Modeling of Columbia River Gorge Emissions

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ABSTRACT

The emission inventory is a key component of any air quality modeling exercise. For the Columbia River Gorge National Scenic Area Air Quality Study (Gorge Study), the Sparse Matrix Operator Kernel Emissions Modeling System (SMOKE) was configured to generate 2004 base year and 2018 future year model-ready emissions for two specific haze episodes occurring in August and November 2004. Hourly emissions were estimated for point, area, non-road mobile, on-road mobile, and fire source emissions on a 36/12/4-km grid system, though we focus on the 4 km grid emissions in this paper. Criteria pollutant emissions were speciated according to the carbon bond (CB4) chemical mechanism with particulate matter (PM). Certain emission subcategories (e.g., electric generating units, on-road mobile sources, fires) were processed through SMOKE in separate streams in order to support source apportionment applications and to allow maximum flexibility in developing and applying alternate strategies in the modeling. Specialized processing was conducted for certain source categories to provide updated and/or day-specific emission estimates for the episodic conditions modeled in this study: large industrial point sources, wildfires, some prescribed fires, Mt St Helens volcanic emissions, on-road mobile sources, non-road mobile sources, biogenics, wind-blown dust, and agricultural ammonia.

Extensive quality assurance (QA) was performed on the emissions. As a result of the QA process, numerous issues were identified and corrected, among which were the following:

> Reduction in Residential Wood Smoke: Annual fine PM emissions from residential wood combustion in Oregon and Washington were found to be overstated by a factor of two, based upon a revised interpretation of a 2000 Residential Wood Combustion survey conducted in Oregon and Washington.
>
> Increase in Agricultural Ammonia: Based on a detailed scrutiny of the Oregon and Washington ammonia inventories against recent emission factors published in the literature, two major issues were identified: (1) ammonia emissions from confined animal feeding operations (CAFO) were understated by factors of 1.5 to approximately 4; and (2) ammonia emissions from fertilizer application were understated by factors of 2.5 to 3.

Application of Canopy Escape Factors: to account for near source removal of fugitive dust such that the air quality model "sees" only about 25% of the estimated PM emissions from fugitive dust.

This paper describes the emissions quality assurance (QA) process, the Microsoft Excel reporting and QA tool that resulted from this study, and the results of the QA process.

INTRODUCTION

The Gorge Study included the following components:

Measurement Program: Additional visibility, particulate matter (PM) components, gaseous species and meteorological data during 2003-2005 within and surrounding the Gorge were collected and archived[1].

Haze Gradient Study: Visibility (nephelometer) and meteorological measurements within the Gorge were analyzed to better understand the causes and movement of visibility impairing pollutants in the Gorge and identified episodes for more detailed analysis[2].

Causes of Haze in the Gorge (CaHaGo) Study: Understanding the cause(s) of haze in the Gorge were enhanced through analyses of additional aerosol chemical composition data that resulted from a follow up work effort to the Haze Gradient Study[3].

Modeling Analysis: Meteorological, emissions, and air quality modeling were conducted to assess base year (2004) and projected year (2018) trends in visibility impairment, to develop an assessment of source apportionment by type and region, and to test several "what-if" scenarios for future year conditions[1].

To meet the goals of the Gorge Study, chemical transport modeling was performed using the Comprehensive Air Quality Model with extensions (CAMx), coupled with emission inputs from the U.S Environmental Protection Agency's (EPA) Models-3 Sparse Matrix Operating Kernel Emissions (SMOKE) system, and meteorological inputs from the Pennsylvania State University / National Center for Atmospheric Research (PSU/NCAR), Fifth Generation Mesoscale Model (MM5)[4,5,6,7]. The general approach for the Gorge Study modeling was to leverage the considerable regional visibility modeling work already conducted by the Western Regional Air Partnership (WRAP) Regional Planning Organization (RPO) that addresses the requirements of the federal Regional Haze Rule[8,9].

CAMx was used to simulate two season-representative high PM/extinction episodes with a wide array of sensitivity tests and Probing Tool applications for two, 2004 base year episodes and corresponding 2018 future year episodes: a summer period – August 10-22; and an autumn period – November 4-18. Modeling was conducted on a series of telescoping nested grids with resolution of 36 km-12 km-4 km, with the finest high-resolution grid (i.e., 4 km) focusing on the Gorge area (Figure 1).

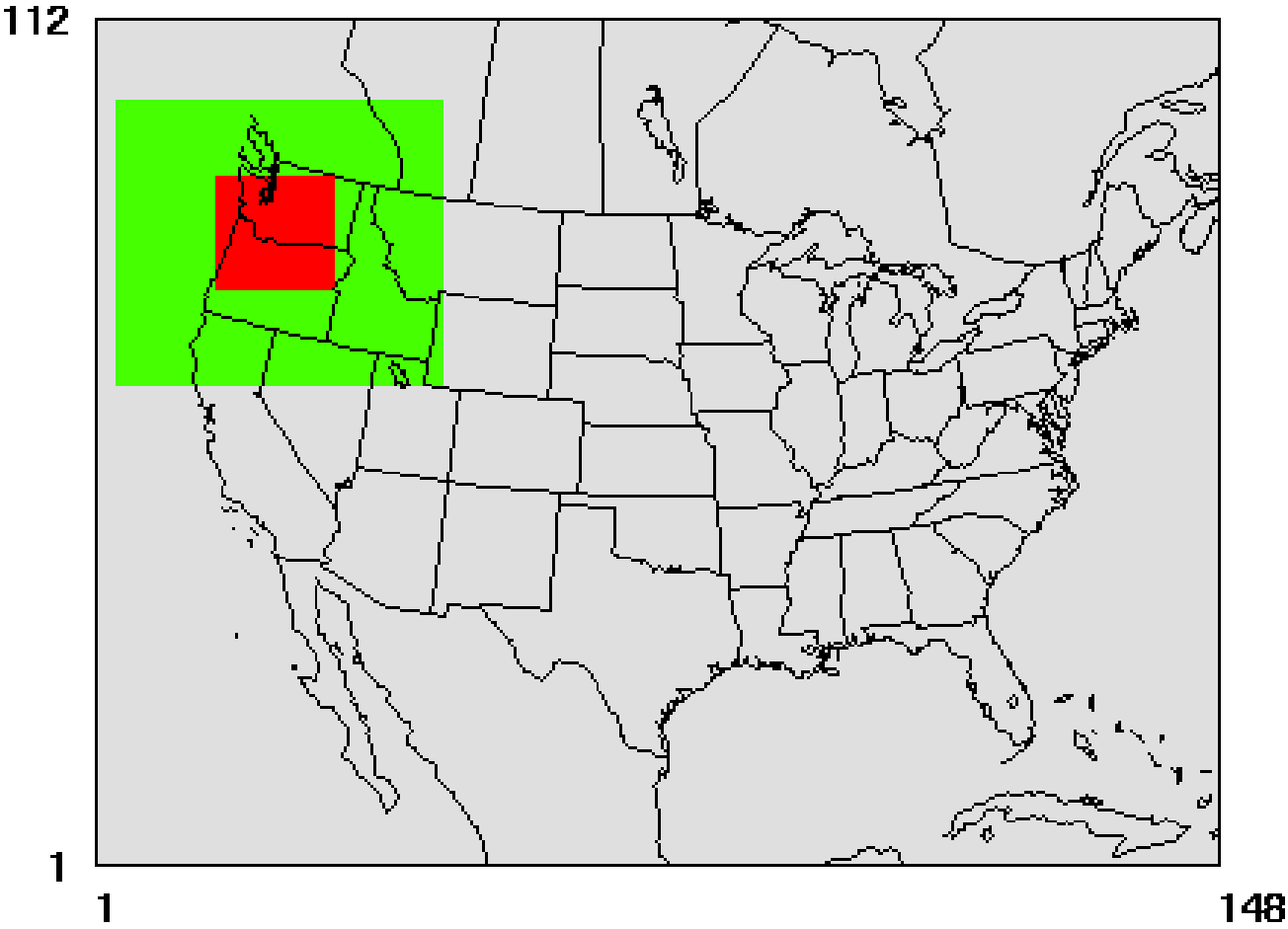


Figure 1. Air quality modeling domain for the Columbia Gorge Air Quality Modeling Study. Outer grid (grey) represents the 36 km domain; middle grid (green) represents the 12 km domain; and inner grid (red) represents the 4 km domain.

The Gorge Study Team expended significant effort developing refined episode-specific emissions for the two 2004 modeling episodes on the 4 km Oregon/Washington grid. 2004 Oregon and Washington emissions data were used for the 4 km domain[10]. The 2002 WRAP emission inventory was grown to 2004 and used for areas outside the 4 km grid[11,12]. Base case air quality model performance was evaluated for the two specific episodes simulated using operational and diagnostic techniques[1,14]. A 2018 future year was also simulated for both episodes to obtain a visibility forecast trend line for the Gorge monitoring sites. The WRAP 2018 emission projections[13] were used for this estimate for all grids, but included additional emission reductions that will be applied to two specific large PM sources by 2018: the Boardman power plant near the eastern end of the Gorge, and the Camas pulp mill at the western end of the Gorge[14].

The CAMx PM Source Apportionment Technology (PSAT) probing tool was used to assess source category and region-specific attribution to sulfate, nitrate, carbonaceous, and primary particulates at several monitoring sites within the Gorge[14, 15]. PSAT was applied for both 2004 base and 2018 future years. Finally, a group of five "what-if" scenarios were simulated to provide estimated visibility improvements with the removal (or significant reduction) of emissions from specific sources[1,14].

Overall the MM5/SMOKE/CAMx modeling system properly replicated the extensive set of PM and light scattering data that was collected as part of the Haze Gradient and "CaHaGo" field studies in 2004[1,14]. The modeling system performed well in characterizing the distributions of individual PM species concentrations that were important in contributing to visibility-impairing haze over each episode. This further translated to a proper characterization of light scattering levels measured at each

site and each episode. Results are as good, and in many ways better, than regional modeling results in the Pacific Northwest area as conducted by the WRAP to address regional visibility/haze rules. The in-depth analyses undertaken in this modeling project have established confidence that the modeling system appropriately projects the individual PM constituent concentrations and resulting visibility impacts into the 2018 future year (according to the WRAP 2018 inventory projections), from which visibility trend lines were constructed.

BODY

Overview of the Emissions Processing for the Columbia River Gorge National Scenic Area Air Quality Study

2004 Base Case Emissions

Spatially and temporally resolved estimates of sulfur dioxide (SO2), volatile organic compounds (VOC), nitrogen oxides (NOx), carbon monoxide (CO), ammonia (NH3), PM and other chemicals from sources such as electric generating utilities (EGUs), pulping mills, automobiles, commercial marine shipping activities, railroad locomotives, natural vegetation (biogenic), and fires (both natural and prescribed) to name a few sources, are critical inputs to an air quality model.

The Southwest Clean Air Agency (SWCAA) and the Oregon Department of Environmental Quality (ODEQ) provided local 2004 annual stationary, area, and non-road mobile source emissions estimates (projected from the 2002 National Emissions Inventory [NEI]) for counties in Washington and Oregon, respectively[10]. SWCAA and ODEQ also provided wildfire and prescribed fire activity data that were used to estimate fire emissions[10]. Finally, SWCAA and ODEQ provided day-specific emissions estimates for the Portland General Electric (PGE) Boardman power plant and the Georgia Pacific Camas Mill wood pulping facility[10]. For all other counties within the modeling domain, we used the SMOKE emissions processing system as configured for the WRAP study as a starting point, which included projecting the 2002 WRAP[11,12] county-level annual stationary and non-road emissions to 2004. Additionally, all temporal and speciation profiles and cross-reference data were taken from the WRAP emission processing efforts. Spatial allocation of the emissions to the 4- and 12-km modeling grids was based on profiles and surrogate factors developed specifically for this project using population and landuse/landcover distributions provided by EPA (and as used in the WRAP modeling)[16]. Special attention was given to the development of high resolution surrogate distributions in the OR/WA region and within the Gorge itself, especially as they related to commercial marine shipping.

MM5 temperature and wind fields[14] were used to generate day- and grid-specific biogenic, wind-blown dust, and agricultural ammonia emissions for the Gorge modeling episodes. The EPA national landuse/landcover dataset used to develop spatial surrogates was also used in the estimation of agricultural ammonia emissions. The processing of on-road mobile sources required the use of OR/WA-specific and/or WRAP activity data (roadway locations, vehicle miles traveled [VMT], speed distributions, vehicle fleet mix, etc.)[10].

Volcanic emissions from Mt. St. Helens were estimated for SO2, based on measurements taken in November 2004 (McGee, 2006). This was a period of increasing geologic activity that resulted in escalating emissions from Mt. St. Helens. Based on conversations with scientists at the United States Geological Survey (USGS)[17], there was no significant SO2 emissions activity during August 2004; hence, volcanic emissions for this episode were set to zero. The USGS does not estimate emissions of ash, which could be used as a surrogate for primary PM. However, given that there was no ash plume activity reported in either November or August 2004, primary PM emissions were considered nonexistent. Therefore, only the SO2 emission estimates were used in this effort.

SMOKE was configured to generate model-ready point, area, non-road mobile, on-road mobile, and fire source emissions for the 36/12/4-km grid system; criteria pollutant emissions were speciated according to the Carbon Bond IV (CB4) chemical mechanism with PM. Certain emission subcategories, such as electric generating units (EGU), on-road mobile sources, fires, etc., were processed through the SMOKE system in separate streams in order to support PSAT applications and to allow maximum flexibility in developing and applying alternate strategies in the modeling. Specialized processing was conducted for certain source categories to provide updated and/or day-specific emission estimates for the episodic conditions modeled in this study: large industrial point sources, wildfires, some prescribed fires, on-road mobile, biogenics, wind-blown dust, and agricultural ammonia.

2018 Future Year Emissions

Similar to the 2004 base case, SMOKE was configured to generate model-ready point, area, non-road mobile, on-road mobile, and fire source emissions for the 36/12/4-km grid system for the August and November 2018 future year episodes. The 2018 emission estimates were taken entirely from the WRAP 2018 data sets[13]. However there are several upcoming federal programs that will have substantial emission reductions that are not included in this inventory. In addition, each of the WRAP states continues to make refinements to their inventories for 2018. The WRAP 2018 emissions estimates were modified for the following sources per the direction of the sponsors: the PGE Boardman power plant; the Georgia Pacific Camas Mill pulping plant; and residential wood smoke[10,14].

Per the direction of the study sponsors, the presumptive Best Available Retrofit Technology (BART) limits for NOx and SO2 were used to model emissions from the Boardman coal-fired EGU. For NOx, the BART limit is 0.23 lbs NOx/MMBtu or 1,323 lbs NOx/hour. For SO2, the BART limit is 0.15 lbs SO2/MMBtu or 863 lbs SO2/hour. PM emissions were left unchanged from 2004 though it is anticipated that the PM emissions will decrease once multi-pollutant controls are installed. The study sponsors provided a spreadsheet of hourly NOx, SO2, CO, and PM emissions estimates to be used to represent the Camas facility[10,14]. These estimates are based on the presumptive BART limits and represent a worst case day. As discussed later, errors were found in the 2004 base case emissions estimates for residential wood combustion, which carried over to the 2018 WRAP data base. The 2004 base case emissions estimates were revised and a growth factor of 4%, representing the expected OR/WA population growth to 2018, was applied to estimate the 2018 emissions for this source category.

The 2004 volcanic, biogenic, wind-blown dust, agricultural ammonia source, wildfire, and other fire emission estimates were used in place of the WRAP 2018 emissions estimates. This is standard practice for "natural" sources. As Mt. St. Helens showed no activity in August 2004, no SO2 emissions for the volcano were incorporated in the 2018 August episode so that a consistent anthropogenic projection to 2018 could be made for visibility. The November 2004 Mt. St. Helens SO2 emissions were used in the 2018 November SMOKE modeling, again to remain consistent in the visibility projection. Following the approach used in WRAP, we assumed zero growth in agricultural ammonia emissions.

As with the 2004 base case emissions, certain emission subcategories, such as EGUs, on-road mobile sources, fires, etc., were processed through the SMOKE system in separate streams in order to support the application of CAMx/PSAT and to support additional quality assurance of the emissions estimates.

For a detailed breakdown and comparison of the resulting base and future year episodic emissions by source category and region, please see the project reports on the emissions inventory[10,14].

Quality Assurance of Emissions Data and Estimates

Quality assurance of emissions data and estimates was a dominant theme through the course of the study. Early in the process of developing the air quality modeling protocol, it was determined that a

candid, open review of the emissions was to be performed. The emissions data and estimates were reviewed at three stages: (1) raw data and estimates input to SMOKE; (2) CAMx-ready emissions estimates output from SMOKE; and (3) review of emissions estimates by comparison to CAMx predictions of air quality. It has been our experience that all three stages are conducted at some level in most if not all air quality modeling studies; however, in this study, significant effort was spent in the first stage prior to making an initial SMOKE run.

The first stage proved valuable for the following reasons:

- Eliminated a few emissions source categories (e.g., residential coal combustion) that were none existent in Washington and Oregon;
- Removed duplicated emissions (e.g., commercial marine shipping in the Gorge);
- Through inventory reconciliation between WRAP emissions estimates and sponsor-provided emissions estimates, included numerous WRAP emissions source categories not estimated in the sponsor-provided data;
- Rebuilt the commercial marine shipping surrogate to cover much more of the Columbia River and Willamette River ship channel; and
- Corrected formatting errors in the data sets.

Once we were satisfied that the stage one "shakedown" of the emissions data and estimates had relieved the emissions data base of significant, preliminary errors, SMOKE was run to produce the CAMx-ready emissions estimates. Because a disparate range in technical understanding of emissions data and estimates existed among the numerous stakeholders who desired to review the data, a common form for delivering the data had to be developed. It quickly became apparent that the vast majority of stakeholders wanting to review emissions data had a desire to deploy the emissions in the form of spreadsheets. Fortunately, the SMOKE-processed forms of the emissions estimates (i.e., reports prepared through the use of Smkreport[18]) are amenable to incorporation into spreadsheets – in this case, Microsoft Excel® spreadsheets.

In order to accommodate this need, we developed an Excel workbook with Visual Basic scripts to read the Smkreports that were prepared during a SMOKE run and to recast the data in the Smkreports to a form more suitable for review. Excerpts from the Excel workbook are shown in Figures 2, 3, 4, and 5.

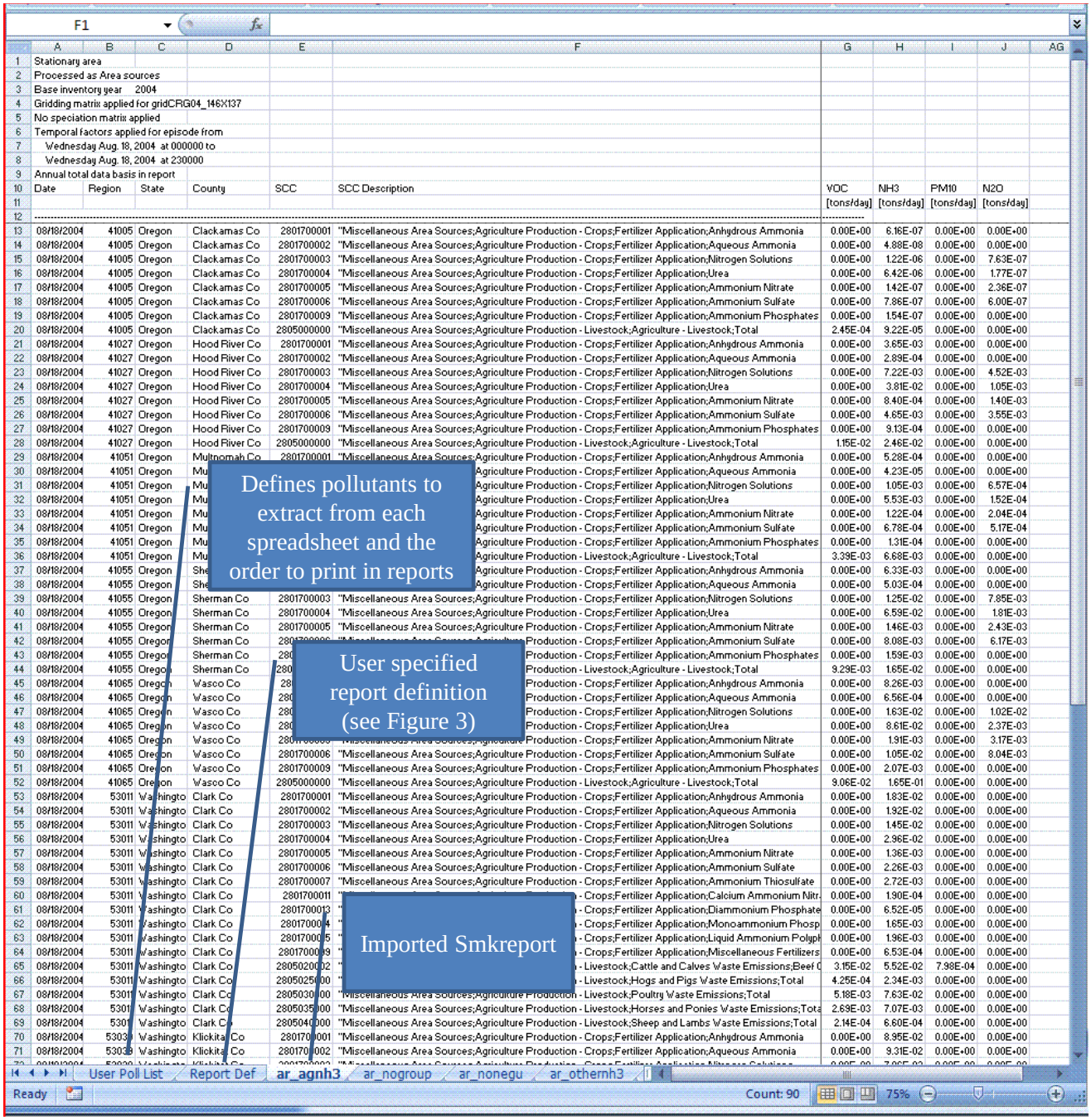


Figure 2. Example of an imported Smkreport -- Area Sources, Agricultural Ammonia. The Excel tab "Report Def" provides a means for a user to define how emissions estimates in the Smkreports can be recast to a form more suitable for review by the user (see Figure 3 for an excerpt of this tab). The Excel tab "User Poll List" identifies the pollutants to extract from the Smkreports (e.g., ar_agnh3) and the order to print the pollutants in the canned and ad-hoc reports.

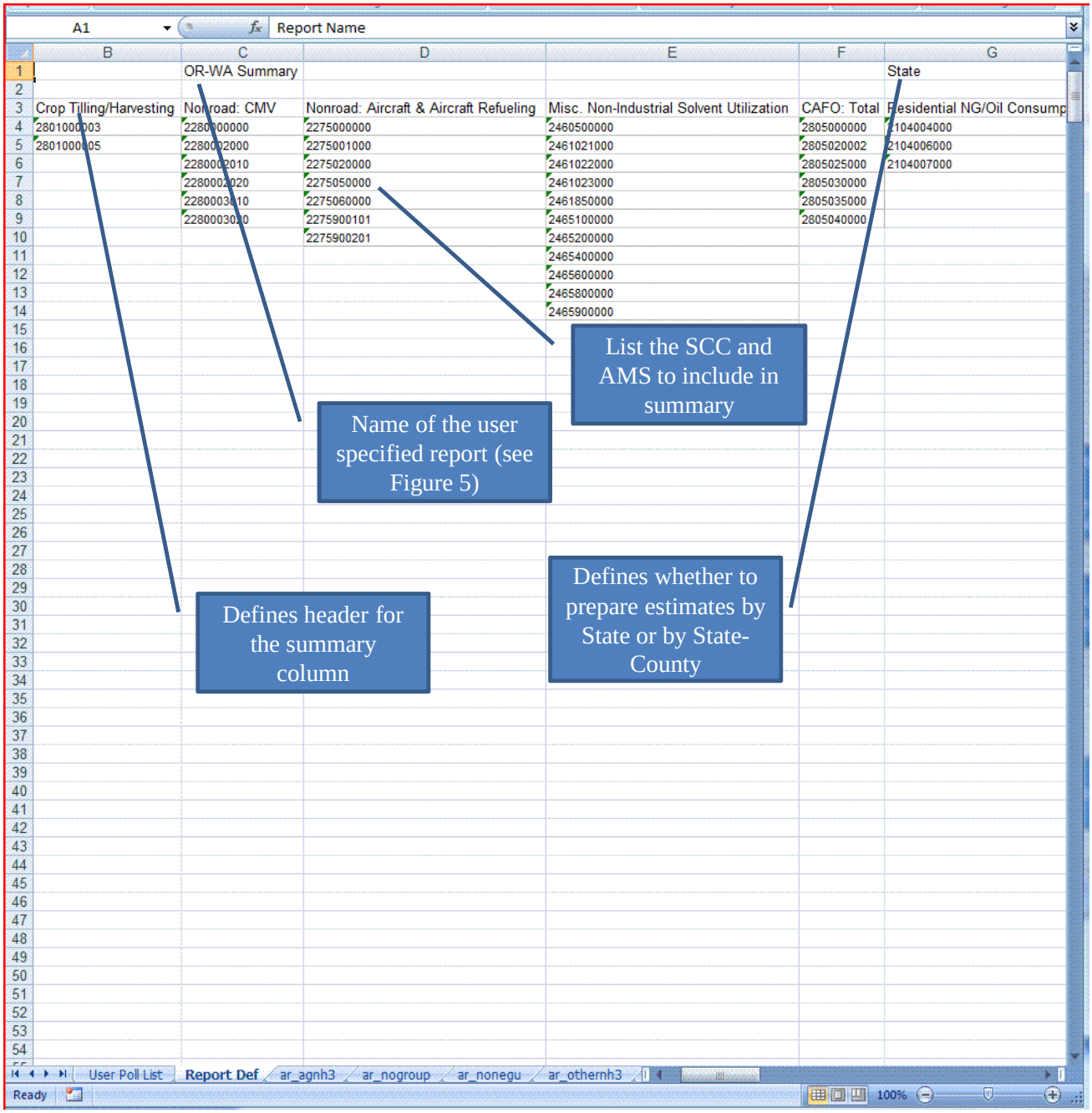
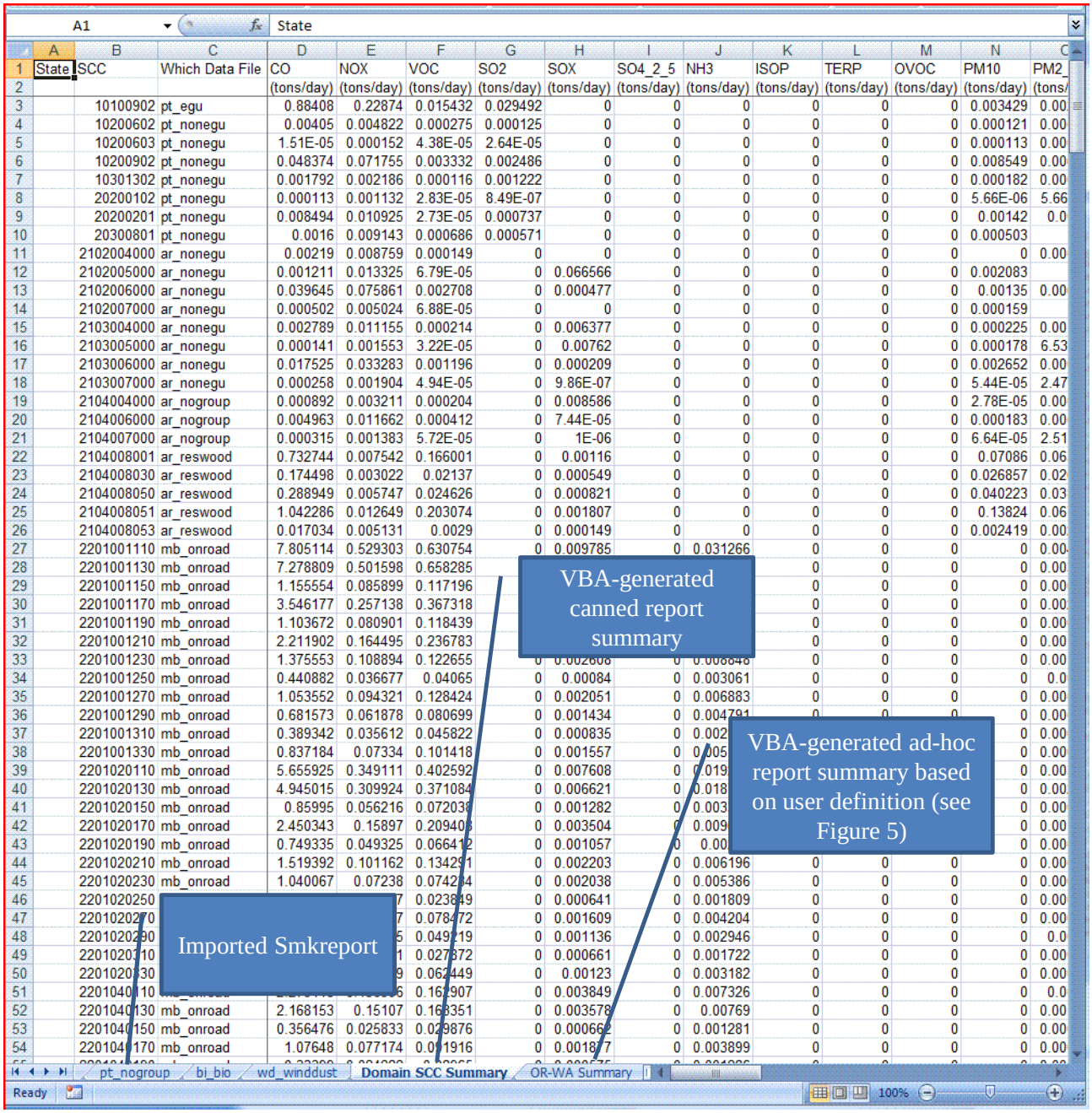


Figure 3. Excerpt of a user specified configuration for an ad-hoc report. The name of this report will appear as an Excel tab named "OR-WA Summary," which is shown in Figure 5. The user specifies column headings (e.g., Crop Tilling/Harvesting) and the list of SCC and AMS codes to include in each category. Further, the user specifies whether to group emissions estimates by "State" or by "State/County" (Column G1).



State	SCC	Which Data File	CO (tons/day)	NOX (tons/day)	VOC (tons/day)	SO2 (tons/day)	SOX (tons/day)	SO4_2_5 (tons/day)	NH3 (tons/day)	ISOP (tons/day)	TERP (tons/day)	OVOC (tons/day)	PM10 (tons/day)	PM2_ (tons/
	10100902	pt_egu	0.88408	0.22874	0.015432	0.029492	0	0	0	0	0	0	0.003429	0.00
	10200602	pt_nonegu	0.00405	0.004822	0.000275	0.000125	0	0	0	0	0	0	0.000121	0.00
	10200603	pt_nonegu	1.51E-05	0.000152	4.38E-05	2.64E-05	0	0	0	0	0	0	0.000113	0.00
	10200902	pt_nonegu	0.048374	0.071755	0.003332	0.002486	0	0	0	0	0	0	0.008549	0.00
	10301302	pt_nonegu	0.001792	0.002186	0.000116	0.001222	0	0	0	0	0	0	0.000182	0.00
	20200102	pt_nonegu	0.000113	0.001132	2.83E-05	8.49E-07	0	0	0	0	0	0	5.66E-06	5.66
	20200201	pt_nonegu	0.008494	0.010925	2.73E-05	0.000737	0	0	0	0	0	0	0.00142	0.0
	20300801	pt_nonegu	0.0016	0.009143	0.000686	0.000571	0	0	0	0	0	0	0.000503	
	2102004000	ar_nonegu	0.00219	0.008759	0.000149	0	0	0	0	0	0	0	0	0.00
	2102005000	ar_nonegu	0.001211	0.013325	6.79E-05	0	0.066566	0	0	0	0	0	0.002083	
	2102006000	ar_nonegu	0.039645	0.075861	0.002708	0	0.000477	0	0	0	0	0	0.00135	0.00
	2102007000	ar_nonegu	0.000502	0.005024	6.88E-05	0	0	0	0	0	0	0	0.000159	
	2103004000	ar_nonegu	0.002789	0.011155	0.000214	0	0.006377	0	0	0	0	0	0.000225	0.00
	2103005000	ar_nonegu	0.000141	0.001553	3.22E-05	0	0.00762	0	0	0	0	0	0.000178	6.53
	2103006000	ar_nonegu	0.017525	0.033283	0.001196	0	0.000209	0	0	0	0	0	0.002652	0.00
	2103007000	ar_nonegu	0.000258	0.001904	4.94E-05	0	9.86E-07	0	0	0	0	0	5.44E-05	2.47
	2104004000	ar_nogroup	0.000892	0.003211	0.000204	0	0.008586	0	0	0	0	0	2.78E-05	0.00
	2104006000	ar_nogroup	0.004963	0.011662	0.000412	0	7.44E-05	0	0	0	0	0	0.000183	0.00
	2104007000	ar_nogroup	0.000315	0.001383	5.72E-05	0	1E-06	0	0	0	0	0	6.64E-05	2.51
	2104008001	ar_reswood	0.732744	0.007542	0.166001	0	0.00116	0	0	0	0	0	0.07086	0.06
	2104008030	ar_reswood	0.174498	0.003022	0.02137	0	0.000549	0	0	0	0	0	0.026857	0.02
	2104008050	ar_reswood	0.288949	0.005747	0.024626	0	0.000821	0	0	0	0	0	0.040223	0.03
	2104008051	ar_reswood	1.042286	0.012649	0.203074	0	0.001807	0	0	0	0	0	0.13824	0.06
	2104008053	ar_reswood	0.017034	0.005131	0.0029	0	0.000149	0	0	0	0	0	0.002419	0.00
	2201001110	mb_onroad	7.805114	0.529303	0.630754	0	0.009785	0	0.031266	0	0	0	0	0.00
	2201001130	mb_onroad	7.278809	0.501598	0.658285					0	0	0	0	0.00
	2201001150	mb_onroad	1.155554	0.085899	0.117196					0	0	0	0	0.00
	2201001170	mb_onroad	3.546177	0.257138	0.367318					0	0	0	0	0.00
	2201001190	mb_onroad	1.103672	0.080901	0.118439					0	0	0	0	0.00
	2201001210	mb_onroad	2.211902	0.164495	0.236783					0	0	0	0	0.00
	2201001230	mb_onroad	1.375553	0.108894	0.122655					0	0	0	0	0.00
	2201001250	mb_onroad	0.440882	0.036677	0.04065	0	0.00084	0	0.003061	0	0	0	0	0.0
	2201001270	mb_onroad	1.053552	0.094321	0.128424	0	0.002051	0	0.006883	0	0	0	0	0.00
	2201001290	mb_onroad	0.681573	0.061878	0.080699	0	0.001434	0	0.004791				0	0.00
	2201001310	mb_onroad	0.389342	0.035612	0.045822	0	0.000835	0	0.002				0	0.00
	2201001330	mb_onroad	0.837184	0.07334	0.101418	0	0.001557	0	0.005				0	0.00
	2201020110	mb_onroad	5.655925	0.349111	0.402592	0	0.007608	0	0.019				0	0.00
	2201020130	mb_onroad	4.945015	0.309924	0.371084	0	0.006621	0	0.018				0	0.00
	2201020150	mb_onroad	0.85995	0.056216	0.072038	0	0.001282	0	0.003				0	0.00
	2201020170	mb_onroad	2.450343	0.15897	0.209408	0	0.003504	0	0.009				0	0.00
	2201020190	mb_onroad	0.749335	0.049325	0.066412	0	0.001057	0	0.00				0	0.00
	2201020210	mb_onroad	1.519392	0.101162	0.134291	0	0.002203	0	0.006196	0	0	0	0	0.00
	2201020230	mb_onroad	1.040067	0.07238	0.074214	0	0.002038	0	0.005386	0	0	0	0	0.00
	2201020250				7 0.023849	0	0.000641	0	0.001809	0	0	0	0	0.00
	2201020270				7 0.078472	0	0.001609	0	0.004204	0	0	0	0	0.00
	2201020290				5 0.049219	0	0.001136	0	0.002946	0	0	0	0	0.0
	2201020310				1 0.027872	0	0.000661	0	0.001722	0	0	0	0	0.00
	2201020330				9 0.062449	0	0.00123	0	0.003182	0	0	0	0	0.00
	2201040110				6 0.162907	0	0.003849	0	0.007326	0	0	0	0	0.0
	2201040130	mb_onroad	2.168153	0.15107	0.168351	0	0.003578	0	0.00769	0	0	0	0	0.00
	2201040150	mb_onroad	0.356476	0.025833	0.029876	0	0.000662	0	0.001281	0	0	0	0	0.00
	2201040170	mb_onroad	1.07648	0.077174	0.091916	0	0.001877	0	0.003899	0	0	0	0	0.00

Figure 4. Example of the canned report named "Domain SCC Summary." This report lists all unique SCC and AMS codes in the Smkreports and summarizes the emissions estimates by pollutant. Further, this canned report identifies from which Smkreport the data were extracted.

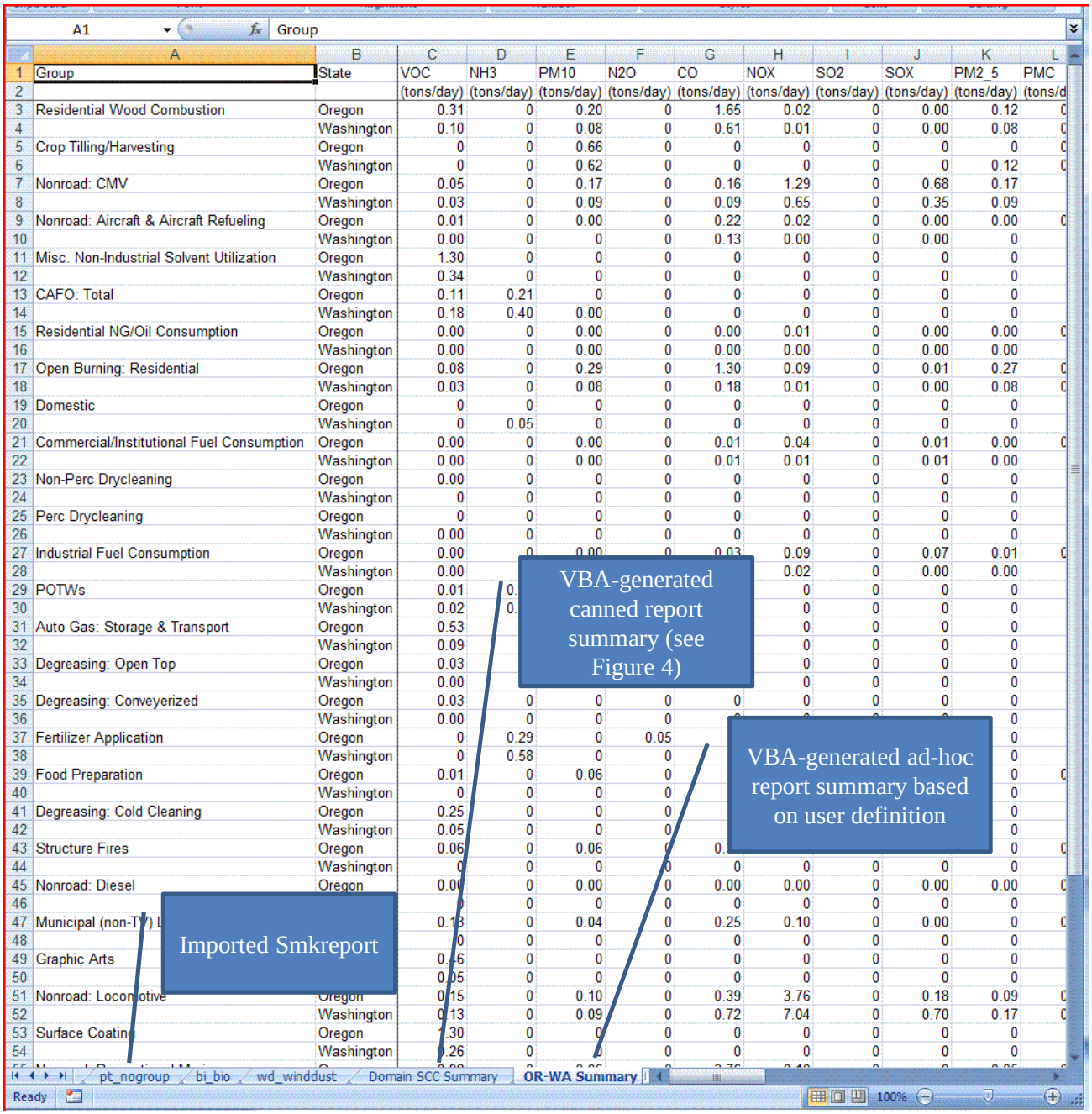


Figure 5. Example of a user specified report which groups emissions estimates per user requirements.

During the second and third stage of the emissions data and estimates review process, these workbooks proved very valuable in identifying errors in the emissions data bases. These workbooks were especially valuable during the third stage of the review process as they served to help link unusual predictions by CAMx with suspect emissions estimates thus providing a critical feedback mechanism that helped to correct errors in the emissions data base.

Upon review of the resulting model-ready emission inventory coupled with a comparison to CAMx predictions, several major issues were identified and rectified:

- Reduction in Residential Wood Smoke: Annual fine PM emissions from residential wood combustion in Oregon and Washington were found to be overstated by a factor of two, based upon an improper interpretation of a 1999 fireplace survey conducted in both states. We thus

applied a 50% reduction to the 2004 annual residential wood combustion categories for both states. Furthermore, since the WRAP 2018 projections for residential wood combustion were found to be too large relative to the revised 2004 estimates, the 2018 emissions for this category were derived from the revised 2004 estimates by applying a 4% growth rate based on published population projections in Oregon and Washington.

- Increase in Agricultural Ammonia: Based on a detailed scrutiny of the Oregon and Washington ammonia inventories against recent emission factors published in the literature[19], two major issues were identified: (1) ammonia emissions from confined animal feeding operations (CAFO), such as dairies and feedlots, were understated by factors of 1.5 to approximately 4; and (2) ammonia emissions from fertilizer application were understated by factors of 2.5 to 3. Ammonia emissions in Oregon and Washington were thus increased on a facility-type (CAFO) and application-type (fertilizers) basis.
- Application of Canopy Escape Factors: It is well known in the air quality modeling field that the impact of fugitive dust sources (such as unpaved and paved road dust; roadway, commercial, and residential construction; and agricultural tilling) on air quality is substantially lower than emissions inventories suggest, often by as much as an order of magnitude[20,21,22]. Numerous studies suggest that removal of fugitive dust occurring near the source, on a scale of tens to hundreds of meters, is beyond the capability of current Eulerian air quality models (e.g., CMAQ, CAMx, etc.) that address scales of 1-10 km. County-specific transport factors were applied to the fugitive dust categories[23,24]. This reduced the amount of fugitive dust that CAMx "saw" by approximately 75%.

Once these major corrections were incorporated the emissions data base was deemed suitable for use in the air quality modeling study.

CONCLUSIONS

CAMx-ready emissions estimates for episodes in August and November 2004, and for the corresponding episodes in 2018, have been developed. Emissions were estimated for a 36 km, 12 km and 4 km modeling domain. Emphasis in this project was focused on developing emissions estimates within the 4 km modeling domain, which covers most of the states of Oregon and Washington. The base data for the emissions estimates were derived from the 2002 and 2018 WRAP emissions data bases. The 2002 WRAP emissions data were grown to 2004 using EGAS-derived growth factors and were replaced or supplemented with 2004 source specific emissions data that were provided by the project sponsors. Day-specific SO2 and NOx emissions for a number of EGUs in Oregon and Washington were extracted from EPA-maintained data bases. The study team prepared estimates of episodic wildfire emissions. The study team revised the commercial marine shipping emissions estimates to better account for spatial distribution of the emissions. The study team prepared estimates of SO2 emissions from Mt. St. Helens. The study team applied canopy escape factors to fugitive dust emissions estimates in an effort to create more realistic estimates from these sources. The study team revised estimates of NH3 emissions from confined animal feeding operations and for certain fertilizer application categories to reflect more current, higher emissions factors. The study team further revised estimates of emissions from residential wood burning operations to reflect more realistic growth assumptions. The sponsors supplied very limited 2018 emissions data; therefore, virtually all 2018 emissions estimates for this study were derived from the 2018 WRAP emissions data base.

Although the 2004 CAMx-ready 4 km domain emission estimates were based on data supplied by the sponsors and the 2018 CAMx-ready 4 km domain emissions estimates were based on data from WRAP, a comparison of the two CAMx-ready data bases revealed that the data sets were consistent in terms of the emission source categories included in each. However, the comparison did reveal a number of inconsistencies and errors that should be addressed in future modeling:

- The Centralia TransAlta power plant in Lewis County, Washington is potentially misplaced in the 2004 data base. Further, the use of Wyoming coal in lieu of local coal at this facility will likely result in a decrease of SO2 emissions in 2018 (currently, the 2018 WRAP data base reflects SO2 emissions using local, high sulfur content coal).
- WRAP's 2002 to 2018 emissions growth for "pulp and paper" and "aluminum ore production," and potentially other industrial source categories, have been overstated based on growth factors in EGAS.
- There appears to be inconsistent growth of NOx emissions for industrial point sources between the PSAT regions "West of Gorge" and "East of Gorge."
- There appears to be an inconsistency in temporal allocation of area source emissions estimates between 2018 and 2004 (i.e., 2004 shows a definite seasonal influence between August and November, whereas in 2018 the emissions are essentially the same); this is especially noticeable in the 12km grid.
- Commercial marine shipping emissions estimates in the Puget Sound area are inconsistent between 2004 and 2018, with 2004 showing far lower emissions than are indicated for 2018.
- The WRAP 2018 inventory could be further refined to account for the numerous federal programs that have been implemented in recent years that will likely have a substantial net reduction in emissions from the following: fuel sulfur content restriction; Maximum Achievable Control Technology (MACT) standards for scores of point and area source categories; and emissions reductions that will be achieved from implementation of BART controls at various industrial sources.

Regardless of these anomalies, the fidelity of the emissions estimates from a qualitative perspective is on par with emissions estimated for similar and regulatory studies conducted throughout the U.S.

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KEY WORDS

Emissions Inventory
Emissions Modeling
SMOKE
PM
CAMX
PSAT
Area Sources
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Quality Assurance