Appendix A

Emissions Overview
WRAP, undated

EMISSIONS MODELING

Overview

In support of the WRAP Regional Haze air quality modeling efforts, the RMC developed annual emissions inventories for a 2002 actual emissions base case, a planning case to represent the 2000-04 regional haze baseline period using averages for key emissions categories, and a 2018 base case of projected emissions determined using factors known at the end of 2005. All emission inventories were developed using the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system. Each of these inventories has undergone a number of revisions throughout the development process to arrive at the final versions used in CMAQ and CAMx air quality modeling. The WRAP emission inventories developed by the RMC include:

- The 2002 base case emissions scenario, referred to as "2002 Base Case" or "Base02". The purpose of the Base02 inventory is to represent the actual conditions in calendar year 2002 with respect to ambient air quality and the associated sources of criteria and particulate matter air pollutants. The Base02 emissions inventories are used to validate the air quality model and associated databases and to demonstrate acceptable model performance with respect to replicating observed particulate matter air quality.
- The 2000-04 baseline period planning case emissions scenario~~,~~ is referred to as "Plan02". The purpose of the Plan02 inventory is to represent baseline emission patterns based on average, or "typical", conditions. This inventory provides a basis for comparison with the future year 2018 projected emissions, as well as to gauge reasonable progress with respect to future year visibility.
- The 2018 future-year base case emissions scenario, referred to as "2018 Base Case" or "Base18". These emissions are used to represent conditions in future year 2018 with respect to sources of criteria and particulate matter air pollutants, taking into consideration growth and controls. Modeling results based on this emission inventory are used to define the future year ambient air quality and visibility metrics.

Emission inventory development and modeling in general is discussed below. Specifics with respect to the development each of these inventories, as well as a discussion of the various revisions and enhancements for each are provided separately for each of these emission scenarios.

Source categories

Emissions inventories are typically divided into area, on-road mobile, point, and biogenic source categories. These divisions arise from differing methods for preparing the inventories, different characteristics and attributes of the categories, and how the emissions are modeled. Generally, emissions inventories are divided into the following source categories:

- *Stationary Area Sources:* 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 nonroad 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, may be treated either as stationary area sources or as point sources.

- *Mobile Sources:* Vehicular sources that travel on roadways. These sources can be computed either as being spread over a spatial extent or as being assigned to a line location (called a link). Data in on-road inventories can be either emissions or activity data. Activity data consist of vehicle miles traveled (VMT) and, optionally, vehicle speed. Examples of on-road mobile sources include light-duty gasoline vehicles and heavy-duty diesel vehicles.

- *Point Sources:* These are 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 can be 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.

- *Biogenic Land Use Data:* Biogenic land use data characterize the types of vegetation that exist in either county-total or grid cell values. The biogenic land use data in North America are available using two different sets of land use categories: the Biogenic Emissions Landcover Database (BELD) version 2 (BELD2), and the BELD version 3 (BELD3) (CEP, 2004b).

In addition to these standard source categories, the inventory development efforts included additional categories either to represent specific emissions processes more accurately or to integrate emissions data that are not compatible with SMOKE. Examples of emissions sectors that fall outside of the standard SMOKE processing categories include emissions generated from process-based models for representing windblown dust and agricultural ammonia (NH_3) sources. An emissions category with data that are not compatible with SMOKE is one with gridded emissions data sets, such as commercial marine sources. Other source categories treated outside the standard SMOKE processing include emissions from oil and gas operations and fires.

Emission source categories were further refined to include more explicit emissions sectors. The advantage of using more detailed definitions of the source categories is that it leads to more flexibility in designing control strategies, substituting new inventory or profile data into the modeling, and managing the input and output data from SMOKE. The major drawback to defining more emissions source categories is the increased level of complexity that results from having a larger number of input data sets. Another motivation behind separating the various emissions categories is related to the size and flexibility of the input data. Additional details regarding the development of each of the source sectors, including emissions inventories and ancillary data for modeling are described in later sections of this documentation. Table 1 summarizes the primary source sectors defining the WRAP emission inventories. Some minor modifications to this list were made for each of specific scenarios and inventory versions, as discussed below.

The development and modeling of each emissions source sector is documented in separate subsections of this document. For each, a description in terms of the SMOKE processing category, the year covered by the inventory and inventory version, and the source(s) of the data are discussed. Additional details about the inventories are also provided, including any modifications that we made to prepare them for input into SMOKE.

Table 1. WRAP emission inventory source sectors.

Emissions Sector	Abbreviation*
Stationary area, including VISTAS county-level fires	ar
CENRAP county-level fires	arf
WRAP point-source fires	awf
Biogenic	bg
Ontario, Canada, point-source fires	bsf
Fugitive dust	fd
WRAP on-road mobile	mb
CENRAP on-road mobile	mbvcen
Other US on-road mobile	mbv
Non-US on-road mobile	nusm
CENRAP/MRPO anthropogenic NH_3	nh3
WRAP anthropogenic NH_3	nh3wrap
Seasonal/monthly nonroad mobile	nrm
Annual nonroad mobile	nry
Non-WRAP point-source fires	nwf
Offshore area	ofsar
Offshore point	ofspt
Commercial marine shipping	ofsmar
Stationary point	pt
Road dust	rd
Windblown dust	wbd
WRAP oil and gas	wog

*These abbreviations are used in the file naming of the SMOKE output files for each sector.

SMOKE Modeling

Emissions models such as SMOKE are computer programs that convert annual or daily estimates of emissions at the state or county level to hourly emissions fluxes on a uniform spatial grid that are formatted for input to an air quality model. Emission inventories were prepared for CMAQ version 4.4 using SMOKE version 2.1 on the WRAP RMC Linux computing cluster. SMOKE integrates annual county-level emissions inventories with source-based temporal, spatial, and

chemical allocation profiles to create hourly emissions fluxes on a predefined model grid. For elevated sources that require allocation of the emissions to the vertical model layers, SMOKE integrates meteorology data to derive dynamic vertical profiles. In addition to its capacity to represent the standard emissions processing categories, SMOKE is also incorporates the Biogenic Emissions Inventory System, version 3 (BEIS3) model for estimating biogenic emissions fluxes (U.S. EPA, 2004) and the MOBILE6 model for estimating on-road mobile emissions fluxes from county-level vehicle activity data (U.S. EPA, 2005a).

SMOKE uses C-Shell scripts as user interfaces to set configuration options and call executables. SMOKE includes flexible QA capabilities to generate standard and custom reports for checking the emissions modeling process. After modeling all of the source categories individually, including those categories generated outside of SMOKE, the model is used to merge all of the categories together to create a single CMAQ input file per simulation day. Also, for use in the CAMx modeling, we converted the CMAQ-ready emissions estimates to CAMx-ready files using a combination of SMOKE and stand-alone Perl scripts developed by ENVIRON. SMOKE was also used to generate CAMx inputs for all low-level emissions (including low-level point sources) and the CMAQ2CAMX converter to create the CAMx inputs for the elevated sources (including fires).

SMOKE Ancillary Data

The development of emission inventories using SMOKE requires a number of ancillary datasets. SMOKE ancillary modeling data include

- temporal and chemical allocation factors by state, county, and source classification code (SCC)
- spatial surrogates and cross-reference files for allocating county-level emissions to the model grid
- hourly, gridded meteorology data
- stack defaults for elevated point sources
- MOBILE6 configuration files
- Federal Implementation Standards (FIPS) codes (i.e., country/state/county codes) definition file
- SCC definition file
- pollutant definition file

All WRAP emission inventories were prepared using a common set of ancillary data with specific revisions and enhancements, as noted below. Default data sets provided by EPA formed the basis for these data except for the meteorological data and the MOBILE6 configuration files. The WRAP RMC provided the meteorology data at 36-km and 12-km grid resolutions (Tonnesen et al., 2005). MOBILE6 configuration files were provided to the RMC by mobile source emissions contractor.

Minor modifications were made to the chemical allocation, pollutant definition, and country/state/county codes files for new sources, pollutants, or counties contained in the WRAP inventories that we had not previously modeled. The temporal and spatial allocation inputs incorporated major modifications, as described below.

Temporal allocation data

Temporally allocating annual, daily, or hourly emissions inventories in SMOKE involves combining a temporal cross-reference file and a temporal profiles file.

- Temporal cross-reference files associate monthly, weekly, and diurnal temporal profile codes with specific inventory sources, through a combination of a FIPS (country/state/county) code, an SCC, and sometimes for point sources, facility and unit identification codes.
- Temporal profiles files contain coded monthly, weekly, and diurnal profiles in terms of a percentage of emissions allocated to each temporal unit (e.g., percentage of emissions per month, weekday, or hour).

The temporal allocation data from the WRAP preliminary 2002 modeling (Tonnesen et al., 2005), which originated from EPA (2005b) formed the basis for all modeling inventories developed fro WRAP. Based on guidance from the developers of some of the inventory files, enhancements were made to the temporal profiles and assignments for some source categories.

The WRAP nonroad mobile-source inventories included weekday/weekend split factors to allocate these data to the various days of the week (Pollack, 2005). These split factors were used to modify the standard EPA temporal profiles for a series of nonroad SCCs specified by the inventory contractor. Specific details regarding these modifications are described in the section on mobile source emissions inventory development.

Other additions to temporal allocation data included updates made for some WRAP sources and updates made by other RPOs that are applicable to their inventories. These other updates to the temporal allocation files included

- VISTAS continuous emissions monitoring (CEM)-specific profiles for EGUs in the VISTAS states
- VISTAS agricultural burning profiles
- Wildfire and prescribed fire profiles developed by VISTAS for the entire U.S.
- MANE-VU on-road mobile profiles
- WRAP weekly and diurnal road dust profiles
- WRAP diurnal wildfire, agricultural fire, and prescribed fire profiles
- WRAP on-road mobile weekly and diurnal profiles
- CENRAP non-Federal rangeland fire profiles

Finally, for all of the monthly and seasonal emissions inventories, temporal cross-reference files were modified to apply uniform monthly profiles to the sources contained in these inventories.

The monthly variability is inherent in monthly and seasonal inventories and does not need to be reapplied through the temporal allocation process in SMOKE. The inventories to which uniform monthly temporal profiles were applied included:

- WRAP, CENRAP, and MRPO nonroad mobile sources
- WRAP on-road mobile sources
- WRAP road dust

Spatial allocation data

SMOKE uses spatial surrogates and SCC cross-reference files to allocate county-level emissions inventories to model grid cells. Geographic information system (GIS)-calculated fractional land use values define the percentage of a grid cell that is covered by standard sets of land use categories. In addition to land use categories, spatial surrogates can also be defined by demographic or industrial units, such as population or commercial area. Similar to the temporal allocation data, an accompanying spatial cross-reference file associates the spatial surrogates (indexed with a numeric code) to SCCs. Spatial allocation with surrogates is applicable only to area and mobile sources. Point sources are located in the model grid cells by SMOKE based on the latitude-longitude coordinates of each source. Biogenic emissions are estimated based on 1-km^2 gridded land use information that is mapped to the model grid using a processing program such as the Multimedia Integrated Modeling System (MIMS) Spatial Allocator (CEP, 2005).

Various sources of spatial surrogate information for the U.S., Canada, and Mexico were used in the development of the WRAP inventories. For the U.S. and Canadian sources, the EPA unified surrogates available through the EFIG web site (EPA, 2005c) were used. For the 36-km grid, EPA provides these data already formatted for SMOKE on the RPO Unified 36-km domain. Spatial surrogates for Canada on the RPO Unified 36-km domain were modified by adding several surrogate categories which were lacking in the EPA data set. For Mexico, GIS shapefiles developed for the Big Bend Regional Aerosol and Visibility Observations Study (BRAVO) modeling were used to create surrogates for Mexico on the RPO Unified 36-km domain (U.S. EPA, 2005c).

2002 BASE CASE INVENTORY

The development of the 2002 Base Case emission inventory for WRAP has undergone a number of revisions throughout the development process to arrive at the final versions used in CMAQ and CAMx air quality modeling. A brief description of these revisions is presented below. More detail with respect to the development of each specific version is provided separately as part of the discussion of each emission source category.

Base02a

Version "a" of the 2002 base case inventory, Base02a, was developed based on preliminary 2002 modeling (Tonnesen et al., 2005). Improved 2002 emissions data for the United States, Mexico, and Canada were used to create a final base 2002 annual emissions database for use in the CMAQ and CAMx model performance evaluations. Sources for emissions inventory and

ancillary modeling data included WRAP emissions inventory contractors, other RPOs, and EPA. Building from the WRAP preliminary 2002 modeling cases completed earlier, several updates to the inventories and ancillary data were incorporated to create final 2002 emissions input files for the 2002 base case A, or Base02a. SMOKE version 2.1 (CEP, 2004) was used to prepare the inventories for input to the air quality modeling systems. More detailed documentation of the SMOKE emissions modeling can be found in Adelman, 2004.

Base02b

2000-04 BASELINE PERIOD PLANNING INVENTORY

This "Plan02" series of inventories was developed to represent baseline period emission patterns based on average, or "typical", conditions. This inventory series (cases Plan02a, b, c) were performed in sequence to diagnose emissions issues and true up the representativeness and accuracy of the emissions for planning purposes, provides a basis for comparison with the future year 2018 projected emissions, as well as to gauge reasonable progress with respect to future year visibility. As with the Base02 inventories, the WRAP planning inventory has undergone a number of revisions and enhancements to arrive at the final versions used in CMAQ and CAMx air quality modeling. A brief description of these revisions is presented below. More detail with respect to the development of each specific version is provided separately as part of the discussion of each emission source category. The Plan02 emissions inventory was developed from the Base02 emissions modeling scenarios by incorporating two major modifications; the inclusion of baseline, rather than actual-year, fire emissions data, and the application of averaged temporal profiles for stationary point sources.

To create the Plan02a emissions inventory, only two changes were anticipated: (1) replacement of actual 2002 fire emissions inventories with the baseline typical fire emissions inventories and (2) replacement of the temporal profiles for large stationary point sources with profiles developed from an average of several years surrounding 2002. Based on the QA performed on the Base02a inventory, however, several errors and issues were discovered which required corrections. As a result, the Plan02a inventory contained not just the originally planned inventory changes but also corrections to the off-road mobile, on-road mobile, offshore Pacific shipping lane, and WRAP oil and gas inventories. Additional issues with the development of the Plan02a inventory were also addressed and incorporated into the version "b" of the planning inventories. A final version "c" planning inventory was developed which incorporated a number of additional minor revisions to the "b" version of the inventory. These revisions and corrections are briefly described below, while more details are provided under source category-specific documentation presented in later sections.

Plan02a

The Plan02a emission inventory was developed from a combination of the WRAP baseline fire inventories, actual 2002 EGU inventories with historically averaged temporal profiles, typical-year inventories from other RPOs, and Base02 emissions for the remaining emission sectors. After completing the Base02a inventory (Tonnesen et al., 2006), several updates to the 2002 base inventories that affected most regions of the modeling domain were collected. Although they were considered components of the Base02 inventories, we applied these updated inventories initially in simulation Plan02a.

The RMC implemented the following changes to the Base02 inventories to develop the Plan02a emission inventory:

- *Stationary Area Sources:* Revised inventories for California, Washington, North Dakota, Oregon, Utah, Mexico, and non-fire sources in the VISTAS states. Additional dust sources extracted from the area-source inventory to be modeled explicitly as fugitive dust.
- *Fugitive Dust Sources:* Revised inventories for California, Washington, North Dakota, Oregon, Utah, Mexico, and non-fire sources in the VISTAS states. Expansion of the fugitive dust list of sources to include a broader definition of dust.
- *Road Dust Sources:* Revised inventory for California and VISTAS states. Note: We extracted the California data from the revised stationary-area-source inventory.
- *On-road Mobile Sources:* Revised inventories for California, Montana, Colorado, and Mexico.
- *Non-road Mobile Sources:* Revised inventories for California, Mexico, and the VISTAS states. Updated temporal profiles for all non-WRAP states, as developed from the NONROAD2004 model by Alpine Geophysics, LLC.
- *Oil and Gas Sources:* Revised inventory for stationary area California oil and gas sources. Note: We extracted the California data from the revised stationary-area-source inventory.
- *Stationary Point Sources:* Revised inventories for California, Alaska, Arizona, Montana, New Mexico, Oregon, Utah, Washington, Wyoming, WRAP Tribes, Mexico, MANE-VU, and VISTAS states. Updated temporal profiles for all non-WRAP EGU sources, as developed from the Integrated Planning Model (IPM) for 2018 emissions.
- *Pacific Commercial Marine Sources:* Revised inventories for Pacific shipping lanes and California on- and near-shore sources
- *Broomfield County, CO:* Revised the 36-km spatial surrogates to include Broomfield County, CO, and applied these to the stationary area, road dust, fugitive, oil and gas, and on-road mobile inventories. As these inventories all explicitly contain emissions for Broomfield County, we revised our spatial allocation approach to include surrogates for this county, as opposed to including these emissions in the surrounding counties. As the nonroad mobile inventories still contain Broomfield County emissions folded into the surrounding counties, we did not change the spatial surrogates for allocating these emissions to the model grid.

These updates were combined with the previously described revisions to the fire inventories and EGU temporal profiles to create simulation Plan02a.

Plan02b

The RMC developed the Plan02b inventory to correct errors discovered in the Plan02a emissions and to include inventory updates received after commencement of the Plan02a inventory development efforts. To create Plan02b from Plan02a, updates were made to the non-WRAP stationary point source emissions, domain-wide fugitive dust and road dust emissions, and Gulf of Mexico offshore area source inventories. Errors were also corrected in the configuration of the WRAP non-Federal rangeland prescribed fire emissions, Pacific shipping emissions, and omissions of sources in the fugitive dust inventories used in simulation Plan02a.

The RMC implemented the following changes to the Base02 and Plan02a inventories to develop the Plan02b emission inventory:

- *Updates to non-WRAP stationary point source emissions:* As part of the QA process for new emissions simulations, qualitative and quantitative comparisons are made to sequential inventories to confirm that the results show the expected changes based on the incremental updates that are made between inventories. Observed differences in the non-WRAP stationary point sources these emissions were much larger than anticipated considering that only updates to the temporal profiles were made for these sources. It was discovered that the IPM-derived temporal profiles used in the Plan02a inventory 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 the Plan02a inventory. 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.

- *Updates to domain-wide fugitive dust and road dust emissions:* Recent information about dust emissions led to a revision in the approach that the RMC uses to model fugitive and road dust emissions. Implementing these updates in simulation Plan02b impacted the fugitive dust, road dust, and stationary-area-source inventories. In May 2006 the EPA Emissions Factors and Inventory Group (EFIG) revised the transport factors that they recommend for scaling dust emissions downward to account for scavenging by vegetation (U.S. EPA, 2006). In implementing these updated factors, an expanded list of source classification codes (SCCs) was used to define the dust sources extracted from the stationary area inventory. This change impacts both the fugitive dust inventory, by increasing the number of sources contained in this sector, and the stationary area source inventory, by removing fugitive dust sources from this sector that previously were modeled as area sources.

  An additional update to the dust emissions evolved from recommendations made by MRI (2005) regarding a revision to the fine fraction of PM from dust sources. Based on these recommendations, the $PM_{2.5}/PM_{10}$ ratios in all of the road dust and fugitive dust inventories were updated prior to SMOKE modeling the Plan02b inventory.

- *Updates to Gulf of Mexico offshore area source inventories:* The RMC also received an updated Gulf of Mexico offshore area source inventory from the U.S. Minerals Management Service during the Plan02a modeling. These data were used to replace the previous inventory data for this region of the modeling domain.

- *Errors in the Pacific shipping emissions, and omissions of sources in the fugitive dust inventories:* Corrections to the Plan02a modeling inventory were incorporated for these source categories. QA of the Pacific shipping emissions revealed an error in converting the pre-speciated VOC emissions from tons to moles. These emissions were corrected with the appropriate conversion factors for the affected pollutants. During the preparation of the fugitive dust inventories, construction and mining dust sources were inadvertently omitted from Arizona, Colorado, Montana, Nevada, New Mexico, South Dakota, and Wyoming. These data were included in the Plan02b inventory. The above updates and revisions were combined with the unaffected sources from Plan02a to produce the Plan02b emission inventory.

Plan02c

The RMC developed the Plan02c emission inventory to correct one error discovered in the Plan02b emissions. To create the Plan02c inventory from Plan02b, the WRAP non-Federal rangeland prescribed fire emissions were updated. When these data were added to the WRAP modeling, updates to the speciation and temporal cross-reference files were omitted. The result was that the default diurnal temporal profile and $PM_{2.5}$ speciation profile were incorrectly applied to these emissions. Although these fire sources account for only 0.5% of the total annual WRAP $PM_{2.5}$ emissions, this change was made because their episodic and localized nature concentrate the emissions in a few grid cells in short time periods, leading to a magnification of the impacts from these sources.

Plan02 Inventory Data Collection and Preparation

The data collection procedures for the development of the Plan02 emission inventories are described in this section. A discussion of the sources of all inventory and ancillary data that changed between the Base02a emissions simulation and the Plan02a, Plan02b, and Plan02c emissions inventories is provided. The RMC worked with emissions inventory contractors, other RPOs, and EPA to collect all of the data that used in updating the Base02a emissions to create the Plan02 emissions.

For the WRAP state and tribal inventories, Air Sciences, Inc., provided all fire inventories; ERG, Inc., provided all stationary area and stationary point inventories and temporal profiles; and ENVIRON provided all mobile, oil and gas, and Pacific shipping inventories used in the Plan02 scenario emissions inventories. Alpine Geophysics, LLC, provided all inventories and temporal profiles for the non-WRAP U.S. data. ERG, Inc. provided all updated Mexican inventory data. All emissions data were received electronically; the inventories as SMOKE-ready IDA-format data, and the temporal profiles as SMOKE-ready ASCII files.

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 Base02a modeling and combined the remaining data with the updated information to build

revised Base02 inventories. This substitution of only the revised portions of the inventories was a general approach applied to several emissions sectors. More specific approaches for preparing the fire, EGU, Pacific shipping, dust, and Mexico inventories were also developed and applied.

- *Fires:* 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, annual inventories were split into monthly files to avoid computer memory problems related to processing very large inventories with SMOKE. For additional information on the development of these fire inventories, refer to WRAP-FEJF (2006).

- *EGUs:* 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.

- *Pacific shipping:* To prepare the new Pacific shipping inventories for the Plan02 scenario, these data were converted directly to the CMAQ-ready format outside of SMOKE. Inventory data were received as annual estimates of criteria pollutants in gridded ASCII files on the WRAP 36-km model grid. A FORTRAN program was developed to convert these files to the SMOKE netCDF format and then apply speciation and temporal adjustments using SMOKE chemical and temporal profiles, respectively, to create gridded, hourly emissions with volatile organic compound (VOC) and $PM_{2.5}$ speciation consistent with the rest of the Plan02 emissions. Because SMOKE is not set up to process pre-gridded data, FORTRAN programs were developed in-house at the RMC to prepare these data for merging with the rest of the source categories.

- *Dust:* The fugitive dust inventory for the entire modeling domain was developed by extracting these sources, based on SCCs, from the stationary-area inventories. A list of the sources defined as fugitive dust is provided in U.S. EPA (2004b). Explicit road dust inventories were received for most of the WRAP states; for California, the non-WRAP states, and the non-U.S. sources, the road dust inventory was built by extracting the paved and unpaved road dust SCCs from the stationary-area inventory. After building the fugitive and road dust inventories, these data were prepared for the Plan02 emissions modeling by applying transport factors to these data and re-adjusting the inventory $PM_{2.5}/PM_{10}$ ratios. To apply the transport factors recommended by EPA (2006), a SMOKE control file (GCNTL) that contains scalars by SCC and location codes was used. The new, adjusted dust inventories with the factors in the GCNTL file were developed using the SMOKE programs Cntlmat and Grwinven. The RMC developed a Fortran program to reapportion the PM inventories using the revised $PM_{2.5}/PM_{10}$ ratios.

- *Mexico:* Entirely new inventories for the six northern states of Mexico for stationary area, stationary point, on-road mobile, and nonroad mobile sources became available at the conclusion of the Plan02a modeling. ERG, Inc., completed an updated 1999 emissions inventory for northern Mexico (Fields et al., 2006) and delivered these data in early 2006.

Quality Assurance

The quality assurance of the Plan02 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 for all three Plan02 cases. The graphical QA summaries include, for all emissions output species that changed from Base02a to Plan02, daily spatial plots summed across all model layers, daily time-series plots, annual time-series plots, and daily vertical profiles. The Plan02a, Plan02b, and Plan02c QA graphics are available on the RMC web site at http://pah.cert.ucr.edu/aqm/308/Plan02a_36.shtml, http://pah.cert.ucr.edu/aqm/308/qa_plan02b36.shtml, and http://pah.cert.ucr.edu/aqm/308/qa_plan02c36.shtml, respectively.

2018 BASE CASE INVENTORY

The Base18 emission inventory, which represents emissions forecasted to 2018, was developed to represent baseline future-year emissions patterns for use in developing emissions control strategies and then evaluating their effects on future-year air quality. The first step in this process is to compare the Base18 future emissions with the Plan02 typical-year emissions. To facilitate direct comparison, the SMOKE configuration between the Base18 and Plan02 inventories was normalized as much as possible, varying only the inventories and ancillary input data. In contrast to the Plan02 cases, the Base18 cases used inventories and SMOKE ancillary data that had not previously been used. WRAP inventory contractors provided 2018 inventories and temporal profiles in SMOKE-ready formats.

The RMC completed two iterations (cases Base18a, b) of the Base18 inventory before settling on a final version for input to CMAQ for visibility modeling. Because version A of the Base18 emissions (case Base18a) was developed using datasets that had never been modeled through SMOKE, encountering multiple errors in the data and incompatibilities between the data and SMOKE was anticipated. As expected, during the QA of the Base18a emission inventories, the RMC was notified about errors in the 2018 inventories and other problems in the modeling of these data were also discovered. After receiving corrected inventories and fixing the errors in the modeling, version B of the Base 2018 emission inventory (Base18b) was developed.

The Base18 emissions were derived from inventory data projected from 2002 to 2018 by WRAP inventory contractors, the RMC, and WRAP and other RPOs. For most inventory sectors, the Base18 input datasets were developed by combining (1) 2018 inventories from inventory contractors both within and outside of the WRAP region and (2) 2018 inventories developed at the WRAP RMC by applying projection factors to the Plan02 inventories. Exceptions to this procedure were the fire inventories, non-U.S. sources, WRAP ammonia, Pacific shipping, and most of the MRPO sources; these were all kept the same as in the Plan02 inventories. The

majority of the emissions sectors used temporal, spatial, and chemical profiles that are consistent with the Plan02 scenario. Details on the differences between the two Base18 cases follow.

Base18a

The RMC created case Base18a from a combination of U.S. baseline fire inventories; 2018 stationary area, point, and mobile inventories; and 2002 inventories for MRPO sources, non-U.S. sources, NH_3 emissions in the WRAP region, and Pacific shipping emissions. For the WRAP, VISTAS, and MANE-VU states, 2018 inventories were received for stationary area, point, on-road mobile and off-road mobile sources. For the CENRAP states, projection factors to "grow" the Plan02 inventories to 2018 were provided. Although a few emission source categories constant with respect to the Plan02 emissions—primarily due to the lack of either 2018 inventories or projection information for these sources—most of the inventories used for Base18a emissions simulation were new and developed by the RPOs specifically for 2018 modeling.

The following data, by source category, were used to develop the case Base18a simulation:

- *Stationary Area Sources:* 2018 inventories for WRAP, MANE-VU, and VISTAS; 2018 projection factors (growth and control) applied to the Plan02 inventories for MRPO and CENRAP; Mexico and Canada held constant with Plan02a.
- *Fugitive and Road Dust Sources:* 2018 inventories for WRAP, MANE-VU, and VISTAS; 2018 growth factors applied to the Plan02 inventories for CENRAP; MRPO, Mexico, and Canada held constant with Plan02a.
- *Windblown Dust Sources:* The entire domain held constant with Plan02a.
- *Agricultural and Animal Ammonia Sources:* WRAP, MANE-VU, VISTAS, Mexico, and Canada held constant with Plan02a; 2018 growth factors applied to the Plan02a inventories for CENRAP and MRPO.
- *Stationary Point Sources:* 2018 inventories for WRAP, MANE-VU, and VISTAS; 2018 projection factors (growth and control) applied to the Plan02 inventories for CENRAP; MRPO, Mexico, and Canada held constant with Plan02a; updated temporal profiles for all non-WRAP EGU sources, as developed from the IPM for 2018 emissions.
- *Fire Sources:* Baseline inventories for WRAP, CENRAP, and VISTAS; these emissions were held constant with Plan02a.
- *On-road Mobile Sources:* 2018 inventories for WRAP, CENRAP, VISTAS, and MANE-VU; MRPO, Mexico, and Canada held constant with Plan02a. As with the Base02 and Plan02 inventories, WRAP, Mexico, and Canada use pre-computed emissions inventories; the rest of the U.S. sources use on-road mobile activity inventories.
- *Non-road Mobile Sources:* 2018 inventories for WRAP, CENRAP, VISTAS, and MANE-VU; MRPO, Mexico, and Canada held constant with Plan02a.
- *Oil and Gas Sources:* 2018 inventories for WRAP states only.

- *Pacific Marine Shipping Sources:* Held constant with Plan02a.
- *Gulf of Mexico Offshore Area and Point Sources:* 2018 growth factors applied to the Plan02a inventories.

The inventory updates were combined with the Plan02a emission inventories for the sources that did not change to create case Base18a.

Base18b

The RMC created case Base18b to correct errors discovered in the Base18a emissions and to include inventory updates that were received after beginning the Base18a emissions simulation. These updates affected emissions both within and outside of the WRAP region. The WRAP updates included corrections to the stationary point inventory, revisions to the $PM_{2.5}$ emissions from fugitive and road dust sources, and updates to the fire emissions. The non-WRAP updates included the creation of new 2018 inventories for CENRAP and MRPO states with revised projection factors; fixing an error in the on-road mobile emissions for non-WRAP U.S. sources; replacing the temporal profiles for EGU sources in the VISTAS, MANE-VU, and MRPO states; and revisions to the $PM_{2.5}$ emissions from fugitive and road dust sources throughout the entire 36-km modeling domain. These revisions are all discussed below.

For the WRAP states and tribal lands, four major corrections were applied to the inventories and emissions inputs for modeling sources to create case Base18b:

- ERG, Inc., the WRAP inventory contractor that prepared the WRAP 2018 stationary point inventory, noted corrections to apply to the Base18a inventory. They provided incremental updates to apply to a group of sources in the WRAP 2018 inventory.
- The expanded list of dust sources, described in Mansell, 2006, and also under the documentation regarding fugitive dust sources, was used to develop the Base18b dust inventories. This change impacted both the dust and stationary-area-source inventories.
- On-shore and near-shore marine shipping sources were added for Washington and Oregon in case Base18b to correct the omission of these sources in Base18a.
- 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 cases.
    - The temporal and speciation profiles that 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 scenario and Base18a case, default temporal and speciation profiles were mistakenly applied to these emissions.

For the non-WRAP areas of the modeling domain, four major corrections to the inventories and emissions inputs for modeling sources were applied to prepare the case Base18b emissions inventories:

- Updated projection factors for the CENRAP and MRPO inventories to correct inconsistencies in their file formats with the IDA-formatted inventories were incorporated in the SMOKE modeling. Corrected projection data was received from CENRAP to apply to the CENRAP and MRPO stationary area, fugitive and road dust, agricultural and animal ammonia, and stationary point inventories.
- An error discovered in modeling of the 2018 on-road mobile activity inventories was corrected. By not resetting the SMOKE emissions factor year from 2002 to 2018, the correct emissions factors were not applied to the non-WRAP U.S. on-road mobile emissions. This problem was corrected by setting up SMOKE to use 2018 emissions factors.
- Similar to the problems encountered in the Plan02 modeling, it was discovered that the IPM-derived temporal profiles used in case Base18a for the non-WRAP stationary point sources produced emissions estimates that appeared unreasonably high, relative to the Plan02b emissions. The IPM-derived temporal profiles were 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.
- The expanded list of fugitive dust sources was used to develop the Base18b dust inventories. As with the WRAP states, this change impacted both the dust and stationary-area-source inventories.

These inventory updates were combined with the unaffected sources from Base18a to produce case Base18b.

Base18 Inventory Data Collection and Preparation

The data collection procedures for the development of the Plan02 emission inventories are described in this section. A discussion of the sources of all inventory and ancillary data that changed between the Plan02 scenario and the Base18 inventories is provided. The RMC worked with emissions inventory contractors, WRAP and other RPOs, and EPA to collect all of the data used to create the Base18 emissions inputs for SMOKE.

For the WRAP state and tribal inventories, Air Sciences, Inc., provided all fire inventories; ERG, Inc., provided all stationary area and stationary point inventories and temporal profiles; and ENVIRON provided all mobile, oil and gas, and Pacific shipping inventories that we used in the Base18 scenario. Alpine Geophysics, LLC, provided all inventories and ancillary data for the VISTAS states and tribes. CENRAP provided the 2018 projection factors for the CENRAP and MRPO states and tribes. The Mid-Atlantic Regional Air Management Association (MARAMA) provided 2018 inventories for the MANE-VU states and tribes. Data from the Plan02 inventory were used for Mexico and Canada emissions. All emissions data were received electronically;

the inventories in SMOKE-ready IDA format and the ancillary data as SMOKE-ready ASCII files.

To prepare the 2018 emissions data for SMOKE, these inventories were reorganized to conform to the list of sources modeled in the Plan02 scenario. Most of this reorganization affected the stationary-area-source inventory. 2018 inventories were prepared for SMOKE modeling in the following ways:

- Apply projection factors to applicable CENRAP and MRPO inventories.
- Extract fugitive and road dust sources from the stationary-area inventories to separate inventory files. Apply transport factors and revised $PM_{2.5}/PM_{10}$ splits to these sources.
- Extract WRAP oil and gas sources from the stationary-area inventories to separate inventory files.
- Extract refueling emissions from the non-WRAP U.S. off-road mobile inventory and discard; these sources are covered in the on-road mobile emissions.
- Split the fire inventories from annual to monthly files.
- For case Base18b, update the stationary-point inventories based on information provided by ERG, Inc.

Quality Assurance

The quality assurance of the Base18 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 for Base18a and Base18b. The graphical QA summaries include, for all emissions output species that changed from Plan02a to Base18, daily spatial plots summed across all model layers, daily time-series plots, annual time-series plots, and daily vertical profiles. The Base18a and Base18b QA graphics are available on the RMC web site at http://pah.cert.ucr.edu/aqm/308/Base18a_36.shtml and http://pah.cert.ucr.edu/aqm/308/qa_base18b36.shtml, respectively.