Appendix D: Emission Inventory

Appendix to Chapter 8 of the State Implementation Plan

Emission Inventory Development

Documentation and Description of Emission Inventory Development for WRAP 2002-2018 Emission Inventories

Information is available at the WRAP Technical Support System

http://vista.cira.colostate.edu/TSS/Results/Emissions.aspx

Stationary Point-Source Emissions

1.1

The stationary point source emission category includes those sources that are identified by point locations, typically because they are regulated and their locations are available in regulatory reports. In addition, elevated point sources will have their emissions allocated vertically through the model layers, as opposed to being emitted into only the first model layer. Point sources are often further subdivided into electric generating unit (EGU) sources and non-EGU sources, particularly in criteria inventories in which EGUs are a primary source of NO_x and SO_2. Examples of non-EGU point sources include chemical manufacturers and furniture refinishers. Point sources are included in both criteria and toxics inventories

Stationary point source emissions data for SMOKE consist of (1) Inventory Data Analyzer (IDA)-formatted inventory files; (2) ancillary data for allocating the inventories in space, time, and to the Carbon Bond-IV chemistry mechanism used in CMAQ and CAMx; and (3) meteorology data for calculating plume rise from the elevated point sources.

The development of the stationary point source emission inventories for WRAP regional modeling is described in this section. The discussion focuses on the development of the 2002 Base inventory; emissions modeling for the 2002 Planning inventory and the 2018 base year inventory use the same processing approach. Variations to the modeling approach and specific revisions and enhancements incorporated into the final modeling versions of the inventories have been described previously (refer to the Emission Overview Documentation). Specific revisions are noted with respect to data sources and source categories for the Plan02 and Base18 emissions inventories.

Data Sources

Non-Oil and Gas Sources

For the Base02 stationary point source inventories, actual 2002 data were used. Data sources include emissions developed by the RPOs for the U.S., version 2 of the year 2000 Canadian inventory, and the BRAVO 1999 Mexican inventory. Entirely new inventories for the six northern states of Mexico for stationary area, as well as stationary point, on-road mobile, and off-road mobile sources, were incorporated into the 2002 Planning inventories.   These data were provided by ERG, Inc., who completed an updated 1999 emissions inventory for northern Mexico (Fields et al., 2006) and delivered these data in early 2006.

The WRAP stationary point inventory consisted of annual county-level and tribal data provided by ERG, Inc. (2005). The CENRAP (E.H. Pechan et al., 2005a) and VISTAS (Stella, 2005) stationary point inventories consisted of an annual data set and monthly CEM data for selected EGUs. CENRAP and Alpine Geophysics provided these data directly to the RMC. The MANE-VU and MRPO 2002 stationary point inventories were obtained from the MANE-VU and LADCO web sites, respectively. For the Base02 inventory, the RMC opted to use the summer season inventory to model the entire year for the MANE-VU states (E.H. Pechan et al., 2005b). The MRPO Base I stationary point inventory was used in the Base02 inventory.

ERG, Inc. provided SMOKE-ready temporal profiles and cross-reference files for representing baseline EGU activities in the WRAP states. The RMC worked closely with ERG to refine the cross-references that associate the profiles with actual inventory sources. For additional information on the development and application of these profiles, refer to Fields et al. (2005). Alpine Geophysics, LLC, provided SMOKE-ready temporal profiles and cross-reference files for representing baseline EGU activities for non-WRAP EGUs

The WRAP RMC entered into a nondisclosure agreement with Environment Canada to obtain version 2 of the 2000 Canadian point-source inventory. This inventory represented a major improvement over the version of the data used in the preliminary 2002 modeling. For Mexico, the same BRAVO 1999 inventory used in the preliminary 2002 modeling (Tonnesen et al., 2005) was used for the current Base02 inventory modeling. New inventory data for Mexico developed by ERG for the six northern Mexican states were used for the Plan02 inventories.

The 2018 point area source emission inventories for WRAP, MANE-VU, and VISTAS were developed from county-level input data processed outside SMOKE. For the MRPO and CENRAP regions, 2018 projection factors (growth and control) were applied to the Plan02 inventories. For all non-WRAP EGU sources, updated temporal profiles, as developed from the IPM for 2018 emissions were used

The Base02 inventory used updated meteorology data and improved the temporal allocation information relative to the preliminary 2002 modeling; the rest of the ancillary data for modeling stationary point sources remained the same (Tonnesen et al., 2005). The meteorology data that used to calculate plume rise for the elevated sources was version 2 of the 2002 MM5 data preprocessed for SMOKE and CMAQ with MCIP version 2.3 (Kemball-Cook et al., 2005). One major improvement to the temporal allocation data based on information provided by the VISTAS RPO was incorporated. For the VISTAS sources, we added EGU-based CEM profiles developed by Alpine Geophysics were included in the SMOKE modeling. These additions included new monthly profiles and month-specific weekly and diurnal profiles.

Oil and Gas Production Operations

The 2002 Base year emission inventory included a number of emissions sectors that WRAP had never modeled before, including oil and gas production operations. Emissions from oil and gas production operations have been sporadically reported by some states in their stationary area source inventories, but for the most part were missing from the modeling inventories. In the Base02 inventories, oil and gas production emissions were represented explicitly as both area and point sources in a handful of states across the WRAP region.

The oil and gas production emissions inventories for the WRAP states and for tribal lands in the WRAP region were provided as stationary area source and stationary point source IDA-formatted inventories. ERG, Inc. provided the point-source inventories with the rest of the stationary-point data (ERG, 2005a). ENVIRON provided the area source oil and gas inventories for non-CA WRAP states and for tribal lands in the WRAP region, along with spatial surrogates for allocating these data to the model grid (Russell and Pollack, 2005). For California, oil and gas inventories were extracted from the stationary area source data used in the preliminary 2002 modeling. Oil and gas production emissions data for outside of the WRAP region, if they exist, are contained in the stationary area inventories received from the other RPOs.

For 2018, ENVIRON and ERG provided projected inventory data for oil and gas operations for the WRAP states. Projection factors were used for all other RPOs.

Emissions Modeling

<u>Non-Oil and Gas Sources</u>

For Base02 emission inventory, SMOKE was configured to process the annual inventories for the U.S., Canada, and Mexico and process hourly CEM data for the VISTAS and CENRAP states. SMOKE was configured to allocate these emissions up to model layer 15, which roughly corresponds to the maximum planetary boundary layer (PBL) heights across the entire domain throughout the year. As coarse particulate matter (PMc) is not an inventory pollutant but is required by the air quality models as input species, SMOKE was set to calculate PMc during the processing as (PM_{10} - $PM_{2.5}$). Also, the SMOKE option WKDAY_NORMALIZE set to "No," to treat the annual inventories based on the assumption that they represent average-day data based on a seven-day week, rather than average weekday data. It was also assumed that all of the volatile organic compound (VOC) emissions in the inventories are reactive organic gas (ROG), and thus used SMOKE to convert the VOC to total organic gas (TOG) before converting the emissions into CB-IV speciation for the air quality models. To capture the differences in diurnal patterns that are contained in the CEM temporal profiles for the VISTAS and CENRAP states, SMOKE was configured to generate daily temporal matrices, as opposed to using a Monday-weekday-Saturday-Sunday (MWSS) temporal allocation approach.

The quality assurance of the stationary point emissions followed the WRAP emissions modeling QA protocol (Adelman, 2004) and a suite of graphical summaries. Tabulated summaries of the input data and SMOKE script settings were used to document the data and configuration of SMOKE. The graphical QA summaries include, for all emissions output species, daily time-series plots, annual time-series plots, and daily vertical profiles. These QA graphics are available at
http://pah.cert.ucr.edu/aqm/308/QA_base02a36.plots/pt/plots/

As part of the QA process for new emissions scenarios, qualitative and quantitative comparisons are made between sequential cases to confirm that the results show the expected changes based on the incremental updates that are made between cases. The comparison of the Plan02 emissions results with Base02 results was consistent with the revisions, as expected, except for the non-WRAP stationary point sources. Observed differences in these emissions were much larger than expected, considering that only the temporal profiles were updated for these sources. It was discovered that the IPM-derived temporal profiles used in Plan02 for the non-WRAP stationary point sources were intended for use only with IPM-projected 2018 inventories, not with the 2002 inventories. The use of these profiles caused the 2002 emissions for non-WRAP EGUs to increase dramatically in case Plan02. The IPM-derived temporal profiles were therefore replaced with baseline CEM temporal profiles calculated as 2000-2003 activity averages for the VISTAS states and with actual 2002 CEM-derived temporal profiles for the CENRAP, MANE-VU, and MRPO states.

Oil and Gas Emissions

The oil and gas production industry includes a large number of processes and equipment types that stretch from the wellhead to fuel distribution networks. Many of these processes emit significant quantities of nitrous oxides (NOx), volatile organic compounds (VOC) and other pollutants. Past emission inventories have estimated emissions from specific pieces of equipment, for limited geographic areas and for other segments of the industry. The largest oil and gas production facilities, gas plants and major compressor stations, have been previously inventoried as stationary sources. All states in the western region had previously compiled emission inventories for the year 2002 that included the major "point" emission sources in the oil and gas production industry. However, what was included in these emission inventories varied from state to state, depending on the permitting and/or reporting thresholds.

Oil and gas production facilities that are geographically distributed and have lesser emissions than the point source threshold are considered area sources. Previously, there had not been a comprehensive emission inventory of oil and gas production operations in the western region that covered both point and area sources. Nor had there been a methodology developed to produce an inventory of this scope. The current WRAP inventory of oil and gas emissions was developed by ENVIRON as part of a WRAP-funded study to develop and implement a uniform procedure for estimating area source emissions from oil and gas production operations across the western region (Russell and Pollack, 2005). The emphasis of this study was placed on estimating emissions of pollutants with the potential to impair visibility near Class I areas in the west, in particular NOx emissions. In developing the emission estimation methodology, considerable resources were devoted to incorporating the insights and guidance of a variety of stakeholders, as well as integrating the point source emissions estimates developed in previous inventory efforts.

The 2002 oil and gas point source emissions have been adopted from the state inventories (ERG, 2005a). The level of coverage in those inventories was evaluated and the point source emissions have been reconciled with emissions estimated using the newly developed area source inventory methodology.

Oil and gas point source emission inventories include location parameters. For the current oil and gas area source emissions, a new spatial allocation scheme was developed to facilitate the integration of these emissions sources into the WRAP regional haze modeling. New spatial surrogates were developed for each of the non-point oil and gas emission sources addressed by this inventory. These surrogates, which are based on the geographic locations of oil and gas production, will enable the appropriate spatial distribution of emissions from oil and gas production operations in the air quality modeling.

Finally, a procedure was formulated and implemented to project the emissions from oil and gas production operations to future year 2018. For the WRAP 2018 base case modeling, only those emission control strategies that have already been adopted are considered. Oil and gas production forecasts were drawn from several sources and combined with the emissions estimates produced for the 2002 inventory and information on future controls to arrive at the 2018 inventory. Oil and gas point source projections are described in a separate report (ERG, 2005b).

Inventoried Sources

The WRAP Oil and Gas inventory was developed for a number of specific processes and equipment not previously inventoried. Emissions were estimated and modeled as both stationary point and distributed area sources. Major sources of NOx and VOC emission were the focus of the inventory.

Major sources of NOx emissions include the following processes and equipment types:

- Compressor engines
- Drill rigs
- Wellheads
- CBM pump engines

Major sources of VOC emissions include the following processes and equipment types:

- Oil well tanks
- Oil well pneumatic devices
- Gas well pneumatic devices
- Gas well dehydrators
- Gas well flaring and venting
- Condensate tanks

For each of these equipment types and processes, new and/or revised estimation methodologies were developed and applied. A detailed discussion of these methodologies can be found in Russell and Pollack, 2005.

Spatial Allocation

For air quality modeling, the EPA default spatial allocation surrogates were not appropriate for the area source oil and gas production emissions. ENVIRON therefore developed a new set of spatial allocation surrogates to be used in SMOKE to allocate the county-level area source emissions to the appropriate oil and gas fields. Oil and gas operation emissions estimated as stationary point sources are allocated based on geographic coordinates.

A total of four different surrogate categories were designed to allocate emissions from the twelve oil and gas emission source categories listed in Table 1. The oil, gas and water production surrogates were based on production data at known well locations, while the drill rig surrogate was based solely on the number and location of wells drilled.

Table 1. Emission sources and surrogate categories.

Source	SCC	Allocation Surrogate	Surrogate Code
Drill rigs	2310000220	Drill Rigs	688
Oil well - heaters	2310010100	Oil Production	686
Oil well - tanks	2310010200	Oil Production	686
Oil well - pneumatic devices	2310010300	Oil Production	686
Compressor engines	2310020600	Gas Production	685
Gas well - heaters	2310021100	Gas Production	685
Gas well - pneumatic devices	2310021300	Gas Production	685
Gas well - dehydration	2310021400	Gas Production	685
Gas well - completion	2310021500	Gas Production	685
CBM pump engines	2310023000	Water production at CBM wells	687
Gas well - tanks, uncontrolled	2310030210	Gas Production	685
Gas well - tanks, controlled	2310030220	Gas Production	685

Once the well locations were known, creation of the surrogates took place in several steps, and relied on the use of ArcINFO GIS software.

1. All wells and drill rigs were labeled with the appropriate grid cell IJ values for the 36-km domain.
2. For each individual well, the oil, gas and water production values were divided by the total oil, gas and water production values corresponding to the county in which the well was located. This division resulted in determination of the fraction of a county's total production taking place at each well. In the case of drill rigs, the number of drills, rather than the production values, were used.
3. For each unique grid cell / county combination with wells, each well's production fractions were summed to create the surrogate value.

The surrogate values for each grid cell / county combination were reformatted to comply with the SMOKE emissions processor AGPRO file format and an accompanying SMOKE AGREF file was created. The purpose of the AGREF file, presented in Table 2, is to define the relationship between the 3-digit codes chosen to represent each of the four surrogate categories in the AGPRO file and the SCC codes for the twelve oil and gas emission categories to be allocated with these surrogates. This file also specifies which county/state/county (COSTCY) should use the given cross-reference. In this case, COSTCY is set to 000000 to indicate that all states and counties can use these cross-references.

Table 2. SMOKE gridding surrogate cross-reference (AGREF) file.

COSTCY	SCC	CODE
000000	2310000220	686
000000	2310010100	688
000000	2310010200	686
000000	2310010300	686
000000	2310020600	686
000000	2310021100	685
000000	2310021300	685
000000	2310021400	685
000000	2310021500	685
000000	2310023000	687
000000	2310030210	685
000000	2310030220	685

2018 Projection Methodology

The 2018 emission estimates from oil and gas production operations reflect the anticipated 2018 emission levels with the future controls currently defined by state and federal regulation. The 2018 oil and gas point source emissions inventory was prepared and reported separately by Eastern Research Group (ERG, 2005b). A detailed discussion of the development of the 2018 oil and gas inventory, including those sources modeled as area sources can be found in Russell and Pollack, 2005.

There were two primary basic methods used to estimate 2018 county-level oil and gas emissions. The first and by far the dominant method was to develop growth factors that were then used to project from the 2002 oil and gas emissions. A second method was necessary to estimate emissions in the handful of counties that had no 2002 oil and gas emissions but are anticipated to see oil and gas development by 2018. The decision of which method was used to estimate 2018 emissions was based on the existence of oil and gas emissions in 2002. Detailed discussions of each of the projection methods, data sources and methodologies for both cases are presented in Russell and Pollack, 2005.

To QA the oil and gas production emissions, we used the WRAP emissions modeling QA protocol (Adelman, 2004) and a suite of graphical summaries. Comparisons of the spatial plots produced from SMOKE output with spatial plots provided by ENVIRON were reviewed to ensure these data were modeled correctly. Tabulated summaries of the input data and SMOKE script settings were used to document the data and configuration of SMOKE. The graphical QA summaries include, for all emissions output species, daily spatial plots, daily time-series plots, and annual time-series plots are available at http://pah.cert.ucr.edu/aqm/308/QA_base02a36.plots/wog/plots/.

Gridded Stationary Point Source Emission Inventory Summaries

Summaries of the gridded point source emissions for the Base02b, Plan02c and Base18b inventories by state and county, annual and seasonal periods, can be found on the TSS at: http://vista.cira.colostate.edu/tss/Results/Emissions.aspx.

References

Adelman, Z. 2004: Quality Assurance Protocol – WRAP RMC Emissions Modeling with SMOKE, Prepared for the WRAP Modeling Forum by the WRAP Regional Modeling Center, Riverside, CA.

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U.S. EPA (U.S. Environmental Protection Agency), 2005d: North American Emission Inventories – Canada, http://www.epa.gov/ttn/chief/net/canada.html.

1.2 Area Source Emissions

The stationary area source emission category includes those sources that are treated as being spread over a spatial extent (usually a county or air district) and that are not movable (as compared to off-road mobile and on-road mobile sources). Because it is not possible to collect the emissions at each point of emission, they are estimated over larger regions. Examples of stationary area sources are residential heating and architectural coatings. Numerous sources, such as dry cleaning facilities and oil and gas production facilities, may be treated either as stationary area sources or as point sources, or a combination of both.

Stationary area source emissions data for SMOKE modeling consist of IDA-formatted inventory files and ancillary data for allocating the inventories in space, time, and to the Carbon Bond-IV chemistry mechanism used in CMAQ and CAMx. The development of the area source emission inventory is described in this section.

1.2.1 Source Categories

In addition to the typical area source emission categories, the WRAP RMC included the following emission source categories in the development of the inventories for this sector:

- Stationary area sources
- Agricultural and natural ammonia emission sources
- Oil and gas production operations
- Biogenic emissions

The development of each of these sectors is described below. The discussion focuses on the development of the 2002 Base inventory; emissions modeling for the 2002 Planning inventory and the 2018 base year inventory use the same processing approach. Variations to the modeling approach and specific revisions and enhancements incorporated into the final modeling versions of the inventories have been described previously (refer to the Emission Overview Documentation). Specific revisions are noted with respect to data sources and source categories for the Plan02 and Base18 emissions inventories.

Data sources

The data sources used in the development of the area sources emissions inventory for the WRAP modeling efforts are documented below.

<u>Stationary Area Sources</u>

The Base02 stationary area source inventories used actual 2002 data developed by the RPOs for the U.S., version 2 of the year 2000 Canadian inventory, and the BRAVO 1999 Mexican inventory. The WRAP stationary area inventory consists of annual county-level and tribal data provided by ERG, Inc. (2005), however, due to the small contribution of the WRAP tribal inventories to the total domain emissions and the lack of readily available spatial allocation data for these parts of the domain, the WRAP tribal data was not incorporated into the final modeling inventories. The CENRAP (E.H. Pechan et al., 2005) and VISTAS Phase II (Stella, 2005) stationary area inventories also consisted of an annual data set and were provided by these RPOs. The MANE-VU and MRPO 2002 stationary area inventories were obtained from the MANE-VU and LADCO websites, respectively.

For Mexico, the same BRAVO 1999 inventory that was used in the preliminary 2002 modeling (Tonnesen et al., 2005), was used in the development of the Base02 inventories. Entirely new inventories for the six northern states of Mexico for stationary area, as well as stationary point, on-road mobile, and off-road mobile sources, were incorporated into the 2002 Planning inventories.   These data were provided by ERG, Inc., who completed an updated 1999 emissions inventory for northern Mexico (Fields et al., 2006) and delivered these data in early 2006 For Canada, the Canadian 2000 inventory version 2, obtained from the U.S. EPA EFIG (U.S. EPA, 2005) was used.

The 2018 area source emission inventories for WRAP, MANE-VU, and VISTAS were developed from county-level input data processed outside SMOKE. For the MRPO and CENRAP regions, 2018 projection factors (growth and control) were applied to the Plan02 inventories; Mexico and Canada data were held constant at 2002 levels.

Agricultural and Natural Ammonia Emissions

Ammonia emissions from agricultural sources (livestock operations and fertilizer application) and natural sources (soil ammonia emissions), were derived from 2002 data and used in the WRAP RMC GIS-based NH3 emissions model. The development of emission inventories from this source sector, and specific data sources used, is described in more detail below and also in Mansell (2005)

CENRAP and MRPO provided monthly IDA-formatted inventories produced from process-based models of their own, along with temporal profiles and spatial cross-reference information for these sources. The rest of the U.S., Canada, and Mexico had agricultural NH_3 emissions contained within their annual stationary area source inventories

The 2018 ammonia source emission inventories for WRAP, MANE-VU, and VISTAS were held constant at 2002 levels. For the MRPO and CENRAP regions, 2018 projection factors (growth and control) applied to the Plan02 inventories. Mexican and Canadian data were held constant at 2002 levels.

Oil and Gas Production Operations

The 2002 Base year emission inventory included a number of emissions sectors that WRAP had never modeled before, including oil and gas production operations.

Emissions from oil and gas production operations have been sporadically reported by some states in their stationary area source inventories, but for the most part were missing from the modeling inventories. In the Base02 inventories, oil and gas production emissions were represented explicitly as both area and point sources in a handful of states across the WRAP region.

The oil and gas production emissions inventories for the WRAP states and for tribal lands in the WRAP region were provided as stationary area source and stationary point source IDA-formatted inventories. ERG, Inc. provided the point-source inventories with the rest of the stationary-point data (ERG, 2005a). ENVIRON provided the area source oil and gas inventories for non-CA WRAP states and for tribal lands in the WRAP region, along with spatial surrogates for allocating these data to the model grid (Russell and Pollack, 2005). For California, oil and gas inventories were extracted from the stationary area source data used in the preliminary 2002 modeling. Oil and gas production emissions data for outside of the WRAP region, if they exist, are contained in the stationary area inventories received from the other RPOs.

For 2018, ENVIRON and ERG provided projected inventory data for oil and gas operations for the WRAP states. Projection factors were used for all other RPOs.

<u>Biogenic Emissions</u>

For Base02 biogenic emissions inventories, the BELD3 land use data and biogenic emissions factors collected during the WRAP preliminary 2002 modeling (Tonnesen et al., 2005) were used. These data included BELD3 1-km resolution land use estimates and version 0.98 of the BELD emissions factors. The Base02 biogenic emissions modeling differed from the preliminary 2002 modeling in the use of improved 2002 meteorology data we developed in 2005 (Kemball-Cook et al., 2005). Biogenic emissions are held constant for the 2018 future year modeling inventories.

Emissions Modeling

To prepare the stationary area inventories for modeling, several modifications to the inventory files were made by removing selected sources either to model them as separate source categories or to omit them from the Base02 inventories completely. Using guidance provided by EPA (U.S. EPA, 2004b) fugitive and road dust sources were extracted from all stationary area source inventories for adjustment by transport factors and modeling as separate source categories (seethe Fugitive Dust Emissions documentation). The stage II refueling sources were also extracted and discarded from the non-WRAP U.S. inventories; these sources were modeled with MOBILE6 as part of the on-road mobile-source emissions. The stage II refueling emissions in the WRAP stationary area inventory were retained because the on-road mobile inventory for this region did not contain these emissions.

Additional steps performed to prepare the area source inventories included moving oil and gas sources from the California inventory to a separate file for explicit treatment, confirming that there is no overlap between the anthropogenic NH_3 inventory and stationary area sources, moving several off-road mobile SCCs from the Mexico inventory to the off-road mobile sector, and moving area source fires in each regional inventory to separate files. In addition to these inventory modifications, a few changes to the ancillary data files for the Base02 inventories were made.

Base02 used improved temporal and spatial allocation information relative to the preliminary 2002 modeling; the rest of the ancillary data for modeling stationary area sources remained unchanged from the preliminary 2002 modeling (Tonnesen et al., 2005). Enhanced spatial allocation data with additional area-based surrogates were incorporated for Canada, and additional surrogates for Broomfield County in Colorado were used.

Improvements to the temporal allocation data for the Base02 inventories included the addition of several FIPS-specific profiles provided by VISTAS and CENRAP. These temporal profiles targeted mainly fire and agricultural NH_3 sources in these regions, such as open burning and livestock operations, respectively.

The quality assurance of the area source emissions followed the WRAP emissions modeling QA protocol (Adelman, 2004) and a suite of graphical summaries. Tabulated summaries of the input data and SMOKE script settings were used to document the data and configuration of SMOKE. The graphical QA summaries include, for all emissions output species, daily time-series plots, annual time-series plots, and daily vertical profiles. These QA graphics are available on the RMC web site at http://pah.cert.ucr.edu/aqm/308/QA_base02a36.plots/ar/plots/.

Ammonia Emission Sources

Ammonia (NH_3) emissions from agricultural activities are a major source of ammonia and are dependent on many different environmental parameters, such as meteorology, crop and soil types, and land use. Traditionally these emissions have been represented in the stationary-area-source inventory as annual, county-level estimates. These estimates did not consider meteorology, and may have used different land use assumptions than were used in the air quality model simulations to which they were input. The WRAP funded development of a process-based agricultural NH_3 emissions model to estimate NH_3 emissions from several different agricultural sources (such as soils, livestock, and fertilizer application) that uses the same meteorology and land use assumptions that are used in CMAQ and CAMx.

The WRAP NH_3 emissions were prepared outside of SMOKE using the WRAP NH_3 model; details of this modeling are available in Mansell (2005). Due to an incorrect assumption in the soil emission factor used in the model, however, we had to discard the emissions from this sector. The WRAP NH_3 model emissions estimates were combined with data provided by the other RPOs to represent agricultural NH_3 emissions in Base02 modeling inventories. CENRAP and MRPO provided monthly IDA-formatted, county-level NH_3 inventories that they developed with their own process-based models. These emissions were modeled as area sources with SMOKE, applying the temporal profiles and the spatial cross-referencing received from these RPOs. The agricultural NH_3

emissions for the rest of the RPOs, Canada, and Mexico are contained within their stationary area inventories. The SMOKE default temporal profiles and spatial surrogates were applied to all non-process-based NH_3 emissions.

The quality assurance of the ammonia emissions followed the WRAP emissions modeling QA protocol (Adelman, 2004) and a suite of graphical summaries. Tabulated summaries of the input data and SMOKE script settings were used to document the data and configuration of SMOKE. The graphical QA summaries include, for all emissions output species, daily time-series plots, annual time-series plots, and daily vertical profiles. These QA graphics are available at http://pah.cert.ucr.edu/aqm/308/QA_base02a36.plots/nh3/plots/.

Oil and Gas Emissions

The oil and gas production industry includes a large number of processes and equipment types that stretch from the wellhead to fuel distribution networks. Many of these processes emit significant quantities of nitrous oxides (NOx), volatile organic compounds (VOC) and other pollutants. Past emission inventories have estimated emissions from specific pieces of equipment, for limited geographic areas and for other segments of the industry. The largest oil and gas production facilities, gas plants and major compressor stations, have been previously inventoried as stationary sources. All states in the western region had previously compiled emission inventories for the year 2002 that included the major "point" emission sources in the oil and gas production industry. However, what was included in these emission inventories varied from state to state, depending on the permitting and/or reporting thresholds.

Oil and gas production facilities that are geographically distributed and have lesser emissions than the point source threshold are considered area sources. Previously, there had not been a comprehensive emission inventory of oil and gas production operations in the western region that covered both point and area sources. Nor had there been a methodology developed to produce an inventory of this scope. The current WRAP inventory of oil and gas emissions was developed by ENVIRON as part of a WRAP-funded study to develop and implement a uniform procedure for estimating area source emissions from oil and gas production operations across the western region (Russell and Pollack, 2005). The emphasis of this study was placed on estimating emissions of pollutants with the potential to impair visibility near Class I areas in the west, in particular NOx emissions. In developing the emission estimation methodology, considerable resources were devoted to incorporating the insights and guidance of a variety of stakeholders, as well as integrating the point source emissions estimates developed in previous inventory efforts.

The 2002 oil and gas point source emissions have been adopted from the state inventories (ERG, 2005a). The level of coverage in those inventories was evaluated and the point source emissions have been reconciled with emissions estimated using the newly developed area source inventory methodology.

Oil and gas point source emission inventories include location parameters. For the current oil and gas area source emissions, a new spatial allocation scheme was developed to facilitate the integration of these emissions sources into the WRAP regional haze modeling. New spatial surrogates were developed for each of the non-point oil and gas emission sources addressed by this inventory. These surrogates, which are based on the geographic locations of oil and gas production, will enable the appropriate spatial distribution of emissions from oil and gas production operations in the air quality modeling.

Finally, a procedure was formulated and implemented to project the emissions from oil and gas production operations to future year 2018. For the WRAP 2018 base case modeling, only those emission control strategies that have already been adopted are considered. Oil and gas production forecasts were drawn from several sources and combined with the emissions estimates produced for the 2002 inventory and information on future controls to arrive at the 2018 inventory. Oil and gas point source projections are described in a separate report (ERG, 2005b).

Inventoried Sources

The WRAP Oil and Gas inventory was developed for a number of specific processes and equipment not previously inventoried. Emissions were estimated and modeled as both stationary point and distributed area sources. Major sources of NOx and VOC emission were the focus of the inventory.

Major sources of NOx emissions include the following processes and equipment types:

- Compressor engines
- Drill rigs
- Wellheads
- CBM pump engines

Major sources of VOC emissions include the following processes and equipment types:

- Oil well tanks
- Oil well pneumatic devices
- Gas well pneumatic devices
- Gas well dehydrators
- Gas well flaring and venting
- Condensate tanks

For each of these equipment types and processes, new and/or revised estimation methodologies were developed and applied. A detailed discussion of these methodologies can be found in Russell and Pollack, 2005.

Spatial Allocation

For air quality modeling, the EPA default spatial allocation surrogates were not appropriate for the area source oil and gas production emissions. ENVIRON therefore developed a new set of spatial allocation surrogates to be used in SMOKE to allocate the county-level area source emissions to the appropriate oil and gas fields. Oil and gas operation emissions estimated as stationary point sources are allocated based on geographic coordinates.

A total of four different surrogate categories were designed to allocate emissions from the twelve oil and gas emission source categories listed in Table 1. The oil, gas and water production surrogates were based on production data at known well locations, while the drill rig surrogate was based solely on the number and location of wells drilled.

Table 1. Emission sources and surrogate categories.

Source	SCC	Allocation Surrogate	Surrogate Code
Drill rigs	2310000220	Drill Rigs	688
Oil well - heaters	2310010100	Oil Production	686
Oil well - tanks	2310010200	Oil Production	686
Oil well - pneumatic devices	2310010300	Oil Production	686
Compressor engines	2310020600	Gas Production	685
Gas well - heaters	2310021100	Gas Production	685
Gas well - pneumatic devices	2310021300	Gas Production	685
Gas well - dehydration	2310021400	Gas Production	685
Gas well - completion	2310021500	Gas Production	685
CBM pump engines	2310023000	Water production at CBM wells	687
Gas well - tanks, uncontrolled	2310030210	Gas Production	685
Gas well - tanks, controlled	2310030220	Gas Production	685

Once the well locations were known, creation of the surrogates took place in several steps, and relied on the use of ArcINFO GIS software.

4. All wells and drill rigs were labeled with the appropriate grid cell IJ values for the 36-km domain.
5. For each individual well, the oil, gas and water production values were divided by the total oil, gas and water production values corresponding to the county in which the well was located. This division resulted in determination of the fraction of a county's total production taking place at each well. In the case of drill rigs, the number of drills, rather than the production values, were used.
6. For each unique grid cell / county combination with wells, each well's production fractions were summed to create the surrogate value.

The surrogate values for each grid cell / county combination were reformatted to comply with the SMOKE emissions processor AGPRO file format and an accompanying SMOKE AGREF file was created. The purpose of the AGREF file, presented in Table 2, is to define the relationship between the 3-digit codes chosen to represent each of the four surrogate categories in the AGPRO file and the SCC codes for the twelve oil and gas emission categories to be allocated with these surrogates. This file also specifies which county/state/county (COSTCY) should use the given cross-reference. In this case, COSTCY is set to 000000 to indicate that all states and counties can use these cross-references.

Table 2. SMOKE gridding surrogate cross-reference (AGREF) file.

COSTCY	SCC	CODE
000000	2310000220	686
000000	2310010100	688
000000	2310010200	686
000000	2310010300	686
000000	2310020600	686
000000	2310021100	685
000000	2310021300	685
000000	2310021400	685
000000	2310021500	685
000000	2310023000	687
000000	2310030210	685
000000	2310030220	685

2018 Projection Methodology

The 2018 emission estimates from oil and gas production operations reflect the anticipated 2018 emission levels with the future controls currently defined by state and federal regulation. The 2018 oil and gas point source emissions inventory was prepared and reported separately by Eastern Research Group (ERG, 2005b). A detailed discussion of the development of the 2018 oil and gas inventory, including those sources modeled as area sources can be found in Russell and Pollack, 2005.

There were two primary basic methods used to estimate 2018 county-level oil and gas emissions. The first and by far the dominant method was to develop growth factors that were then used to project from the 2002 oil and gas emissions. A second method was necessary to estimate emissions in the handful of counties that had no 2002 oil and gas emissions but are anticipated to see oil and gas development by 2018. The decision of which method was used to estimate 2018 emissions was based on the existence of oil and gas emissions in 2002. Detailed discussions of each of the projection methods, data sources and methodologies for both cases are presented in Russell and Pollack, 2005.

To QA the oil and gas production emissions, we used the WRAP emissions modeling QA protocol (Adelman, 2004) and a suite of graphical summaries. Comparisons of the spatial plots produced from SMOKE output with spatial plots provided by ENVIRON were reviewed to ensure these data were modeled correctly. Tabulated summaries of the input data and SMOKE script settings were used to document the data and configuration of SMOKE. The graphical QA summaries include, for all emissions output species, daily spatial plots, daily time-series plots, and annual time-series plots are available at http://pah.cert.ucr.edu/aqm/308/QA_base02a36.plots/wog/plots/.

Biogenic Emissions

The BEIS3.12 model, integrated in SMOKE, was used to prepare biogenic emissions for the Base02 modeling inventories. BEIS3 is a system integrated into SMOKE for deriving emissions estimates of biogenic gas-phase pollutants from land use information, emissions factors for different plant species, and hourly, gridded meteorology data. The results of BEIS3 modeling are hourly, gridded emissions fluxes formatted for input to CMAQ or CAMx.

Most of the preparation for the biogenic emissions processing was completed during the preliminary 2002 modeling. As the modeling domains did not change from the preliminary 2002 to the Base02 modeling, the gridded land use data and vegetation emissions factors prepared for the preliminary simulations were used. The major difference in the emissions processing between the preliminary 2002 and Base02 modeling was in the integration of improved meteorology in the Base02 inventories.

The quality assurance of the biogenic emissions followed the WRAP emissions modeling QA protocol (Adelman, 2004) and a suite of graphical summaries. Tabulated summaries of the input data and SMOKE script settings were used to document the data and configuration of SMOKE. The graphical QA summaries include, for all emissions output species, daily time-series plots, annual time-series plots, and daily vertical profiles. These QA graphics are available at http://pah.cert.ucr.edu/aqm/308/QA_base02a36.plots/b3/plots/.

Gridded Area Source Emission Inventory Summaries

Summaries of the gridded area source emissions for the Base02b, Plan02c and Base18b inventories by state and county, annual and seasonal periods, can be found on the TSS at: http://vista.cira.colostate.edu/tss/Results/Emissions.aspx.

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1.3 Mobile Source Emissions

Introduction

Mobile sources include on-road and off-road vehicles and engines. On-road mobile sources include vehicles certified for highway use – cars, trucks, and motorcycles. For reporting on-road mobile source emissions, vehicles are divided into two major classes – light-duty and heavy-duty. Light-duty vehicles include passenger cars, light-duty trucks (up to 8500 lbs gross vehicle weight [GVW]), and motorcycles. Heavy-duty vehicles are trucks of more than 8500 lbs GVW.

Off-road mobile equipment encompasses a wide variety of equipment types that either move under their own power or are capable of being moved from site to site. Off-road mobile equipment sources are defined as those that move or are moved within a 12-month period and are covered under the EPA's emissions regulations for nonroad mobile sources. Off-road mobile sources are vehicles and engines in the following categories:

- Agricultural equipment, such as tractors, combines, and balers;
- Aircraft, jet and piston engines;
- Airport ground support equipment, such as terminal tractors;
- Commercial marine vessels, such as ocean-going deep draft vessels;
- Commercial and industrial equipment, such as fork lifts and sweepers;
- Construction and mining equipment, such as graders and back hoes;
- Lawn and garden equipment, such as leaf and snow blowers;
- Locomotives, switching and line-haul trains;
- Logging equipment, such as shredders and large chain saws;
- Pleasure craft, such as power boats and personal watercraft;
- Railway maintenance equipment, such as rail straighteners;
- Recreational equipment, such as all-terrain vehicles and off-road motorcycles; and
- Underground mining and oil field equipment, such as mechanical drilling engines.

Road dust emissions estimates are also included in the mobile source emissions category, and are discussed separately with the fugitive dust emissions inventory summary.

Mobile Source Inventory Scope

The scope of the WRAP mobile sources emission inventories is as follows:

> Geographic domain: Emissions were estimated by county for all counties in 14 states: Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming.
>
> Temporal resolution: Emissions were estimated for an average day in each of the four seasons, and for an average annual weekday. Seasons are defined as three-month periods: spring is March through May; summer is June through August; fall is September through November; and winter is December through February.

Emissions were estimated for the 2002 base year and for three future years – 2008, 2013, and 2018.

Pollutants: Emissions were estimated for primary particulate matter (PM_{10} and $PM_{2.5}$), nitrogen oxides (NO_x), sulfur dioxide (SO_2), volatile organic compounds (VOCs), carbon monoxide (CO), ammonia (NH_3), elemental and organic carbon (EC/OC), and sulfate (SO4).

Sources: For all pollutants, emissions were estimated separately by vehicle class for on-road sources and by equipment type/engine type for off-road sources. Emissions were summarized for gasoline and diesel-fueled engines.

Approach For Estimating Mobile Source Emissions

As with most emissions sources, on-road and off-road mobile source emissions are estimated as the products of emission factors and activity estimates. Except for California, the on-road mobile sources emission factors were derived from EPA's MOBILE6 model, available at http://www.epa.gov/OMSWWW/m6.htm. Activity for on-road mobile sources is vehicle miles traveled (VMT). State and local agencies were provided default modeling inputs and VMT levels for base and future years for review and update; all states and several agencies provided updated. The California Air Resources Board (CARB) provided on-road emissions estimates by county and vehicle class directly; these were based on CARB's in-house version of their EMFAC model.

For all states except California, EPA's draft NONROAD2004 model was used to estimate so-called traditional off-road sources[1], all sources listed above except aircraft, commercial marine, and locomotives. The NONROAD model includes estimates of emission factors, activity levels, and growth factors for all traditional off-road sources. The default activity levels were provided to state agencies for input and update; however, no state provided updated off-road activity data. Emissions estimation methods for aircraft, commercial marine, and locomotives were similar to approaches EPA has recently used in developing national emission inventories. For California, CARB provided off-road emissions estimates by source category and county directly.

Emissions Models Used and Additional Calculations for Air Quality Modeling

On-road and off-road mobile source emissions are estimated as the products of emission factors and activity estimates. Except for California, the on-road mobile sources emission factors were derived from the EPA MOBILE6 model. Activity for on-road mobile sources is vehicle miles traveled (VMT). EPA's NONROAD2004 model was used to estimate emissions from off-road mobile sources except for aircraft, commercial marine, and locomotives.

[1] The final version of NONROAD (NONROAD2005, available at http://www.epa.gov/otaq/nonrdmdl.htm) was released after the work in this project was completed.

EPA MOBILE6 Model

The MOBILE model is EPA's regulatory model for estimating on-road mobile source gram per mile emission factors for VOC (exhaust and evaporative), NO_X, CO, PM, NH_3, and SO_2. The current regulatory version of the model is MOBILE6, released in 2002. The model and supporting documentation may be found on EPA's web site at http://www.epa.gov/OMSWWW/m6.htm.

The MOBILE6 model includes the effects of all of the following "on the books" Federal regulations for on-road motor vehicles:

- Tier 1 light-duty vehicle standards, beginning with, beginning MY 1996;
- National Low Emission Vehicle (NLEV) standards, beginning MY 2001;
- Tier 2 light-duty vehicle standards beginning MY 2005, with low sulfur gasoline beginning summer 2004;
- Heavy-duty vehicle standards beginning MY 2004; and
- Heavy-duty vehicle standards beginning MY 2007, with low sulfur diesel beginning summer 2006.

MOBILE6 estimates emissions by vehicle class, for 28 vehicle classes. For the WRAP modeling, the emissions were estimated for eight vehicle classes, which are combined from these 28. The eight vehicle classes are those that were modeled in the prior generation of the mode, MOBILE5, as shown in Table 1.

Table 1. MOBILE5 vehicle classes for which emissions were estimated.

Vehicle Class	MOBILE Code	Weight Description
Light-duty gasoline vehicles (passenger cars)	LDGV	Up to 6000 lb gross vehicle weight (GVW)
Light-duty gasoline trucks[1] (pick-ups, minivans, passenger vans, and sport-utility vehicles)	LDGT1	Up to 6000 lb GVW
	LDGT2	6001-8500 lb GVW
Heavy-duty gasoline vehicles	HDGV	8501 lb and higher GVW equipped with heavy-duty gasoline engines
Light-duty diesel vehicles (passenger cars)	LDDV	Up to 6000 lb GVW
Light-duty diesel trucks	LDDT	Up to 8500 lb GVW
Heavy-duty diesel vehicles	HDDV	8501 lb and higher GVW
Motorcycles[2]	MC	

[1] Emissions for light-duty trucks are modeled separately for two weight classes with different emissions standards in the Clean Air Act

[2] Highway-certified motorcycles only are included in the model. Off-road motorcycles, such as dirt bikes, are modeled as a no-road mobile source in EPA's NONROAD model.

The particulate matter emission factors in MOBILE6 are from an earlier EPA particulates emission factor model called PART5. The tire and brake wear estimates from PART5 used in MOBILE6 are dated, and newer brake wear estimates were available (Garg et al,) and were used to develop revised brake wear emission factors, the same as used in the previous WRAP mobile sources emission inventory (Pollack et al., 2004).

EPA NONROAD Model

Off-road mobile equipment encompasses a wide variety of equipment types that either move under their own power or are capable of being moved from site to site. Off-road mobile equipment sources are defined as those that move or are moved within a 12-month period and are covered under the EPA's emissions regulations for nonroad mobile sources. Emissions for so-called traditional nonroad sources are estimated by EPA in their NONROAD emissions model, available on the NONROAD web page at http://www.epa.gov/otaq/nonrdmdl.htm.

At the time that the off-road emissions were estimated for this project, the latest version of the model was draft NONROAD2004. In December of 2005 final NONROAD2005 was released. The web page above provides now only the NONROAD2005 final model.

The NONROAD model includes both emission factors and default county-level population and activity data. The model therefore estimates not just emission factors but also emissions. Technical documentation of all aspects of the model can be found on the EPA NONROAD web page.

The NONROAD model includes more than 80 basic and 260 specific types of nonroad equipment, and further stratifies equipment types by horsepower rating and fuel type, in the following categories:

- airport ground support, such as terminal tractors;
- agricultural equipment, such as tractors, combines, and balers;
- construction equipment, such as graders and back hoes;
- industrial and commercial equipment, such as fork lifts and sweepers;
- recreational vehicles, such as all-terrain vehicles and off-road motorcycles;
- residential and commercial lawn and garden equipment, such as leaf and snowblowers;
- logging equipment, such as shredders and large chain saws;
- recreational marine vessels, such as power boats;
- underground mining equipment; and
- oil field equipment.

The NONROAD model does not include commercial marine, locomotive, and aircraft emissions. Emissions for these three source categories are estimated using other EPA methods and guidance documents (described in Sections 5-7). However, support equipment for aircraft, locomotive, and commercial marine operations and facilities are included in the NONROAD model.

The NONROAD model estimates emissions for six exhaust pollutants: hydrocarbons (HC), NO_X, carbon monoxide (CO), carbon dioxide (CO_2), sulfur oxides (SO_X), and PM. The model also estimates emissions of non-exhaust HC for six modes — hot soak, diurnal, refueling, resting loss, running loss, and crankcase emissions.

The NONROAD model used in this study incorporates the effects of all of the following “on the books” Federal nonroad equipment regulations:

$ Emission standards for new nonroad spark-ignition engines below 25 hp;
$ Phase 2 emission standards for new spark-ignition hand-held engines below 25 hp;
$ Phase 2 emission standards for new spark-ignition nonhandheld engines below 25 hp;
$ Emission standards for new gasoline spark-ignition marine engines;
$ Tier 1 emission standards for new nonroad compression-ignition engines above 50 hp;
$ Tier 1 and Tier 2 emission standards for new nonroad compression-ignition engines below 50 hp including recreational marine engines;

$ Tier 2 and Tier 3 standards for new nonroad compression-ignition engines of 50 hp and greater not including recreational marine engines greater than 50 hp; and
$ Tier 4 emissions standards for new nonroad compression-ignition engines above 50 hp, and reduced nonroad diesel fuel sulfur levels.

The NONROAD model provides emission estimates at the national, state, and county level. The basic equation for estimating emissions in the NONROAD model is as follows:

$$Emissions = (Pop)(Power)(LF)(A)(EF)$$

where

Pop = Engine Population
Power = Average Power (hp)
LF = Load Factor (fraction of available power)
A = Activity (hrs/yr)
EF = Emission Factor (g/hp-hr)

The national or state engine population is estimated and multiplied by the average power, activity, and emission factors. Equipment population by county is estimated in the model by geographically allocating national engine population through the use of econometric indicators, such as construction valuation. The manner in which the geographic allocation is performed is as follows:

$$(County\ Population)_i\ /(National\ Population)_I = (County\ Indicator)_i\ /(National\ Indicator)_i$$

where

i is an equipment application like construction or agriculture.

Activity is temporally allocated through the use of monthly, and day of week fractions of yearly activity.

The NONROAD model has default estimates for all variables and factors used in the calculations. All of these estimates are in model input files, and can be changed by the user if data more appropriate to the local area are available.

California Models

The California Air Resources Board (CARB) provided on-road and off-road emissions data for base and future years for use in this project. CARB has developed their own models for on-road and off-road emissions estimation. CARB's on-road model is referred to as EMFAC. The version of the model that was used to generate the CARB on-road emissions was EMFAC2002 (available at http://www.arb.ca.gov/msei/on-road/latest_version.htm), with internal updates for some of the activity data that were not publicly available.

For many years, CARB has been developing its own off-road emissions model, called OFFROAD. Although CARB has developed most of the model inputs as part of their analyses in support of their off-road equipment regulations, the model has never been publicly released.

For all California emissions, CARB provided their emissions estimates for the base and future years. Emissions data only were provided, not activity data and emission factors.

Pollutants Added for Air Quality Modeling

For CMAQ modeling, additional model species are required beyond what is estimated in MOBILE, NONROAD, EMFAC, and OFFROAD. Specifically, particulate matter needed to be split into elemental carbon (EC), organic carbon (OC), and sulfate (SO_4); and NO_X needed to be split into NO and NO_2.

EC and OC were estimated by applying EC/OC fractions to the PM_{10} and $PM_{2.5}$ emissions estimates. The EC/OC splits used for these calculations are summarized in Table 2. These are the same EC/OC fractions used in the previous WRAP mobile sources emissions estimates; their derivation is described in Pollack et al., 2004. Sulfate was then estimated as PM – EC – OC, for both PM10 and PM2.5. Coarse PM is calculated as PM10 – PM2.5

Table 2. Elemental carbon/organic carbon fractions.

Process/Pollutant	EC	OC	Source
Gasoline Exhaust	23.9%	51.8%	Gillies and Gertler, 2000
Light-Duty Diesel Exhaust	61.3%	30.3%	Gillies and Gertler, 2000
Heavy-Duty Diesel Exhaust	75.0%	18.9%	Gillies and Gertler, 2000
Tire Wear	60.9%	21.75%	Radian, 1988
Brake Wear	2.8%	97.2%	Garg et al, 2000

While there have been several studies and reviews of particulate composition (e.g. EPA, 2001 and Turpin and Lim, 2000) since the time of the work referenced in Table 2, there has not been a comparable comprehensive evaluation of particulate composition. Many particulate source/receptor statistical modeling efforts have been attempted, but all used source profiles that predate those listed in Table 2. A comprehensive evaluation of source profiles needs to include the effect of the proper age distribution and maintenance history of in-use vehicles. No recent studies have investigated the source profiles using such an evaluation, and so could not be used for this work. In addition, the default EPA resource for compositional estimates of emissions, SPECIATE, has not provided any revised profiles since October 1999.

The ratio of NO to NO2 for NOx emissions from mobile sources is a result of the chemical equilibrium formed during internal combustion with NO the primary constituent of NOx. Aftertreatment devices may begin to perturb the ratio of NO and NO2 as NOx and particulate control are applied to diesel engines (Tonkyn, 2001, Herndon, 2002, and Chatterjee, 2004). However, these systems have not yet been widely employed, so it is not possible to judge what the proportion of NOx that NO and NO2 will be in the future. For this work the EPA default proportions of NO and NO2 (90/10) were used to apportion the NOx emission estimates.

Temporal Profiles

The on-road and off-road emissions are estimated as average day, per season. For use in air quality modeling, these average day emissions must be temporally allocated to the 24 hours of the day for each day of the week. This temporal allocation is done in the SMOKE emissions processing system. The EPA temporal profiles for on-road and off-road emissions were reviewed and found to be deficient for on-road sources. The EPA defaults for on-road temporal profiles vary only by weekday vs. weekend; for both weekdays and weekends the 24-hour profiles do not vary by vehicle class. And there are only two day of week profiles – one for light-duty gasoline vehicles and one for all vehicle classes.

ENVIRON has analyzed an extremely large database of detailed traffic counter data by vehicle class, roadway type, and state under contract to EPA (Lindhjem, 2004). From this work using national databases of vehicle activity maintained by the Federal Highway Administration (FHWA), revised temporal profiles for on-road sources were developed. The databases used were the FHWA Traffic Volume Trends (http://www.fhwa.dot.gov/policy/ohpi/travel/index.htm) for temporal activity of vehicles, and the FHWA Vehicle Travel Information System (VTRIS) (http://www.fhwa.dot.gov/ohim/ohimvtis.htm) that identifies individual vehicle classes to estimate temporal variation in the vehicle mix. Three sets of profiles were developed: day of week profiles by vehicle class (Figure 1); hour of day profiles for weekdays, by vehicle class (Figure 2); and hour of day profiles for weekends, by vehicle class (Figure 3). These temporal profiles show important differences in vehicle activity by vehicle class across the days of the week and the hours of the day.

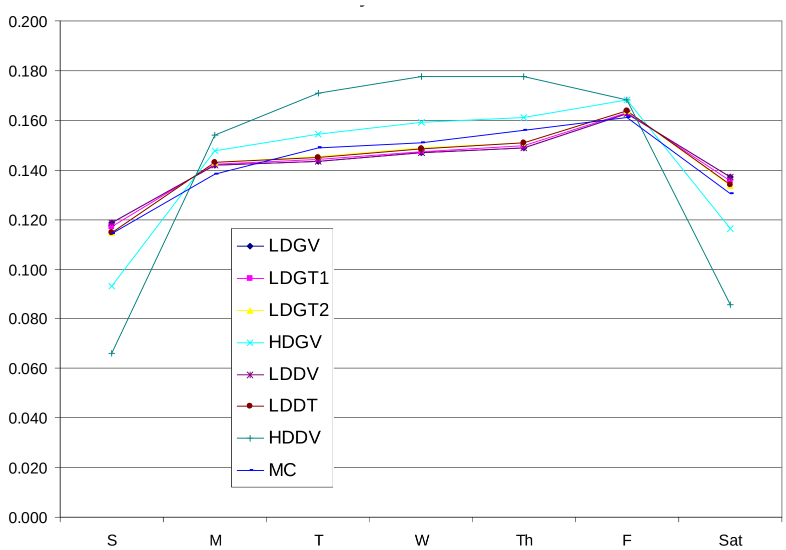

Figure 1. Day of week profiles by vehicle class.

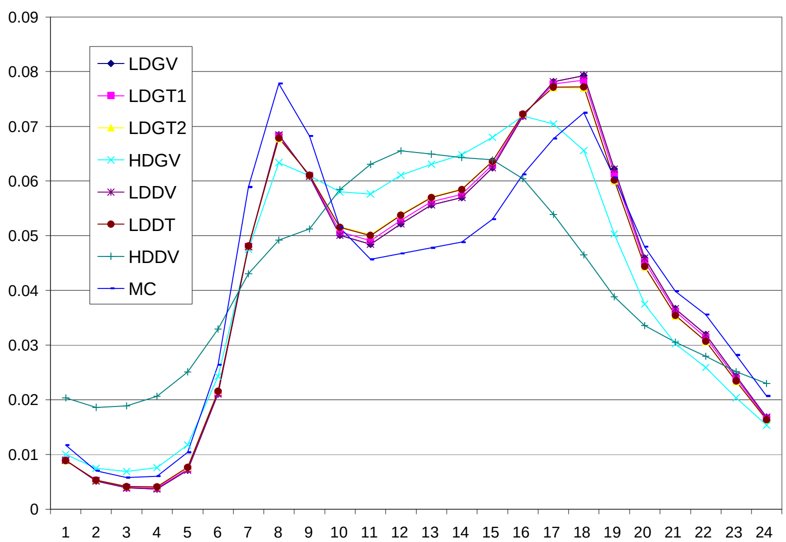

Figure 2. Weekday hour of day profiles by vehicle class.

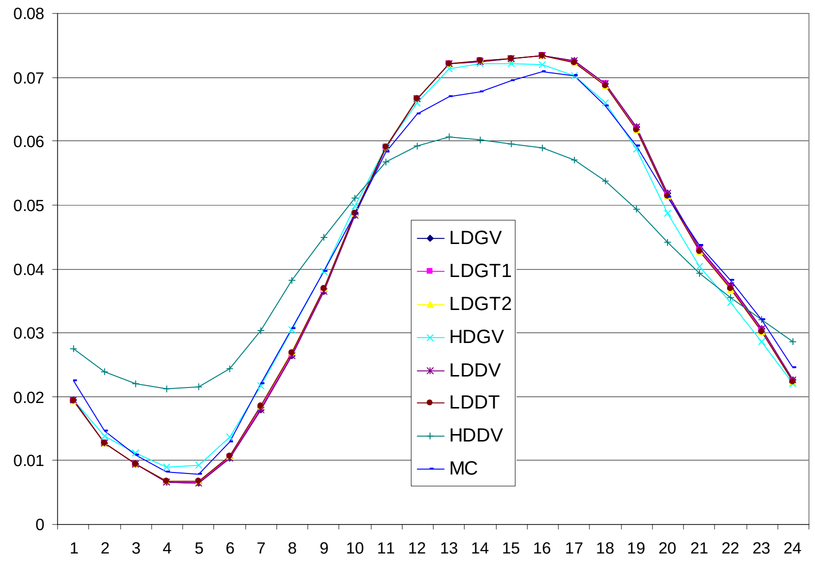

Figure 3. Day of week profiles by vehicle class.

Locomotive Emissions Estimation Methodology

County level locomotive emissions estimates were estimated as the product of locomotive fuel consumption and average locomotive emission factors. Previous WRAP locomotive emissions estimates (Pollack et al., 2004) allocated national fuel consumption estimates to counties using emissions data offered by the National Emissions Inventory. A detailed revision to that allocation method was developed for allocating 2002 national fuel consumption estimates. Emission factors were also revised to combine line-haul and switching engines because only national total fuel consumption was available. Additional emission factors for ammonia and fuel sulfur provided by EPA were also incorporated and form the basis from which sulfur dioxide was estimated.

2002 Locomotive Emissions

Development of the 2002 locomotive emissions involved spatially allocated 2002 national locomotive activity, in the form of fuel consumption, using historic data of freight movements. The 2002 Class I railroad activity data were derived from national fuel consumption data reported by the Association of American Railroads (AAR, 2003), and the activity data for Class II/III railroads from data reported by the American Short Line & Regional Railroad Association (ASLRRA, 1999 and Benson, 2004). To allocate this national fuel consumption to the county level, ENVIRON used the most recent county level rail activity estimates available. These activity estimates were ton-miles of freight movement estimated by the Bureau of Transportation Statistics (2002), using data from 1995. The 2002 national activity data were allocated to each county in the WRAP states using the fraction of the 1995 national rail activity that occurred in each county and then multiplying that fraction by the 2002 national rail activity, as demonstrated in equation (1).

$$CA02 = NA02 * (CA95/NA95) \qquad (1)$$

where

CA02 = 2002 county locomotive fuel consumption
NA02 = 2002 national locomotive fuel consumption
CA95 = 1995 county million gross ton miles (MGTM)
NA95 = 1995 national total MGTM

The spatial allocation of the national emissions in this work followed the methods of the EPA National Emission Inventory (NEI, 1999 and unchanged for 2002) of allocating locomotive activity. The 1995 activity data were obtained as GIS shapefiles containing track segments and an associated database of rail density per mile (MGTM/mi) corresponding to those segments. The segment-specific rail density estimates were provided as ranges. For each segment, the midpoint of the density range was assumed to represent the average track loading on that segment. Table 3 shows a list of the ranges and the midpoint values used in this study. The top end density was reported as an open-ended range, greater than 100 MGTM/mi, which was estimated as 120 MGTM/mi. This differs from the allocation method used in the NEI 2002, which represented the top end traffic density as 100 MGTM/mi. The use of 120 MGTM/mi is expected to more accurately reflect the relative importance of those main line track segments than using the minimum value of 100 MGTM/mi.

Table 3. Track segment density ranges used for allocation to counties (MGTM/mi).

Density ID	Segment Density Range	Assumed Segment Density
0	unknown, abandoned, or dummy	0
1	0.1 to 4.9	2.5
2	5.0 to 9.9	7.45
3	10.0 to 19.9	14.95
4	20.0 to 39.9	29.95
5	40.0 to 59.9	49.95
6	60.0 to 99.9	79.95
7	100.0 and greater	120

To obtain county level rail density from track segment density, a shapefile was first created that contained all US counties. Next, the two shapefiles were projected to the same map projection so that the counties were overlaid by the BTS track segments. Then, track segments were intersected by the county borders so that county-specific track segments were created. For each county it was then possible to sum the products of segment densities and county-specific segment lengths to obtain the total county activity as 1995 ton-miles. The county fraction of 1995 national rail activity was then the sum of activity in that county over the sum of activity in all counties. The relative county locomotive activity for the western States is shown in Figure 4.

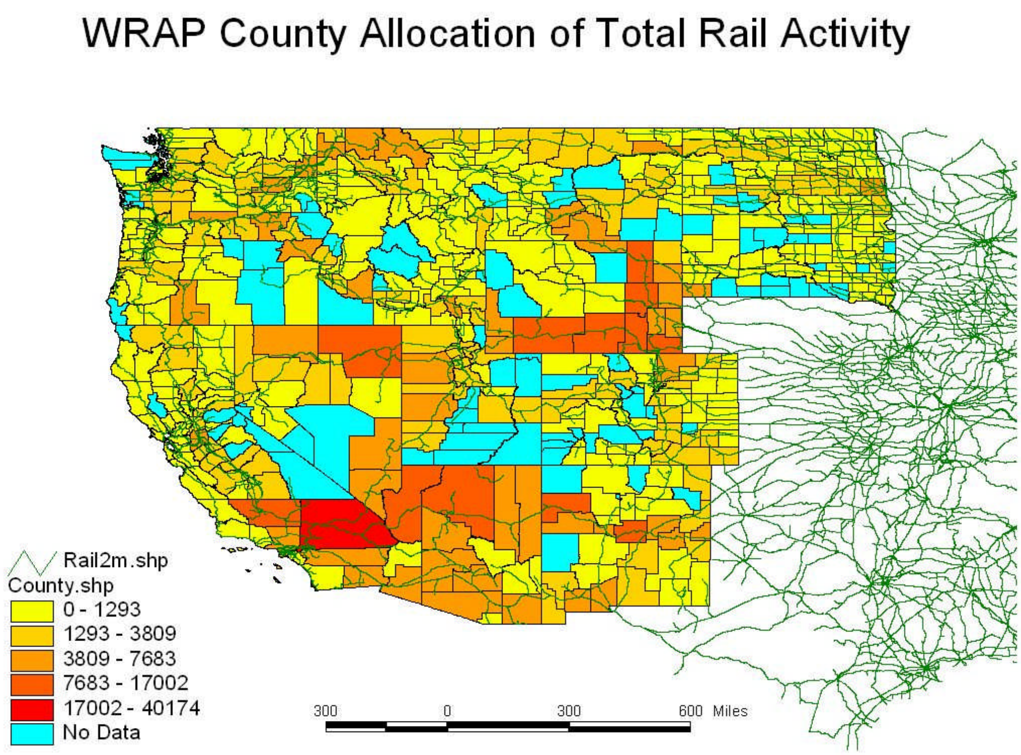

Figure 4. County level rail activity in the WRAP states.

Year 2002 county rail fuel consumption was estimated using the 1995 county fraction of national rail activity as demonstrated in equation (1). National locomotive fleet average emissions factors with units of grams per gallon of fuel were obtained from the EPA (1997). The emission factors for 2002 are summarized in Table 4. County level emissions of hydrocarbons (HC), NOx and particulate matter (PM10) were calculated by multiplying 2002 county level fuel consumption by these emission factors.

Table 4. National fleet average emission factors (gram per gallon) from EPA (1997).

Engine Type	HC	CO	NOx	PM	SO2[1]	NH3[2]
2002 Fleet Average	10.7	27.4	248.8	6.8	16.4	0.116

[1] Reported as SO_2 and derived from an average sulfur level of 2600 ppm. (EPA, 2004b)
[2] EPA (2004a)

One issue was to determine the fraction of the total PM emissions that is sulfate. Equation (2) was derived from test data from an EPA study that measured the PM weight change that resulted from a change in the fuel sulfur level. The percentage of sulfate PM was estimated to be 19.4%. The remaining PM was split between EC and OC using the historic National Emission Trends report estimate of 80% as elemental carbon and 20% as organic carbon.

$$\text{Sulfate PM (BSFC units)} = \text{BSFC} * 7.0 * 0.02247 * 0.01 * (SOx_{fuel} - SOx_{bas}) \quad (2)$$

where

SOx_{bas} = 0% sulfur for entirely elemental and organic carbon PM
SOx_{fuel} = % sulfur in fuel used (0.26%)

Sulfate PM = 0.0004 (g/gram fuel) or 1.32 (g/gallon) or 19.4% of the PM rate in Table 4.

Equation (2) was derived by estimating that the fuel sulfur partially (2.247%) converts to SO_3 (with the remainder emitted as SO_2), which rapidly hydrolyzes in the humid exhaust to hydrated sulfuric acid [H_2SO_4*(7)H_2O] and condenses on other PM. From this assumption arises the molecular weight adjustment of 7.0 (ratio of hydrated sulfuric acid to elemental sulfur). The figure 0.01 in the equation is to adjust values in percent (%) to fractional values.

County level locomotive emissions were estimated for all WRAP counties based on the procedure described above, except for those areas for which emissions data were supplied by local or state agencies. Four states - Alaska, Arizona, Wyoming, and Idaho - and one county - Clark County, NV - supplied more detailed locomotive emissions estimates from local surveys and other information derived from specific activity in those states. In the case of Arizona and Wyoming, ENVIRON performed surveys of all railroad activity (Pollack et al, 2004a; Pollack et al, 2004b). The Alaska Department of Environmental Conservation (Edwards, 2005) and the Idaho Department of Environmental Quality

(Reinbold, 2005) supplied their own estimates, as did the Clark County Department of Air Quality Management (Li, 2005).

The spatial allocation of annual locomotive NOx emissions is shown in Figure 5. Seasonal emissions were estimated based on an assumption of uniform year-round activity. Figure 5 shows the effect of the major east-west corridors from Los Angeles through Arizona and New Mexico, Northern California through Nevada, Utah and Wyoming, and Washington, Northern Montana and North Dakota; the north-south corridor through California, Oregon, and Washington; and the coal mining region of eastern Wyoming. Other major and minor routes are also evident though the size of the county affects the emission totals estimated, so a major line that runs through a small or narrow county may not appear significant, and, likewise, a large county may appear over-weighted compared with a neighboring county with less through mileage.

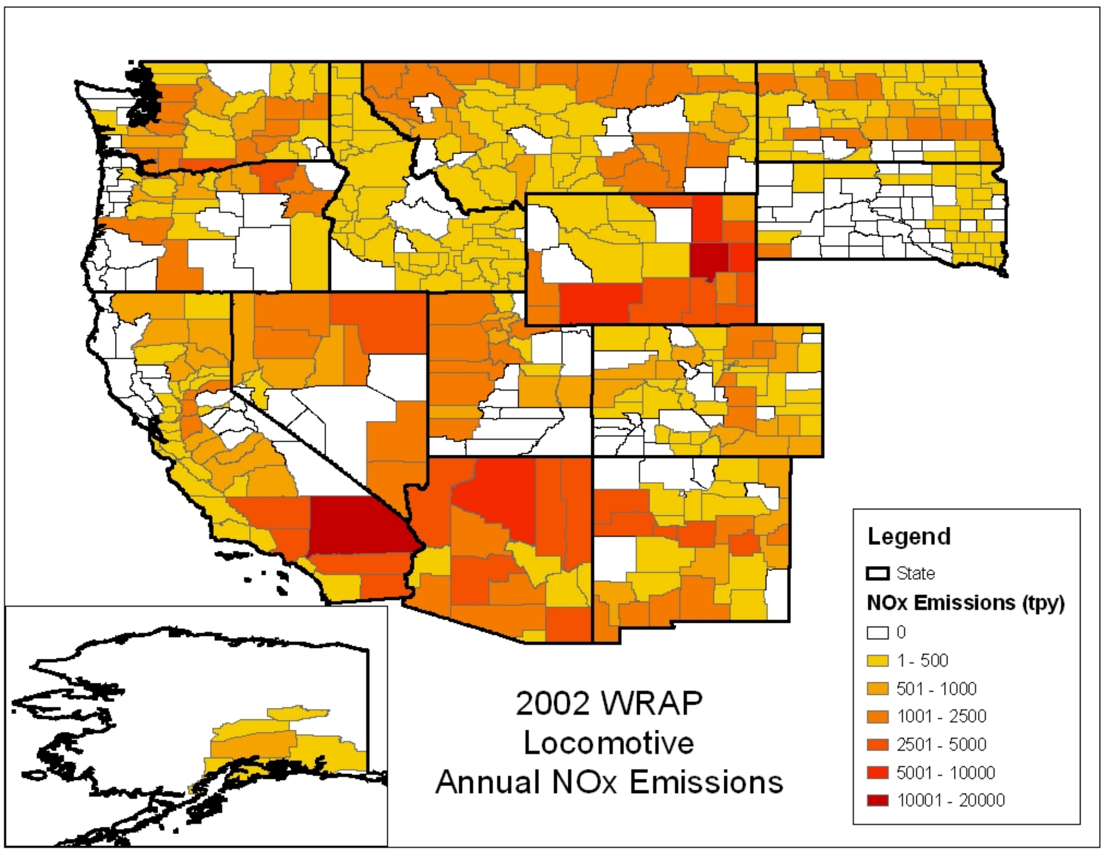

Figure 5. County level rail NOx emissions (tons per year) in the WRAP states.

2018 Locomotive Emissions

To estimate future year activity, a trend analysis was performed on the historical fuel consumption of the activity of the two predominant (in the West, Union Pacific and BNSF) railroads' activity. Figure 6 shows the company-wide fuel consumption calculated from historic revenue ton-mile and fuel consumption per revenue ton-mile. National freight transfers and the regression of fuel efficiency were used to determine the fuel consumption trend over as long a period as possible. Freight transfers (ton-mile) are not a sufficient activity indicator alone because the efficiency (ton-miles per gallon of fuel consumed) of railroads has been improving over time. AAR (2005) provided historical efficiency (gallons per ton-mile) for Burlington Northern (predating the merger with the Atchison Topeka and Santa Fe [ATSF] railroad) and Union Pacific (predating the merger with Southern Pacific and others). The historic trend in fuel efficiency for each company (Union Pacific and Burlington Northern) was combined with the revenue ton-mile for Union Pacific and Southern Pacific, and BN and ATSF. A trend in fuel consumption for the combined companies was thus estimated from 1990 through 2002 as shown in Figure 5-3 despite the merger activity that occurred during this period. The future year projected activity was then determined from a linear regression of the fuel consumption for the combined company operations of the predominant railroads in their current configuration as Union Pacific and BNSF.

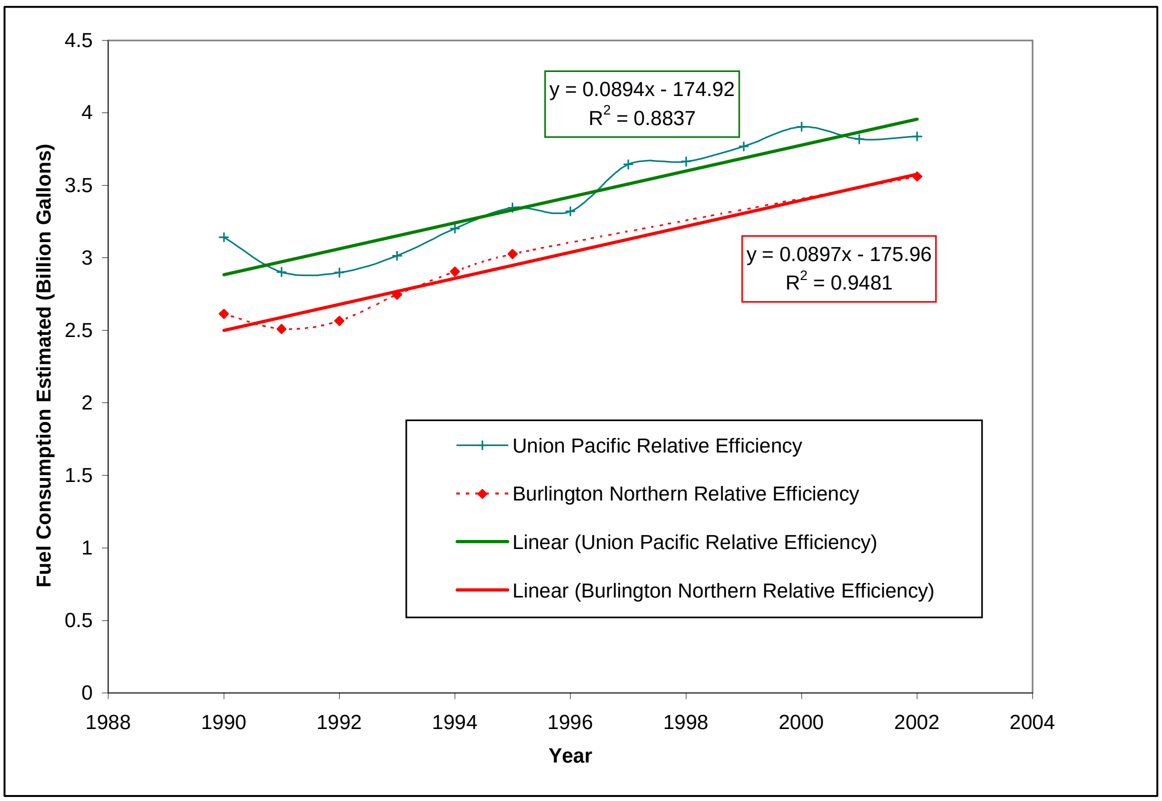

Figure 6. Trends in historical rail fuel consumption by railroad.

The resulting future year projection factors are listed in Table 5 for the two major railroads and the combined projection. The trends for the two railroads are very similar.

Table 5. Locomotive activity growth projection for this work.

Comparison Years	Union Pacific	BNSF	Combined

2008 / 2002	1.13	1.15	1.14
2013 / 2002	1.24	1.27	1.26
2018 / 2002	1.35	1.40	1.37

In addition to projected railroad activity, the emission rates were projected using EPA future year emission rates (1997, Regulatory Support Document), as shown in Table 6.

Table 6. Locomotive emission rate projections.

Comparison Years	HC	CO	NOx	PM	SO2*	NH3
2008/2002	0.892	1.000	0.693	0.882	0.192	1
2013/2002	0.819	1.000	0.627	0.802	0.006	1
2018/2002	0.763	1.000	0.580	0.740	0.006	1

* Fuel sulfur averaged 2600 ppm in 2002, assumed to average 500 ppm in 2008 and 15 ppm in 2013 and 2018. (EPA, Clean Air Nonroad Diesel Rule Fact Sheet, May, 2004) PM emission rates were not adjusted for fuel sulfur level though a reduction should be realized with low sulfur fuel.

The overall emissions from locomotives for future years were then determined by combining the activity growth in Table 5 and the emission rate projections in Table 6.

California Locomotive Emissions

CARB provided locomotive emissions for the base and three future years from their internal emissions data bases. CARB's emission estimates assumed 2500 ppm sulfur in the fuel for all years, and so adjustments were made to the SO2 and PM emissions to reflect the lower mandated levels in future years. Federal requirements are for sulfur levels to be 500 ppm in 2008 and 15 ppm in 2013 and 2018. However, ARB expects fuel sulfur levels to be 129 in 2008. SO2 emissions were adjusted using a direct scalar of the fuel sulfur levels assumed in the emissions estimated by ARB and the regulated levels. The PM emissions were adjusted to reflect the lower sulfur levels using a PM adjustment derived by ARB staff, as provided to ENVIRON.

The CARB emissions did not include NH3; NH3 was estimated by developing a scaling factor based on SO_X emissions. Yearly fuel consumption estimates were derived based on SO_X emissions and the CARB assumed 2500ppm fuel sulfur content. A per-volume NH3 emission factor was applied to the estimated fuel consumption to estimate NH3 emissions for each year at the county level. Lastly, PM was split among sulfate, EC, and OC using the same methods as for the other states described above.

Aircraft Emissions Estimation Methodology

County-level aircraft emissions for 2002 for the WRAP states were obtained from work performed for EPA's 2002 National Emissions Inventory (NEI2002). Activity data for aircraft emissions are takeoff cycles (LTOs), and emission factors are primarily from the Federal Aviation Administration (FAA) Emissions and Dispersion Modeling System

(EDMS). The 2002 emissions were projected to future years using forecast LTOs available from the FAA. More detailed estimates were provided for some states.

The FAA EDMS model combines specified aircraft and activity levels with default emissions factors in order to estimate annual inventories for a specific airport. Aircraft activity levels in EDMS are expressed in terms of LTOs, which consist of the four aircraft operating modes: taxi and queue, take-off, climb-out, and landing. Default values for the amount of time a specific aircraft spends in each mode, or the time-in-modes (TIMs), are coded into EDMS.

Aircraft emissions are estimated for four aircraft categories:

- Air carriers, which are larger turbine-powered commercial aircraft with at least 60 seats or 18,000 lbs payload capacity;
- Air taxis, which are commercial turbine or piston-powered aircraft with less than 60 seats or 18,000 lbs payload capacity;
- General aviation aircraft, which are small piston-powered, non-commercial aircraft; and
- Military aircraft.

<u>2002 Aircraft Emissions</u>

For the 2002 aircraft emissions, annual emissions files prepared for the NEI2002 formed the basis of the work. These files were sent to ENVIRON by EPA's contractor, Eastern Research Group (Billings, 2005). For this work, ERG ran the EDMS model for about 1100 towered airports across the U.S. using detailed 2002 aircraft/LTO activity data. Additional calculations were performed to estimate the additional pollutants needed for WRAP modeling. Key elements of those calculations are described by aircraft type below.

Air Carriers – The NEI2002 inventory data for VOC, CO, NOx, and SO_2 for Air Carriers were used directly. Additional calculations were made to estimate the emissions of the additional pollutants in the WRAP inventory:

- The NOx inventory speciation values for NO and NO_2 were assumed to be 90% and 10%, respectively, which are the default EPA speciations.
- It was assumed that no NH_3 is emitted from air carrier turbine engines, which normally run lean.
- All of the fuel-bound sulfur was assumed to form SO_2 in the engine exhaust.
- Due to the lack of other, more recent sources for aircraft particulate emission factors, the total suspended particulate (TSP) emissions from the air carriers were estimated using a commercial fleet-average emission factor from EPA's 1985 National Acid Precipitation Assessment Program (NAPAP). To calculate PM2.5, according to the NEI2002, 97.6% of the particulate matter emitted from

Commercial Aircraft was assumed to be $PM_{2.5}$, as is assumed in the NEI2002.

Air Taxi, General Aviation and Military Aircraft – The NEI2002 inventory data for VOC, CO, NOx, SO_2, PM10, and PM2.5 for these Aircraft types were used directly. Additional calculations were made to estimate the emissions of the additional pollutants in the inventory:

- As for the air carriers, 90% of the NOx emissions were assumed to be NO and 10% were assumed to be NO_2.
- For ammonia, air taxi and military aircraft were assumed to be dominated by turbine-powered aircraft running lean, thus producing a negligible amount of ammonia. For general aviation, ammonia was estimated using a fleet-average fuel consumption rate from the EDMS data for piston engines, operational mode-specific fuel flow rates weighted by the typical time spent in each mode, average hours of operation estimated from FAA data, and a g/gallon emission factor for non-catalyst light-duty gasoline engines.
- As for air carriers, all of the fuel-bound sulfur was assumed to form SO_2 in the engine exhaust.

State Updates

The NEI2002-based inventory estimates were updated with additional information provided for six areas:

For Alaska, Sierra Research, under contract to the WRAP Emissions Forum, developed seasonal aircraft emissions estimates for all aircraft types for Alaska in 2002. These data were used instead of the NEI2002 data described above. A number of minor modifications needed to be made to the data to make them consistent with the rest of the aircraft data. The most significant difference was that air carriers and air taxis were lumped into one category. These were then coded as the air carriers SCC, and WRAP Alaska air taxi emissions were set to zero.

For Arizona, the NEI2002-based inventory was updated with emissions estimates from the Arizona 2002 inventory work previously done by ENVIRON (Pollack et al., 2004). This work included detailed EDMS modeling based on activity data obtained from both the FAA and local sources. Further updates were made for specific airports with emissions data provided by Pima and Maricopa Counties.

The Idaho DEQ provided 2002 aircraft emissions for all counties for general aviation and military aircraft.

Clark County (Nevada) provided 2002 emissions estimates for three airports in the county, based on a recent airport emissions study (Ricondo, 2004).

For Wyoming, the NEI2002-based inventory was updated emissions estimates from Wyoming 2002 inventory work previously done by ENVIRON (Pollack et al., 2004a). This work included detailed EDMS modeling based on activity data obtained from both the FAA and local sources.

The California Air Resources Board (CARB) provided both base and future year aircraft emissions estimates, discussed below.

Seasonal Emissions Estimates

The NEI2002 aircraft emissions are annual estimates, as were most of the updates provided by state and local agencies. To estimate seasonal county-level emission inventories, the monthly distribution of activity for airports in the WRAP region was obtained from the FAA's Air Traffic Activity Data System (ATADS) (**http://www.apo.data.faa.gov/main/atads.asp**). The ATADS is the official source for historical monthly or annual air traffic statistics for airports with FAA-operated or FAA-contracted traffic control towers. The average seasonal distribution was calculated by state and aircraft type from the ATADS dataset. These state-level seasonal distributions were then applied to the annual county-level emissions in each state to derive the seasonal county-level emissions for each state.

2018 Aircraft Emissions

For all states except California, aircraft emissions were projected to the three future years from the 2002 emissions, by county and aircraft type, using FAA LTO forecasts as the activity data. Emission factors were assumed to be unchanged over time. The International Civil Aviation Organization (ICAO) has promulgated NO_x and CO emission standards for commercial aircraft, exempting general aviation and military engines from the rule (ICAO, 1998), and the majority of engines are already meeting this standard. EPA officially promulgated the ICAO standards for air carriers in a final rule in November 0f 2005.

The historic and projected LTO data by airport are available online from the Federal Aviation Administration (FAA) Terminal Area Forecast (TAF) database (http://www.apo.data.faa.gov/main/taf.asp) for all aircraft categories for which emissions were estimated. Projected LTO data for years 2008, 2013 and 2018, and historic data for 2002 were used to develop future year growth factors for all aircraft types. Growth factors were calculated as the ratio of the sum of LTOs by county and aircraft type in each future year to the sum of LTOs by county and aircraft type in 2002. These future year growth factors were then applied to 2002 emission estimates by county and aircraft to develop future year emission inventories.

A small number of counties had no aircraft LTOs in 2002 and a significant number of LTOs in future years. For these counties, emissions were calculated using projected future year LTOs and Emission Factors by aircraft type.

California Aircraft Emissions

CARB provided annual, winter, and summer aircraft emissions estimates by county and aircraft type for the 2002 base year and the three future years. A number of processing steps were required to generate off-road emissions for California that are similar in content and format to the emissions for the remaining WRAP states:

- The CARB aircraft emissions for commercial aircraft and air taxis were combined. The SCC for commercial aircraft was assigned to the combined emissions, and zero emissions were assigned to the SCC for air taxis.
- Spring and call emissions were calculated at the county and SCC level as
  Spring or fall emissions = (4 * annual emissions – winter emissions – summer emissions) / 2
- Ammonia emissions were calculated using NH3/SOX scaling factors at the county and SCC level.
- The additional pollutants needed for WRAP modeling were calculated using speciation factors and appropriate formulas.

Detailed discussions of the development of the mobile source emissions inventories can be found n Pollack, et al., 2006.

Generation of SMOKE and NIF Files

All mobile source emissions files were generated in the format needed for SMOKE emissions processing. Annual average day county-level locomotive emissions SMOKE files were generated, for all WRAP states combined, only for years 2002 and 2018, the years for which the WRAP air quality modeling is performed. The pollutants included in the SMOKE files are VOC, NO_X, CO, NH3, SO_2, PM10, EC10, OC10, SO4(10), PM2.5, EC2.5, OC2.5, SO4(2.5), coarse PM (PMC), NO, and NO2. Separate files were prepared for each year.

Emissions Summaries

Summaries of the gridded mobile source emissions for the Base02b, Plan02c and Base18b inventories by state and county, annual and seasonal periods, can be found on the TSS at: http://vista.cira.colostate.edu/tss/Results/Emissions.aspx.

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1.4 Fugitive dust emissions, as represented in the WRAP modeling inventories, include the following general source categories:

- Agricultural Operations
- Construction and Mining Operations
- Road Dust
- Windblown Dust from Vacant lands

In general, each of these emissions source categories includes more specific sub-categories, as described below. For each, a brief description characterizing the source and the general methodology used to estimate emission rates are provided. For the most part, the estimation methodologies are based on AP-42 guidance. In the case of the WRAP inventory development, specific modifications and/or deviations from these general methodologies are noted.

<u>Agricultural Operations</u>

Dust emissions from agricultural operations result from the disturbance of soil inherent in the preparation of agricultural lands for planting and after harvest activities. These include discing, leveling, and other mechanical operations. Dust emissions from this category exhibit a seasonal pattern as planting and harvesting generally occur in the spring and fall, respectively. In addition, agricultural practices and planting and harvesting calendars are crop-specific in many cases. In addition to operations associated with agricultural land preparation and harvesting, this emission source category includes dust emissions arising from the transport of agricultural crops as well as dust from agricultural feedlots or confined animal feeding operations (CAFOs).

While the current version of AP-42 guidance (5th Edition) does not include estimation methodologies for this dust emission category, guidance was provided in previous versions. However, the California Air Resource Board has developed procedures for estimating PM10 dust emissions from agricultural activities, and these procedures were adopted for development of the WRAP modeling inventories, as describe below.

Particulate dust emissions from agricultural operations are estimated as the product of crop-specific emission factors and appropriate activity data. Emission factors vary as a function of the specific soil preparation operation used for a particular crop, while the activity data is based on harvested acreage, modified by factors to account for the typical number of passes per acre required to prepare a field for planting. The activity data used for estimating land preparation emissions are based on state summaries of crop acreage harvested, further spatially allocated by county and crop type for the each state.

Acre-passes (the total number of passes typically performed to prepare land for planting during a year) are used to compute crop specific emission factors for land preparation. These land preparation operations may occur following harvest or closer to planting, and can include discing, tilling, land leveling, and other operations. Each crop is different in the type of soil operations performed and when they occur; crop profiles from similar crops are used for cases where specific crop data has not been updated. For updating acre-pass data, specific information on when agricultural operations occur is used to create detailed temporal profiles for PM emissions from agricultural land preparations.

Operation specific PM10 emission factors used to estimate the crop specific emissions for agricultural land preparations are based on data developed by the University of California Davis. Five emission factors were developed using 1995 to 1998 test data measured in cotton and wheat fields in California. Operations tested included root cutting, discing, ripping and subsoiling, land planing and floating, and weeding. The PM2.5/PM10 ratio for agricultural tilling dust used by CARB is 0.222.

PM dust emissions from agricultural activities were developed for the WRAP by Eastern Research Group (ERG). A detailed discussion of the development and data sources used by ERG can be found in ERG, 2006.

Construction Operations

Construction operations are significant source of dust emissions that may have a substantial temporary impact on local air quality. This emission source category includes both residential and non-residential construction as well as road construction. Dust emissions during the construction of buildings or roads are associated with land clearing, drilling and blasting, ground excavation, and cut and fill operations (i.e., earth moving). Dust emissions can vary substantially from day to day, depending on the level of activity, the specific operations, and the prevailing meteorological conditions. A significant amount of the dust emissions result from construction vehicle traffic over temporary roads at construction sites.

Residential Construction

PM dust emissions from residential construction are a function of the total acres of land disturbed and the volume of soil excavated. The volume of soil excavated also varies by type of structure under construction. County-level housing starts by structure type are used to estimate the disturbed acreage for construction. These data can be obtained from the US Census Bureau and the Department of Commerce. Volume of soil excavated is estimated based on assumed characteristics of single-family homes and whether the structures include basements.

Emission factors are estimated based on structure type and duration of construction. For single family houses, construction duration is assumed to be 6 months; for apartment buildings, 12-month construction duration is assumed. The emissions factors vary from approximately 0.011 tons PM10/acre-month to 0.11 tons PM10/acre-month. Additional adjustments are applied based on soil moisture, silt content and control efficiency. The ratio of PM2.5 to PM10, as documented in AP-42, is assumed to be 0.20.

Non-residential/Commercial Construction

Dust emissions from non-residential and commercial construction are a function of the total acres of land disturbed. Activity data is based on the total value of the construction in $MM. Data for construction values are typically obtained on a national basis from the Department of Commerce. County-level data is allocated from national estimates using employment statistics. County-level valuation data is then used to estimate total acreages disturbed during construction. An assumed value of 1.55 acres/$MM is applied to the county-level valuation data, as specified in AP-42.

An emission factor of 0.19 tons PM10/acre-month is used for the initial emissions estimate. The assumed construction duration is typically 11 months. As with residential construction, emission factors are adjusted to reflect variations in silt content, soil moisture and control efficiency. The ratio of PM2.5 to PM10, as documented in AP-42, is assumed to be 0.20.

Road Construction

PM dust emissions from road construction activities are a function of acres disturbed during construction. Activity data is based on data obtained from the4 Federal Highway Administration (FHWA) as a function of road type. State-level new miles of road constructed are estimated from 2002 FHWA state expenditures for capital outlay data, in thousands of dollars. These data are then converted to new miles of road constructed using 4/mile conversions from the North Carolina Department of Transportation (NCDOT) data. These data also vary by type of road. The new miles of road constructed is then used to estimate total acres disturbed using conversion factors for acres disturbed/mile of road constructed, as a function of road type. State-level acre disturbed are allocated top the county-level based on residential housing starts data.

An emission factor of 0.42 tons PM10/acre-month is used to estimate PM10 dust emission from road construction activities. A construction duration of 12 months is typically assumed. Adjustments are applied for variations in silt content, soil moisture and control efficiency

PM dust emissions from construction activities were developed for the WRAP by Eastern Research Group (ERG). A detailed discussion of the development and data sources used by ERG can be found in ERG, 2006.

<u>Paved Road Dust</u>

Particulate emissions occur whenever vehicles travel over a paved surface such as a road or parking lot. Particulate emissions from paved roads are due to direct emissions from vehicles in the form of exhaust, brake wear and tire wear emissions, and resuspension of loose material on the road surface. In general terms, resuspended particulate emissions from paved roads originate from, and result in the depletion of the loose material present on the surface (i.e., the surface loading). In turn, that surface loading is continuously replenished by other sources. At industrial sites, surface loading is replenished by spillage of material and trackout from unpaved roads and staging areas.

Dust emissions from paved roads have been found to vary with the "silt loading" present on the road surface as well as the average weight of vehicles traveling the road. The term silt loading (sL) refers to the mass of silt-size material (equal to or less than 75 micrometers [µm] in physical diameter) per unit area of the travel surface. The total road surface dust loading consists of loose material that can be collected by broom sweeping and vacuuming of the traveled portion of the paved road. The silt fraction is determined by measuring the proportion of the loose dry surface dust that passes through a 200-mesh screen using the ASTM-C-136 method. Silt loading is the product of the silt fraction and the total loading, and is abbreviated "sL."

The surface silt loading (sL) provides a means of characterizing seasonal variability in a paved road emission inventory. In many areas of the country, road surface silt loadings are heaviest during the late winter and early spring months when the residual loading from snow/ice controls is greatest. Once replenishment of fresh material is eliminated, the road surface silt loading can be expected to reach an equilibrium value, which is substantially lower than the late winter/early spring values.

Particulate emissions from road surfaces due to vehicle travel on a dry paved road may be estimated using the following empirical expression:

$$E = k\left(\frac{sL}{2}\right)^{0.65} \times \left(\frac{W}{3}\right)^{1.5} - C$$

where,

E = particulate emission factor (having units matching the units of k),
k = particle size multiplier for particle size range,
sL = road surface silt loading (grams per square meter, g/m^2),
W = average weight (tons) of the vehicles traveling the road, and
C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear.

<u>Unpaved Road Dust</u>

When a vehicle travels an unpaved road, the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The quantity of dust emissions from a given segment of unpaved road varies linearly with the volume of traffic. Dust emissions also depend on source parameters that characterize the condition of a particular road and the associated vehicle traffic. Characterization of these source parameters allow for "correction" of emission estimates to specific road and traffic conditions present on public and industrial roadways.

Dust emissions from unpaved roads have been found to vary directly with the fraction of silt (particles smaller than 75 micrometers [µm] in physical diameter) in the road surface materials. As the silt content of a rural dirt road will vary with geographic location, it should be measured for use in projecting emissions. For a conservative approximation, the silt content of the parent soil is often used. Tests, however, show that road silt content is normally lower than in the surrounding parent soil, because the fines are continually removed by the vehicle traffic, leaving a higher percentage of coarse particles.

Other variables are important in addition to the silt content of the road surface material. For example, at industrial sites, where haul trucks and other heavy equipment are common, emissions are highly correlated with vehicle weight. On the other hand, there is far less variability in the weights of cars and pickup trucks that commonly travel publicly accessible unpaved roads throughout the United States. For those roads, the moisture content of the road surface material may be more important in determining differences in emission levels between a hot desert environment and a cool moist location.

The PM10 emission factors presented below are based on stepwise linear regressions of field emission test results of vehicles traveling over unpaved surfaces. Due to a limited amount of information available for PM2.5, the expression for that particle size range has been scaled against the PM10 results. The following empirical expressions may be used to estimate the quantity of size-specific particulate emissions from an unpaved road in pounds (lb) per vehicle mile traveled (VMT). For vehicles traveling on unpaved surfaces at industrial sites, emissions are estimated from the following equation:

$$E = k\,(s/12)^{a}(W/3)^{b}$$

and, for vehicles traveling on publicly accessible roads, dominated by light duty vehicles, emissions may be estimated from the following equation:

$$E = \frac{k\,(s/12)^{a}(S/30)^{d}}{(M/0.5)^{c}} - C$$

where k, a, b, c and d are empirical constants, and

- E = size-specific emission factor (lb/VMT)
- s = surface material silt content (%)
- W = mean vehicle weight (tons)
- M = surface material moisture content (%)
- S = mean vehicle speed (mph)
- *C* = emission factor for 1980’s vehicle fleet exhaust, brake wear and tire wear.

The source characteristics s, W and M are referred to as correction parameters for adjusting the emission estimates to local conditions.

For the WRAP, paved and unpaved road dust emissions were estimated using updated VMT for the base and future years provided by state and local contacts as part of the base and future year survey work. Any updated road dust controls provided were also incorporated into the estimates. It is important to note that since the previous WRAP road dust emissions estimates were prepared, EPA's guidance on estimating paved and unpaved road dust emissions was updated; see http://www.epa.gov/ttn/chief/ap42/ch13/index.html. The WRAP Emissions Forum opted to update the road dust emissions only to reflect updated VMT and controls, and not to reflect the updated EPA guidance methodology.

A more detailed discussion of the development of paved and unpaved road dust emissions can be found in Pollack, et al., 2006

Windblown Dust from Vacant lands

Fugitive dust from wind erosion of agricultural and vacant lands represents a significant source of particulate matter emissions, particularly throughout the Western US. For agricultural windblown dust, emission factors may be estimated using the USDA wind erosion equation (WEQ) (ARB, 1997) which relates the PM10 emission factors to various parameters characterizing the specific crops, soil erodibility, surface roughness, vegetative cover and climatic factors. PM10 emissions are obtained by multiplying the resulting emission factor by the total crop acreage in units of tons/acre/yr. For non-agricultural vacant lands, numerous wind tunnel studies have been conducted to estimate appropriate emission factors based on soil types, surface conditions and threshold friction velocities.

Windblown fugitive dust emissions have not been estimated by EPA in previous national emission inventories. ENVIRON has recently completed the development of a windblown dust model for use in WRAP regional haze modeling efforts (Mansell, et. al, 2006). A description of the model development and the most recent results for the WRAP states can be found at http://www.wrapair.org/forums/dejf/fderosion.html. The model estimates fugitive PM dust emissions from vacant lands given wind speed data. All vacant land types are considered; mechanically disturbed lands, e.g., agricultural tilling, are not included. The current version of the model is set up to use the regional-scale land use databases for characterizing vacant lands, and also requires specification of soil characteristics, specifically soil texture. The model provides hourly gridded emission estimates that can be easily summarized on a county level. A complete detailed description of the model development and requisite input databases is included in the project Final Report and related documentation (Mansell, et al., 2006)

Emissions Modeling for Fugitive Dust Sources

For regional air quality modeling, the county-level, annual (or seasonal/monthly) PM dust emissions are spatially allocated to the modeling grid and temporally allocated hourly. In addition, fugitive dust transport fractions are applied to the PM dust emissions estimates prior to their use in the air quality model. The WRAP RMC utilized the

SMOKE emissions processing system to develop the necessary air quality model-ready dust emissions data.

Similar to emissions modeling for other source sectors, the fugitive dust emissions were extracted from the point, area and mobile source inventory data files and processed separately through SMOKE. Dust emissions were extracted from the inventory files based on SCCs. Processing the dust emissions separately allows for more efficient quality assurance of the data and the direct application of the fugitive dust transport fractions. The application of transport fractions is discussed in more detail below. With the exception of the windblown dust emissions, transport fractions are applied using the growth and control modules of SMOKE. The windblown dust emission models incorporate the transport fractions directly in the estimation methodologies used. Note that, except for the gridded emissions summaries, the data presented in the summaries below do not reflect the application of transport fractions.

The final step in preparation of PM dust emissions for air quality modeling involves the spatial and temporal allocation of annual, county-level emissions estimates. The PM10 emissions estimates are also speciated as PMC (=PM10–PM2.5) and PMFINE (=PM2.5). Speciation and spatial and temporal allocation is performed based on detailed SCCs. The revised PM2.5/PM10 ratios, developed by MRI (MRI, 2005), were applied the final versions of the gridded dust emission inventories presented below.

Fugitive Dust SCCs and PM2.5/PM10 Ratios

The development of the WRAP Base02b fugitive dust emissions inventory were based on the specific SCCs extracted from the area and point source inventory data used in the SMOKE emissions processing. As noted in Mansell (2006), several detailed source category codes that were either not included in the initial list of SCCs for fugitive dust processing, or were found to be reported using the most general SCC descriptions. For example, in some counties in Arizona, construction dust emissions were reported in terms of the general “all processes” SCC and were not included extracted from the area source inventory files. Likewise, agricultural dust emissions in California were provided separately from other fugitive dust source categories and were therefore initially not processed as fugitive dust within the SMOKE emissions modeling.

The ratio of PM2.5 to PM10, as reported in the inventory data were evaluated for the Base02b fugitive dust emission inventory (Mansell, 2006). The PM2.5/PM10 ratios are generally consistent with AP-42 guidance documents, although some exceptions were found in the Base02b inventory. Table 1 summarizes these ratios based on AP-42 and also presents the revised factors as recommended by MRI. In 2005, the DEJF initiated a project to evaluate the fine fraction of particulate matter in fugitive dust. The result of this study indicated that the analysis procedures and findings on which the EPA's AP-42 Guidance is based may be biased by as much as a factor of 2. The completed DEJF study (MRI, 2005) provided recommended revisions, by dust emission source category, and are included in Table 1.

Table 2 presents the complete listing of fugitive dust emission source category codes used by the RMC for extracting data from area and point source inventory data files. Also included in Table 2 are the original and revised PM2.5/PM10 ratios used in the SMOKE processing. Note that several SCCs listed were not included in the development of the Base02b modeling inventories. Based on the initial review of emissions data for the Base02b inventory, these SCCs have subsequently been included in the current SMOKE processing procedures and are reflected in the Plan02b and Base18a fugitive dust emissions inventory summaries described below.

Table 1. AP-42 PM2.5/PM10 ratios and recommended ratios from MRI, 2005.

Source Category	AP-42 Section	PM2.5/PM10 Ratio	
		Current	Proposed
Paved Roads	13.2.1	0.25	0.15
Unpaved Roads	13.2.2	0.15	0.10
Construction & Demolition	--	0.208	0.10
Aggregate Handling/Storage Piles	13.2.4	0.314	0.10 (traffic) 0.15 (transfer)
Industrial Wind Erosion	13.2.5	0.40	0.15
Agricultural Tilling	--	0.222	0.20

Table 2. Fugitive dust emission SCCs extracted from area and point source emissions inventory data files.

SCC	Description	PM2.5/PM10 Original	PM2.5/PM10 Revised
2801000001	Agriculture Production - Crops;Agriculture - Crops;Land Breaking	0.222	0.2
2801000002	Agriculture Production - Crops;Agriculture - Crops;Planting	0.222	0.2
2801000003	Agriculture Production - Crops;Agriculture - Crops;Tilling	0.222	0.2
2801000004	Agriculture Production - Crops;Agriculture - Crops;Defoliation	0.222	0.2
2801000005	Agriculture Production - Crops;Agriculture - Crops;Harvesting	0.222	0.2
2801000006	Agriculture Production - Crops;Agriculture - Crops;Drying	0.222	0.2
2801000007	Agriculture Production - Crops;Agriculture - Crops;Loading	0.222	0.2
2801000008	Agriculture Production - Crops;Agriculture - Crops;Transport	0.222	0.2
2805000000	Agriculture Production - Livestock;Agriculture - Livestock;Total	0.222	0.2
2805001000	Agriculture Production - Livestock;Beef Cattle Feedlots;Dust Kicked-up by Hooves	0.222	0.2
2805001001	Agriculture Production - Livestock;Beef Cattle Feedlots;Feed Preparation	0.222	0.2
2805005000	Agriculture Production - Livestock;Poultry Operations;Total (use 2805030000)	0.222	0.2

SCC	Description	PM2.5/PM10 Original	PM2.5/PM10 Revised
2805005001	Agriculture Production - Livestock;Poultry Operations;Feed Preparation	0.222	0.2
2805010000	Agriculture Production - Livestock;Dairy Operations;Total (use 2805020000 and subsets)	0.222	0.2
2805010001	Agriculture Production - Livestock;Dairy Operations;Feed Preparation	0.222	0.2
2805015000	Agriculture Production - Livestock;Hog Operations;Total (use 2805025000)	0.222	0.2
2805015001	Agriculture Production - Livestock;Hog Operations;Feed Preparation	0.222	0.2
2805020000	Agriculture Production - Livestock;Cattle and Calves Waste Emissions;Total	0.222	0.2
2805025000	Agriculture Production - Livestock;Hogs and Pigs Waste Emissions;Total	0.222	0.2
2805030000	Agriculture Production - Livestock;Poultry Waste Emissions;Total	0.222	0.2
2805035000	Agriculture Production - Livestock;Horses and Ponies Waste Emissions;Total	0.222	0.2
2805040000	Agriculture Production - Livestock;Sheep and Lambs Waste Emissions;Total	0.222	0.2
2805045001	Agriculture Production - Livestock;Goats Waste Emissions;Total	0.222	0.2
2275085000	Aircraft;Unpaved Airstrips;Unpaved Airstrips	n/a	0.1
2311000000	Construction: SIC 15 - 17;All Processes;Total	0.208	0.1
2311000010	Construction: SIC 15 - 17;All Processes;Land Clearing	0.208	0.1
2311000040	Construction: SIC 15 - 17;All Processes;Ground Excavations	0.208	0.1
2311000050	Construction: SIC 15 - 17;All Processes;Cut and Fill Operations	0.208	0.1
2311000060	Construction: SIC 15 - 17;All Processes;Construction	0.208	0.1
2311000070	Construction: SIC 15 - 17;All Processes;Vehicle Traffic	0.208	0.1
2311010000	Construction: SIC 15 - 17;General Building Construction;Total	0.208	0.1
2311010010	Construction: SIC 15 - 17;General Building Construction;Land Clearing	0.208	0.1
2311010040	Construction: SIC 15 - 17;General Building Construction;Ground Excavations	0.208	0.1
2311010050	Construction: SIC 15 - 17;General Building Construction;Cut and Fill Operations	0.208	0.1
2311010060	Construction: SIC 15 - 17;General Building Construction;Construction	0.208	0.1
2311010070	Construction: SIC 15 - 17;General Building Construction;Vehicle Traffic	0.208	0.1
2311020000	Construction: SIC 15 - 17;Heavy Construction;Total	0.208	0.1
2311020010	Construction: SIC 15 - 17;Heavy Construction;Land Clearing	0.208	0.1
2311020040	Construction: SIC 15 - 17;Heavy Construction;Ground Excavations	0.208	0.1
2311020050	Construction: SIC 15 - 17;Heavy Construction;Cut and Fill Operations	0.208	0.1
2311020060	Construction: SIC 15 - 17;Heavy Construction;Construction	0.208	0.1
2311020070	Construction: SIC 15 - 17;Heavy Construction;Vehicle Traffic	0.208	0.1
2311030000	Construction: SIC 15 - 17;Road Construction;Total	0.208	0.1
2311030010	Construction: SIC 15 - 17;Road Construction;Land Clearing	0.208	0.1
2311030040	Construction: SIC 15 - 17;Road Construction;Ground Excavations	0.208	0.1
2311030050	Construction: SIC 15 - 17;Road Construction;Cut and Fill Operations	0.208	0.1
2311030060	Construction: SIC 15 - 17;Road Construction;Construction	0.208	0.1
2311030070	Construction: SIC 15 - 17;Road Construction;Vehicle Traffic	0.208	0.1
2311040000	Construction: SIC 15 - 17;Special Trade Construction;Total	0.208	0.1
2305000000	Industrial Processes;Mineral Processes: SIC 32;All Processes;Total	n/a	0.1
2305070000	Industrial Processes;Mineral Processes: SIC 32;Concrete, Gypsum, Plaster Products;Total	n/a	0.1
2305080000	Industrial Processes;Mineral Processes: SIC 32;Cut Stone and Stone Products;Total	n/a	0.1
2325020000	Industrial Processes;Mining and Quarrying: SIC 14;Crushed and Broken Stone;Total	n/a	0.1
2325030000	Industrial Processes;Mining and Quarrying: SIC 14;Sand and Gravel;Total	n/a	0.1
2325040000	Industrial Processes;Mining and Quarrying: SIC 14;Clay, Ceramic, and Refractory;Total	n/a	0.1
2530000020	Storage and Transport;Bulk Materials Storage;All Storage Types;Cement	n/a	0.1
2530000100	Storage and Transport;Bulk Materials Storage;All Storage Types;Limestone	n/a	0.1

SCC	Description	PM2.5/PM10 Original	PM2.5/PM10 Revised
2530000120	Storage and Transport;Bulk Materials Storage;All Storage Types;Sand	n/a	0.1
2325000000	Mining and Quarrying: SIC 14;All Processes;Total	n/a	0.1
2294000000	Paved Roads;All Paved Roads;Total: Fugitives	0.25	0.12
2294000001	Paved Roads;All Paved Roads;Total: Average Conditions - Fugitives	0.25	0.12
2294000002	Paved Roads;All Paved Roads;Total: Sanding/Salting - Fugitives	0.25	0.12
2294005000	Paved Roads;Interstate/Arterial;Total: Fugitives	0.25	0.12
2294005001	Paved Roads;Interstate/Arterial;Total: Average Conditions - Fugitives	0.25	0.12
2294005002	Paved Roads;Interstate/Arterial;Total: Sanding/Salting - Fugitives	0.25	0.12
2294010000	Paved Roads;All Other Public Paved Roads;Total: Fugitives	0.25	0.12
2294010001	Paved Roads;All Other Public Paved Roads;Total: Average Conditions - Fugitives	0.25	0.12
2294010002	Paved Roads;All Other Public Paved Roads;Total: Sanding/Salting - Fugitives	0.25	0.12
2294015000	Paved Roads;Industrial Roads;Total: Fugitives	0.25	0.12
2294015001	Paved Roads;Industrial Roads;Total: Average Conditions - Fugitives	0.25	0.12
2294015002	Paved Roads;Industrial Roads;Total: Sanding/Salting - Fugitives	0.25	0.12
2296000000	Unpaved Roads;All Unpaved Roads;Total: Fugitives	0.15	0.1
2296005000	Unpaved Roads;Public Unpaved Roads;Total: Fugitives	0.15	0.1
2296010000	Unpaved Roads;Industrial Unpaved Roads;Total: Fugitives	0.15	0.1

Fugitive Dust Transport Fractions

The concept of fugitive dust transport fractions has been considered and refined in recent years. It has been recognized that, due to various mechanisms, dust particles are subject to near source removal. These mechanisms include gravitational settling, particle deposition to the ground and impaction and removal due to particle capture by the surrounding vegetation canopy and other physical structures. The EPA for many years had promoted the "divide by four" approach for reducing the emission from fugitive dust sources to account for these processes. The idea is that only a limited amount of the dust emitted by a particular source is transported significantly to affect the total available emissions in the atmosphere for air quality grid modeling.

Recent research has shown that the amount of fugitive dust captured in the surround canopy or on physical structures can be related to the physical characteristics of the land surface, i.e., land use/land cover. The EPA recently developed county-level transport fractions for use in emissions inventory development for air quality modeling (Pace, 2003; 2005). The county-level transport fractions were based on the percentage of land use in each county. The transport fractions were calculated as a weighted sum of landuse-specific fractions for each landuse type. Previously, landuse percentages were derived from the BELD3 LULC database. In the WRAP fugitive dust emission inventory, transport fractions were revised to reflect a more current LULC database. The current gridded dust emissions for the WRAP are based on the 2000 North American Land Cover (2000 NALC) database. A description of the 2000 NALC database can be found in Mansell and Hoats, 2005.

For the windblown dust emissions, transport fractions were developed and applied within the wind blown dust model based on the gridded landuse data used in the estimation methodology. A discussion of the application of the transport fraction for windblown dust emissions can be found in Mansell, et al., 2006. The original and revised transport fractions for each of the relevant land use types are presented in Table 3.

Table 3. Fugitive dust transport fractions as a function of landuse.

Fugitive Dust Transport Fractions		
LULC Category	**Original**	**Revised**
Urban	0.30	0.00
Agriculture	0.85	0.75
Grassland	0.70	0.75
Shrubland	0.60	0.75
Forest	0.30	0.00
Barren/Water	0.97	1.00

Gridded Fugitive Dust Emission Inventory Summaries

Summaries of the gridded fugitive dust source emissions for the Base02b, Plan02c and Base18b inventories by state and county, annual and seasonal periods, can be found on the TSS at: http://vista.cira.colostate.edu/tss/Results/Emissions.aspx.

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1.5 Fire Emissions

Fire emissions data for SMOKE have traditionally been represented as county-level area-source inventories that were placed in only the first vertical model layer. The representation of fire emissions for air quality modeling was enhanced by preparing the inventory data as point sources with specific latitude-longitude coordinates for each fire centroid and pre-computed plume rise parameters that were derived from individual fire characteristics. These new inventories consist of annual, daily, and hourly IDA-formatted emissions inventory files and ancillary data for allocating the inventories in space, time, and to the Carbon Bond-IV chemistry mechanism used in CMAQ and CAMx. The development of the fire emissions inventory is described in this section.

Source Categories

The fire emission inventories developed for the WRAP modeling efforts were organized into the following individual categories:

- Wildfires
- Agricultural fires
- Wildland fire use
- Natural prescribed
- Anthropogenic prescribed
- Non-Federal rangeland fires
- non-WRAP fires

For the non-WRAP fire emissions inventory, most of the data were modeled as area sources, with the exception of fire emissions for Canada, which were treated as elevated point sources.

The development of the fire emission inventory is described below. The discussion focuses on the development of the 2002 Base inventory; emissions modeling for the 2002 Planning inventory and the 2018 base year inventory use the same processing approach. Variations to the modeling approach and specific revisions and enhancements incorporated into the final modeling versions of the inventories have been described previously (refer to the Emission Overview Documentation). Specific revisions are noted with respect to data sources and source categories for the Plan02 and Base18 emissions inventories.

1.5.1 Data sources

For the fire inventories in Base02 inventory, actual 2002 data were used as developed by the RPOs for the U.S., version 2 of the year 2000 Canadian inventory, and actual 2002 data for Ontario, Canada. There were no fire emissions in the BRAVO 1999 Mexico inventories, so Mexican fires were not included in the Base02 inventories. The inventories used consisted of both area- and point-source data for the U.S. and Canada. Air Sciences provided the WRAP inventories divided among six different fire categories:

wildfires, agricultural fires, wildland fire use, natural prescribed, anthropogenic prescribed, and non-Federal rangeland fires (Air Sciences, Inc., 2005). These inventories consisted of annual, daily, and hourly IDA-formatted files with information on daily emissions totals and hourly plume characteristics for each fire. Similar point source fire inventories for the VISTAS states were received from Alpine Geophysics (Stella, 2005). In addition, county-level fire inventories represented as area sources for the VISTAS and CENRAP states were also included. Monthly temporal profiles received from Alpine Geophysics were used to distribute these annual inventories throughout the year. The area source inventories for the rest of the RPOs and Canada also contained fire emissions that were not distributed separately. These sources were modeled with the rest of the stationary-area-source sector. Finally, a 2002 fire inventory for Ontario, Canada was received from MANE-VU and formatted to take advantage of the SMOKE fire plume rise algorithm (Pouliot et al., 2005).

For the development of the Plan02 inventories, the RMC received corrected U.S. data for only the updated portions of the Base02 inventories. The previous inventory data for the affected states were removed from the files used in the Base02 modeling and combined the remaining data with the updated information to build revised Base02 inventories. The resulting dataset was used to develop the Plan02 inventory. This substitution of only the revised portions of the inventories was a general approach applied to several emissions sectors. More specific approaches were also developed for preparing the Plan02 fire inventories as described below.

Air Sciences, Inc., provided annual Baseline Phase III fire inventories for each of the five fire categories (wildfires, agricultural fires, prescribed fires, non-Federal rangeland prescribed fires, and wildland fire use) as three-file sets for each category. Consistent with the fire inventories for Phases I and II, each fire category consisted of an annual IDA file with physical fire event information, a daily IDA file with daily emissions by criteria pollutant, and an hourly IDA file with hourly pre-computed plume rise values. Upon receiving these data, the annual inventories are split into monthly files to avoid computer memory problems related to processing very large inventories with SMOKE. Additional information on the development of these fire inventories is available in WRAP-FEJF (2006).

Baseline fire emission inventories for 2018 (Base18a) for WRAP, CENRAP, and VISTAS were held constant at Plan02 emission levels. For the 2018b inventory, a number of revisions were incorporated as follows:

- The WRAP inventories for prescribed and agricultural fires were updated and errors corrected in the application of temporal and speciation profiles for non-Federal rangeland prescribed fires.

- Air Sciences, Inc. provided revisions to the Phase III prescribed and agricultural fire inventories to estimate the emissions reductions from applying fire emissions reduction techniques (ERTs) to controllable fire emissions (Randall, 2006). They based the revised emissions on the same data that the RMC used in case Plan02b to illustrate the changes that resulted from controlling prescribed and agricultural fires between the Plan02b and Base18b emission scenarios.

- The temporal and speciation profiles applied to the non-Federal rangeland prescribed fires were corrected. By not adding the SCC for this source to the input cross-reference files in the Plan02 and Base18a inventories, default temporal and speciation profiles were mistakenly applied to these emissions. The appropriate cross-reference for this source were added to the SMOKE input files in case Base18b.

1.5.2 Emissions processing

SMOKE is instrumented to distribute point-source-formatted fire inventories to the vertical model layers either by using a pre-computed plume rise approach or by computing the plume rise dynamically using actual 2002 meteorology. Both approaches for modeling point source fire emissions were applied for the Base02 inventories. For the pre-computed plume rise approach, SMOKE reads an annual inventory file with information on fire locations, a daily inventory file with daily emission totals for each fire, and an hourly inventory file with hourly plume bottom, plume top, and layer 1 fractions for each fire. SMOKE uses this information to locate the fires on the horizontal model grid and to distribute the plume of each fire vertically to the model layers. Because some of these fires have plumes that reach the model top, the number of emissions layers for processing these inventories are set to the full 19 layers of the meteorology. This approach was applied to the point-source fires for the WRAP and VISTAS regions.

The alternative plume rise approach uses information on fuel loading and the heat flux of the fires to distribute the fires vertically to the model layers. The data are provided to SMOKE in the form of an annual inventory with information on fire locations and a daily inventory with daily emission totals for each fire, daily heat flux, and daily fuel loading. This approach to the point source fires was applied for Ontario, Canada.

All of the point-source fires used diurnal temporal profiles and speciation profiles for VOC and $PM_{2.5}$ developed by Air Sciences during the preliminary 2002 modeling (Tonnesen et al., 2005).

For the area source fires outside of the WRAP region, including Canada, monthly temporal profiles developed by VISTAS were applied.. While these profiles appear to be an improvement over the EPA defaults, they are specific to the VISTAS region and will misrepresent the seasonality of the fires in other regions of the modeling domain. Flat weekly temporal profiles, and the diurnal profiles developed by Air Sciences were also used in the fire emissions modeling. In addition, the forestland spatial surrogates were used to distribute these county level (province level for Canada) data to the model grid. Using spatial surrogates to locate fires is a crude approach that results in the artificial smearing of the emissions over too large an area. Both of these issues can be remedied by moving to a point source approach for representing these fires, similar to the approach used by Air Sciences for preparing the WRAP fire inventories.

The RMC discovered several errors with the WRAP Phase II inventories. Some of these errors were fixed with corrections made by the RMC with guidance from Air Sciences, and others will be addressed by Air Sciences in Phase III of the 2002 WRAP fire inventories. The errors identified, with corrections, were as follows:

- Missing or malformed dates in several agricultural burning events in CA. These events were intended to be dropped and were ultimately deleted from the inventories by the RMC.
- Missing dates in several prescribed burning events in AZ. These records were corrected by Air Sciences and redistributed to the RMC.
- Inconsistencies between the records in the hourly and annual inventory files for several agricultural burning events in CA. These records were corrected by Air Sciences and redistributed to the RMC.

The quality assurance of the fire emissions followed the WRAP emissions modeling QA protocol (Adelman, 2004) and a suite of graphical summaries. Tabulated summaries of the input data and SMOKE script settings were used to document the data and configuration of SMOKE. The graphical QA summaries include, for all emissions output species, daily time-series plots, annual time-series plots, and daily vertical profiles. These QA graphics for the 2002 inventories are available at http://pah.cert.ucr.edu/aqm/308/QA_base02a36.plots/allf/plots/.

Gridded Fire Emission Inventory Summaries

Summaries of the gridded fire source emissions for the Base02b, Plan02c and Base18b inventories by state and county, annual and seasonal periods, can be found on the TSS at: http://vista.cira.colostate.edu/tss/Results/Emissions.aspx.

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