visibility protection program.

Although it is mentioned briefly in Sections 1.1, 4.1, and 6.2 of the report, we believe it would be useful to provide more detailed information on the recent establishment of visibility monitoring in several of Washington's Class I areas (e.g., areas affected, monitoring locations, equipment used, dates of inception, etc.). As a suggestion, these details could be included in Section 6.2, with reference to this section provided in Sections 1.1 and 4.1. The visibility monitoring strategy is an important element of the State's overall visibility plan, and we believe it is also an indicator of progress to improving visibility conditions in the future.

Some of the analysis methods used in the assessment and other studies cited in the report (e.g., the Bonneville Power Administration (BPA) Cumulative Impact Study) help to further our understanding of the nature and causes of visibility impacts and indicate program areas that can be improved to assure the State continues to make reasonable progress toward the national visibility goal. As discussed in the draft report, the BPA study has helped to highlight that significant visibility effects can occur at Class I areas through the permitting of many, relatively small emission sources. We strongly encourage the State to pursue the resources necessary to develop cumulative impact assessment capabilities as soon as possible. The draft report lists this issue as its highest priority of additional measures needed to assure the viability of DOE's visibility protection program, and depending on the degree of emissions growth in the State, it may be an essential capability to have in-house to prevent future degradation of visibility in Class I areas in and near Washington State.

Though perhaps not critical to securing the Environmental Protection Agency's approval of the State's periodic review report, there are some technical issues concerning the draft report that we would like to bring to your attention.

As in past reports, the State often uses the term "plume blight" to describe the scope of its Phase I visibility protection program. Plume blight is actually a limited form of "reasonably attributable" visibility impairment that is relatively easy to identify, but it is not the only type of impairment that is required to be addressed in the State's current visibility implementation plan. Some parts of the draft report correctly refer to impairment that can be reasonably attributed to existing stationary sources (e.g., in discussions on Best Available Retrofit Technology), so there may be a need for the report to identify the term "plume blight" as shorthand for "reasonably attributable" impairment. The findings regarding the Centralia Power Plant visibility impacts on Mount Rainier National Park are illustrative of a Phase I-type impact that could not be categorized as simple plume blight.

The discussion on Reasonably Available Control Technology for Centralia (page 101 of the draft report) refers to the plant's sulfur dioxide emissions limit for one unit as 5,000 tons per day. This should actually state that the limit is 5,000 tons per year.

Some changes have been implemented regarding the IMPROVE monitoring network operations and data analysis protocols that are different from those cited and used in the draft report. Most recently, rather than seasonal analyses based on predominant weather similarities, IMPROVE is using calendar quarters beginning January 1 each year. Also, nitrate sampling changes were made several years ago (1996) and will affect comparability between data sets (i.e., there would be an artificial decrease after 1996 due to protocol changes).

The draft report uses the long-term IMPROVE monitoring site in Tahoma Woods (near Ashford) for analysis of mass loadings and visibility effects in Section 1, but for purposes of the trajectory analyses in Section 3 the Paradise site is used (this site is several miles away from Tahoma Woods and quite a bit higher in elevation). We are not certain how this may have influenced the outcome of the analyses, but we do not expect this will have a material effect on the acceptability of DOE's final report.

Finally, we note that DOE extended the deadline for FLM comments on this draft report to today (September 20) a few weeks ago, and Section 5 should be amended to reflect this change.

Thank you very much for coordinating the development and review of this report with the NPS and other stakeholders. We are hopeful that your agency will be able to continue making progress to improve visibility conditions in Class I areas affected by sources in the State and to prevent future degradation as required by the Clean Air Act. We look forward to working with you to assure mutual accomplishment of these goals. If you or your staff have any questions, please contact Mr. Brian Mitchell at 303-969-2819.

Sincerely,

Christine L. Shaver
Chief, Air Resources Division

cc: Air Programs - EPA Region 10

Appendix D

Summary of the Northwest Regional Modeling Center Demonstration Project

Northwest Regional Modeling Center Demonstration Project

Background

The states of Washington, Oregon, and Idaho, EPA Region 10, and Washington State University (WSU) have created the Northwest Regional Modeling Center (RMC) to provide states the technical capacity to conduct aerosol modeling for visibility as required under EPA's regional haze regulations. In addition to any future modeling efforts for regional haze, participants also envision using the modeling center for other regulatory or special projects that require regional modeling. Environment Canada recently elected to participate to enhance the capability for addressing emissions that transport across international boundaries.

Computer hardware dedicated for running modeling software resides at WSU. WSU staff members and/or graduate students are trained to run the Community Multi-scale Air Quality Model (CMAQ) and the Sparse Matrix Operating Kernel Emissions (SMOKE) processor. WSU maintains a RMC website that facilitates electronic file transfer among the participants. Emission inventories are developed based upon a consistent methodology agreed upon by the states. Modeling center participants have the option of either downloading SMOKE inventory files to run SMOKE and CMAQ in-house or contracting WSU to conduct model runs.

Demonstration Project Summary

EPA Region 10 funded the Regional Modeling Center "Demonstration Project" to demonstrate the capability to model regional haze impacts for Class I Wilderness Areas in the Pacific Northwest states of WA, OR and ID. The project design emphasized developing "the process", a collaborative effort by the participants to develop modeling capacity, versus producing "a product", intensive effort to develop the best data. The process also emphasized identification of specific areas of emission inventory improvements needed for future efforts.

The modeling center elected to model a fifteen day episode in July of 1996, expanding upon WSU's previous ozone modeling effort of a four day episode in July of 1996. The states sponsored a workshop that prioritized sources of emissions to insure that those sources most likely to impair visibility during the July period were included in the inventory. The modeling center elected to use the same models, SMOKE and CMAQ, as those chosen by the Western Regional Air Partnership (WRAP) to meet the modeling requirements under Section 309 of EPA's Regional Haze regulations. WA, OR, and ID are all members of the WRAP. WA Department of Ecology, working in coordination with ID and OR, prepared SMOKE emission inventory files for point, area, and mobile sources. The inventory included the pollutants of PM_{10}, $PM_{2.5}$, sulfates, nitrates, volatile organic compounds, and ammonia. WSU processed the emissions files using SMOKE, providing CMAQ formatted, gridded emissions inputs. WSU conducted the CMAQ runs and compared these modeled outputs to IMPROVE monitor data for this July period.

Summary of Project Tasks

The complete demonstration project included three primary tasks. Descriptions of the tasks undertaken by the RTC can be found in the comprehensive work plan developed for this project, which is included in the appendices of the "RTC Demonstration Project Summary Report", March 27, 2002.

Task 1:

Task 1 was divided into two concurrent efforts. First, the Community Multi-scale Air Quality Model (CMAQ) dispersion model was applied to an ozone episode from July, 1996 which was previously modeled with the MM5/CALMET/CALGRID system. The objectives of this effort were to: gain familiarity with CMAQ; obtain experience with the compilation of the emission inventory for CMAQ; and evaluate the performance of CMAQ in comparison to previous modeling studies and to available air quality observations.

The second effort included the organization of an emission inventory conference/workshop and documentation of common methods and practices for use by the RTC. The objectives of this effort were to organize and host a conference/workshop to develop and document 1) a common approach to emission inventory production, 2) quality assurance/quality control training, 3) data quality grading, 4) discussion of the distribution practices that were utilized by the technical center and 5) to further document the policies, practices, and expectations associated with the operation of the RTC demonstration.

Task 2:

Task 2 involved application of the CMAQ dispersion model to a large-scale particulate pollution episode. The objectives of this task were to: use the CMAQ system for aerosol and regional haze predictions; develop capabilities for regional emission inventory consolidation; and evaluate the performance of the model compared to available air quality observations. The final product was a full implementation of Models-3/CMAQ in the Pacific Northwest nested within a coarser WRAP domain and an initial investigation of regional particulate pollution and regional haze.

Task 3:

Task 3 involved the development and application of an extensive outreach and training effort through the WRAP and Western States Air Resources Council (WESTAR) to promote the formation and support of local RTCs.

Summary of Regional Modeling Efforts

The NWRMC was officially established via a successful demonstration of the application of the MM5/SMOKE/CMAQ system using a virtual center approach with multiple collaborators across the Pacific Northwest. The project involved two phases:

1) intercomparison of MM5/CALGRID with MM5/CMAQ based upon a four-day July, 1996 ozone episode along the I-5 corridor.

2) initial evaluation of CMAQ for simulating aerosol and visibility for a multi-state domain during a 15 day period in July 1996.

Phase I Summary:

In this phase, both modeling systems were initiated with the same observational nudging MM5 simulation (Barna and Lamb, 2001) and both used the same gridded domain and emission inventory (with conversion to the appropriate chemical mechanism). The CALGRID model employed the SAPRC-97 chemical mechanism, while CMAQ simulations were completed using both the Carbon Bond 4 (CB4) and RADM2 mechanisms. Results from all of the model runs were compared to available ozone observations. Process analysis methods were also used in both models to examine the relative importance of different model processes at different sites and to determine whether or not each model reached similar results in the same manner. The two modeling systems both yielded similar performance statistics in comparison to observations. However, the process analysis revealed that for specific monitoring sites, there were substantial differences between the models in terms of specific processes (advection, diffusion, chemical production, etc). Details and examples of the intercomparison are included in a summary report.

Phase II Summary:

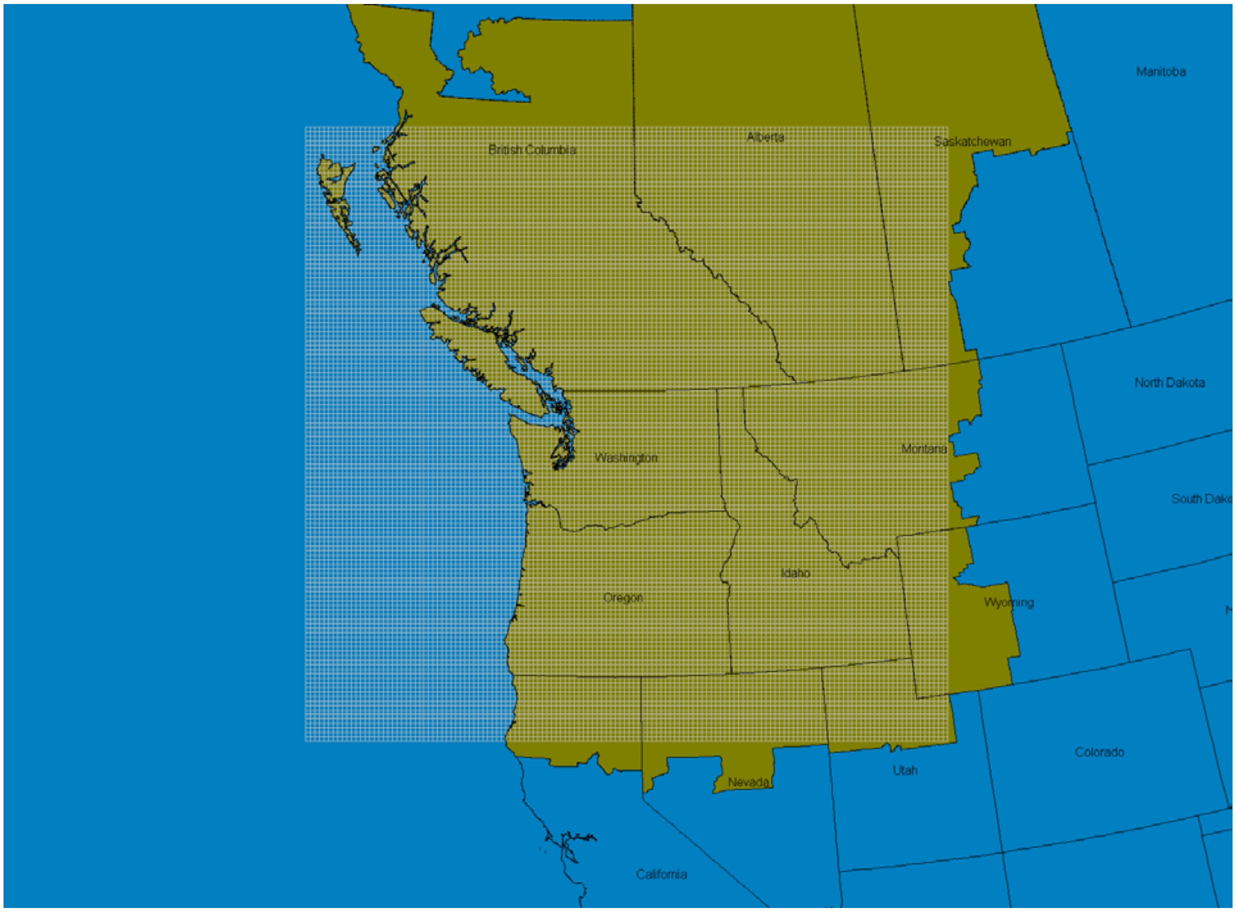
In this phase, the MM5/CMAQ system was applied to a regional haze period covering July 1-15, 1996 for a domain encompassing Idaho, Oregon, Washington and a significant portion of southern Canada. The horizontal grid cell size was 12 km x 12 km for this domain. Results were obtained for two different emission inventories. The first inventory was obtained through interpolation of the 36 km gridded NET96 emission inventory. These data were processed with the SMOKE emissions system and included biogenic emissions obtained with BEIS2. The second inventory was compiled through the NWRMC and involved updated input from each of the states and Canada. In this case, spatial information was based upon 12 km compilations. The GLOBEIS biogenic emissions model was used for biogenic VOC emissions.

Results from the MM5 simulation were compared to available surface and upper air data in terms of wind speed, wind direction, and temperature. CMAQ output for ozone and various aerosol and particulate species were compared to data from ozone monitoring sites, from IMPROVE sites, and from the data collected through the Spokane Health Effects Program. CMAQ output was processed using the PMx software developed by the National Research Council of Canada to yield PM2.5 and PM10 mass concentration output. Analysis of these simulations is still underway.

Website

The Regional Modeling Center has established a website, http://nwrmc.ce.wsu.edu. The FTP/website, hosted by WSU, contains information on the NWRMC, plus model results from the demonstration project, and also facilitates the technology transfer of information for the CMAQ modeling runs to the individual members of the NWRMC.

Figure D-1 Northwest Modeling Center Domain



Appendix E

Summary of the BPA Cumulative Impact Study

Summary of the BPA Cumulative Impact Study

The Regional Air Quality Study commissioned by the Bonneville Power Administration (BPA) was designed to assure BPA that the cumulative effect of the power generating facilities requesting connection to the BPA power distribution grid would not create an adverse impact on the Class I areas in Washington and the northern half of Oregon. The study began with Phase I, which included 45 proposed power generating facilities that would be capable of generating more than 24,000 MW. This phase presented results in two parts: facilities slated for initial operation before January 2004 and for all facilities. A second phase to this study has been completed evaluating the impacts of fifteen power projects that are well along in their permitting process.

In Phase 1 concentration, deposition, and visibility impacts in the Class I areas, the Columbia River Gorge National Scenic Area (CRGNSA), and the Mt. Baker Wilderness Area were evaluated. All power projects, even those designated as peaking plants, were assumed to operate at full capacity. The study domain included all of Washington, roughly the northern two-thirds of Oregon, the northern portion of the Idaho panhandle, and small portions of western Montana and southwestern British Columbia. The study grid used the 12 km MM5 and the calculations were also carried out at the 12 km spacing. The 24,000 MW is well in excess of the 4,000 to 8,000 MW projected requirement for the region in the next eight years. The cumulative SO_2 emissions of the 44 projects amounts to approximately two percent of the current emissions in the study domain. The new projects would also add slightly more than two percent to the current emissions of NOx. These projects add approximately seven to eight percent to the current PM_{10} emissions.

The increased concentration levels in the Class I areas from the 28 power projects slated to be operational before January 2004 exceeded the EPA significant impact level (SIL) for PM_{10} (24-hour) and SO_2 (3- and 24-hour) at the CRGNSA, Mt. Baker, and the Spokane Indian Reservation. Of these, only the Spokane Indian Reservation is a Class I Area (the Spokane Indian Reservation is a *redesignated* Class I area and is not subject to the same long-term visibility improvement plan as mandatory Class I federal areas). The addition of the remaining 16 power projects did not add any new pollutants or averaging times above the SIL but did increase the number of areas showing impacts above the SIL. It should be noted that the SIL is a level for a single source and is being used here only to indicate the level of impact. The impact from each of these 44 projects individually remains below the SIL.

Figure 6.4 shows the general pattern of impact from the first group of 28 projects for PM_{10} for the winter months. Impacts are highest in regions where the sources are clustered (look for the small plus circumscribed by a circle to designate source locations.) Figure 6.5 shows the impact with all 44 sources included. Although the cumulative impacts to concentrations in the Class I Areas from all 44 sources are above the SIL, they remain below the allowable increment by a wide margin.

Figure E-1 24-hour maximum PM_{10} (ug/m^3) from 28 sources.

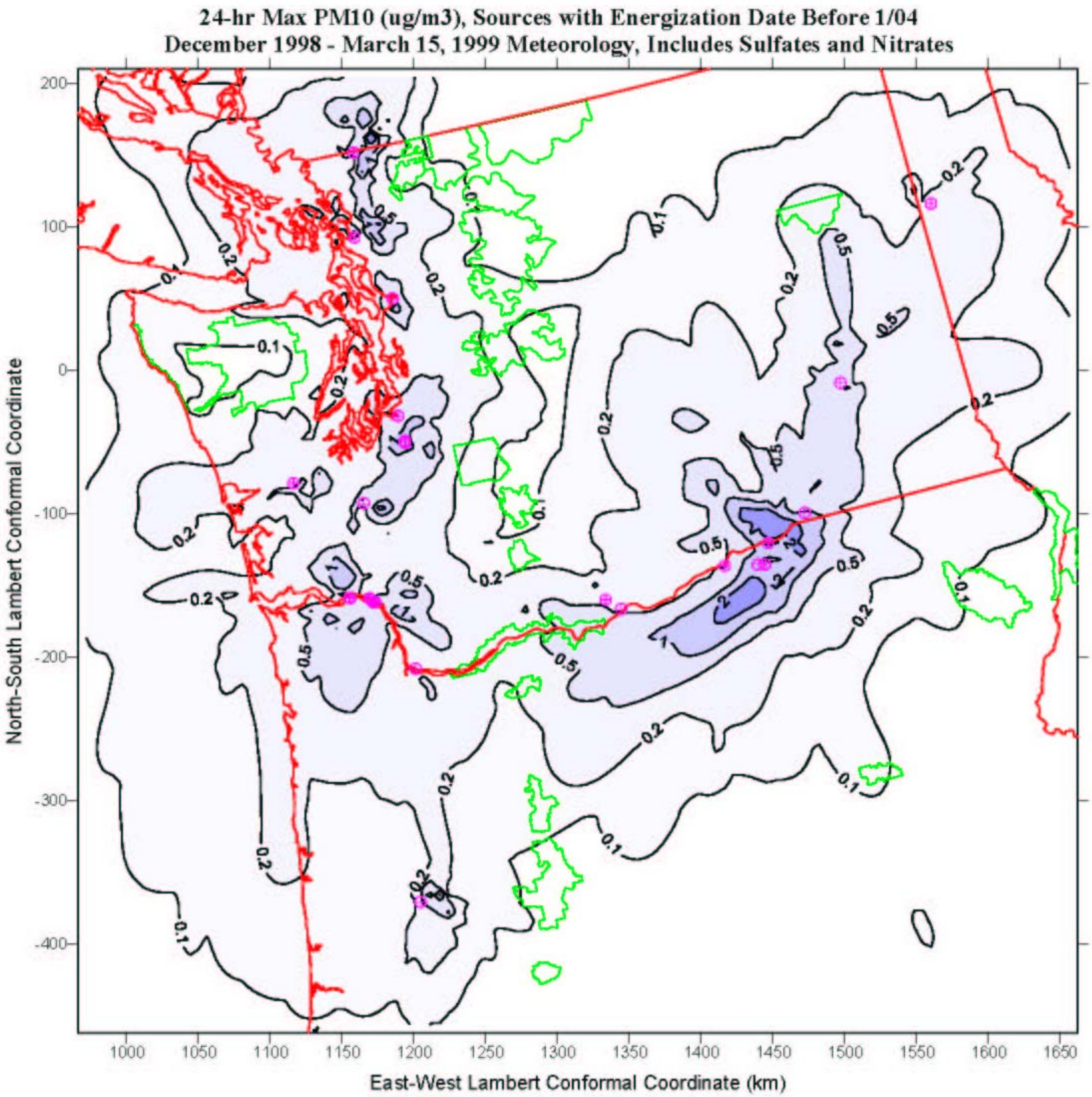
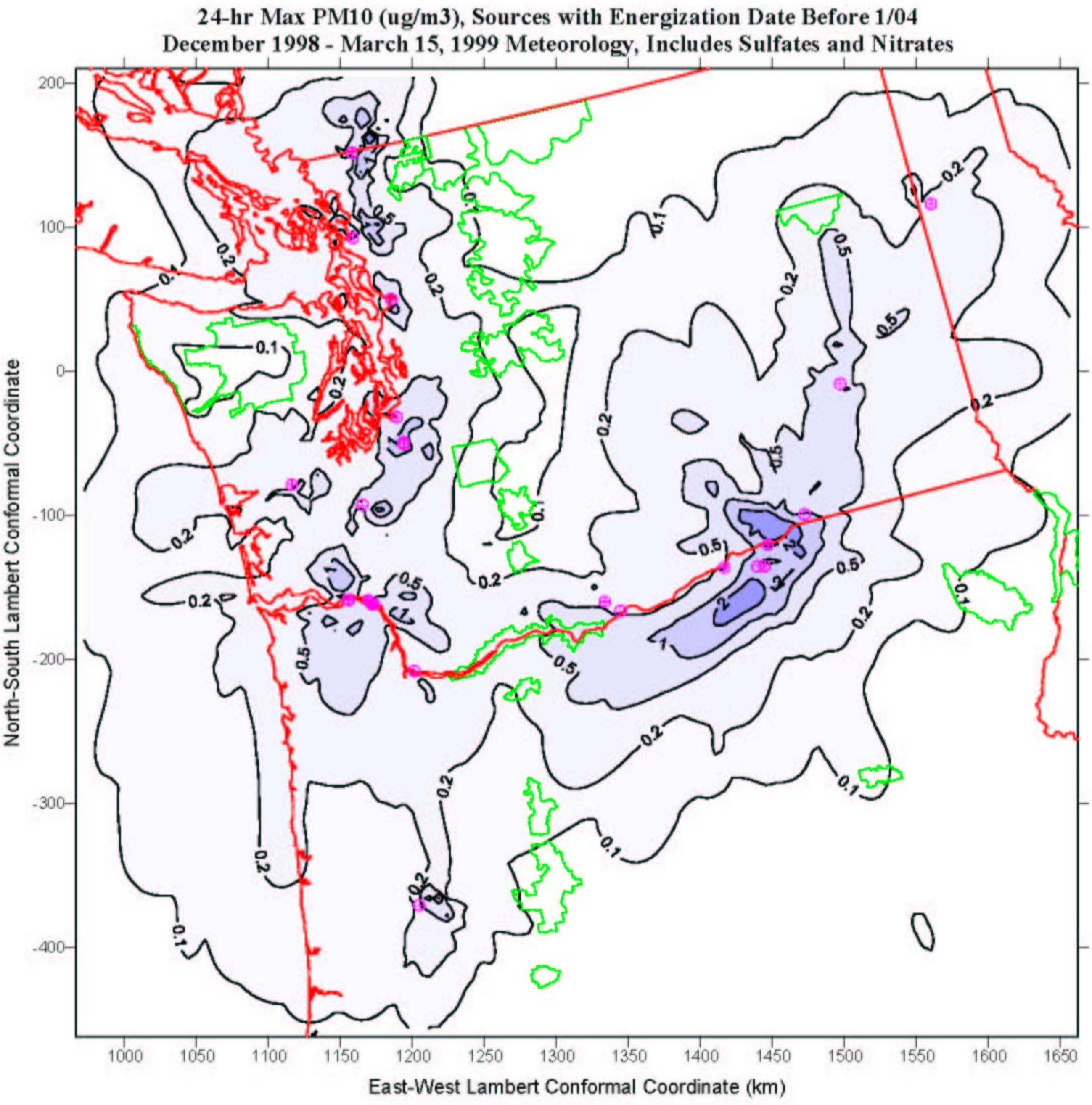


Figure E-2 24-hour maximum PM_{10} (ug/m^3) from 44 sources.



The added deposition of sulfur and nitrogen in the Class I areas also exceeds the significance levels established by the federal land managers for single sources. However, the new emissions from the sum of all 44 projects increase the current deposition levels of sulfur and nitrogen in the Class I areas by fractions of a percent. Figures 6.6 and 6.7 show the pattern of deposition over the study domain for nitrogen and sulfur. As expected, the areas of maximum are located close to clusters of the new sources.

There is a much greater impact to visibility in the Class I areas as even the initial subset of 25 sources produces an increase of extinction greater than ten percent for five days at two Class I areas.

The most important conclusion of this study is that relatively small increases in emissions have the potential to produce unacceptable changes in visibility in the nearby Class I areas.

The second phase of the study examined the impact of fifteen power projects with a total generating capacity of 7000 MW to regional haze. These projects, when gas-fired, exceed the ten percent change in visibility only one time, at Mt. Hood (a mandatory Class I federal area in Oregon). However, many of the projects have requested to be allowed to use oil and analysis shows unacceptable impacts at Mt. Rainier (seven days with greater than ten percent change in visibility.) The second phase is a continuing analysis with periodic updates planned for groups of sources as applications are processed.

Figure E-3 Total nitrogen deposition (kg/ha/yr)

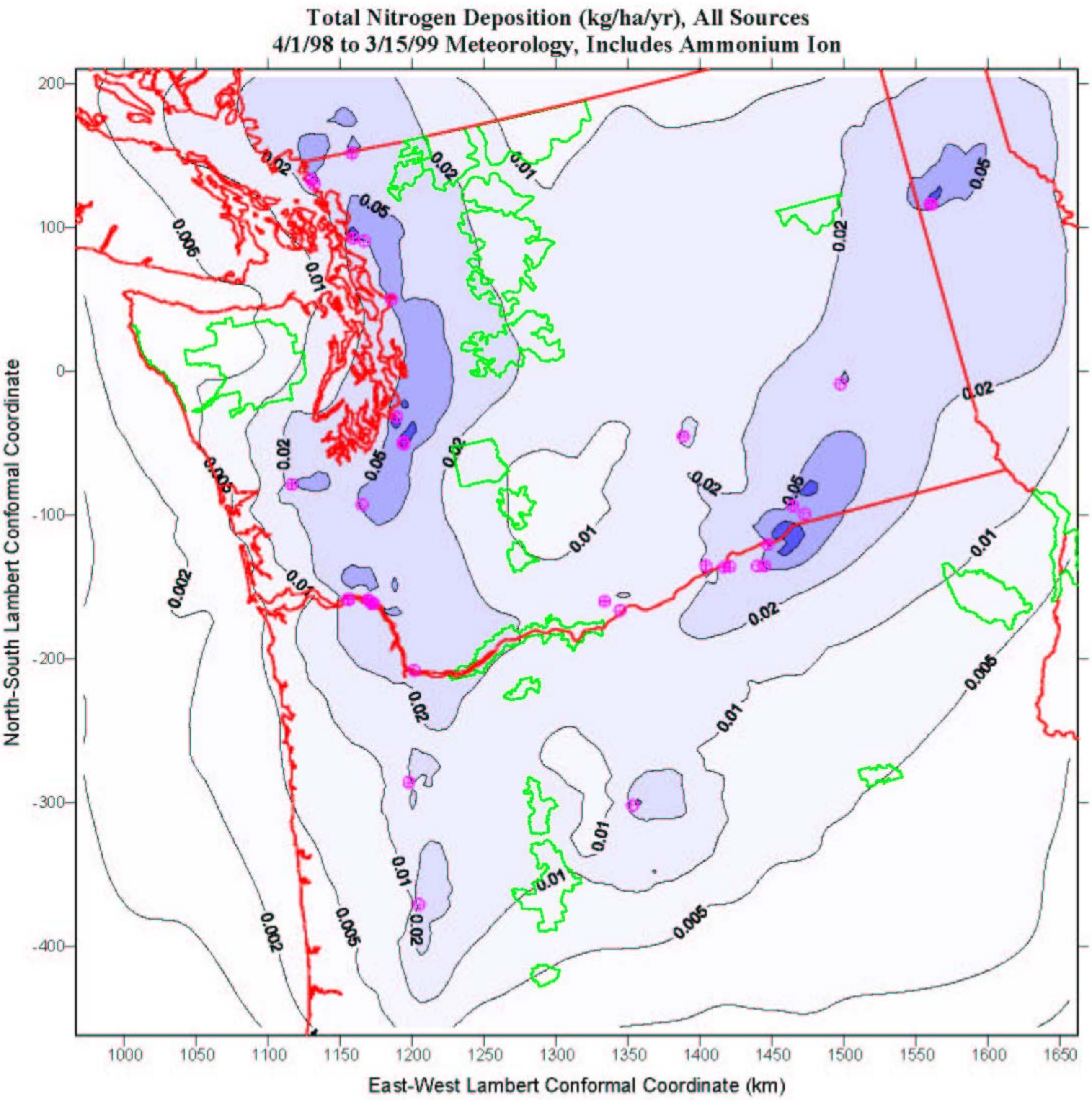


Figure E-4 Total sulfur deposition (kg/ha/yr)