ST. LOUIS 8-HOUR OZONE TECHNICAL SUPPORT DOCUMENT

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Department of Natural Resources
Division of Environmental Quality

Air Pollution Control Program
P.O. Box 176
Jefferson City, Missouri 65102
Telephone: (573) 751-4817

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1.0 EXECUTIVE SUMMARY

On April 15, 2004, U.S. EPA designated portions of the St. Louis metropolitan area, including counties in both Missouri and Illinois, as nonattainment for the 8-hour ozone NAAQS. These designations became effective on June 15, 2004. Nine counties in the St. Louis area are designated as "moderate" nonattainment area for this new 8-hour standard (based on 2001-2003 observed ozone data). In Missouri, they are St. Louis City, Franklin, Jefferson, St. Charles, and St. Louis Counties. In Illinois, the nonattainment counties are Jersey, Madison, Monroe, and St. Clair.

One of the primary goals of the St. Louis 8-hour ozone modeling study was to develop photochemical modeling databases and allied analysis tools necessary to reliably simulate the processes responsible for 8-hour ozone exceedances in the region. This is done to assist the States of Missouri and Illinois in their development of realistic emissions reduction strategies for inclusion in the St. Louis ozone State Implementation Plan (SIP) due by June 2007. The St. Louis modeling study included episodic emissions, meteorological, and ozone simulations using a nested 36/12/4 km grid covering the central U.S. and centered on St. Louis. The modeling effort used SMOKE and supplemental EMS emissions, MM5 meteorological, and the CAMx and CMAQ air quality modeling systems for estimating ozone on the nested 36/12/4 km St. Louis grid during three 8-hour ozone episodes from the summer of 2002.

The 2002 Baseline CAMx and CMAQ modeling databases were evaluated against monitored ozone data from the St. Louis area in order to evaluate the fitness of the databases for use in the modeled attainment test. Initial simulations illustrated that the CMAQ modeling system exhibited a larger under-prediction ozone bias than CAMx. Given this large under-prediction bias, the higher computational efficiently of CAMx over CMAQ and the resource constraints of the study, the MDNR and IEPA elected to proceed with CAMx as the lead model and CMAQ as a corroborative model.

After several iterations of modeling inventories, meteorology, and modeling set-up, the modeling team reached a consensus regarding the appropriate inputs and model for the best and most accurate base case. On most episode days, the model achieved EPA's model performance evaluation goals for surface layer 8-hour and 1-hour ozone concentrations. Many of the days that did not meet these goals exhibited low ozone concentrations. These days were included in the modeling because they were bounded by two periods of high ozone concentrations or were needed as "ramp-up" days for the study. In general, the 1-hour and 8-hour ozone performance statistics suggest a systematic underestimation of ozone that is related to the over-estimation of ozone suppression by oxides of nitrogen in the St. Louis urban core, and the model's tendency to delay ozone formation in the St. Louis urban plume relative to observations. However, the St. Louis 2002 baseline model simulation exhibited sufficient skill in meeting most performance goals (especially on key days). Therefore, the modeling team decided that it may be used to project future-year ozone air quality and 8-hour ozone attainment, recognizing the inherent uncertainties in the atmospheric modeling process.

After detailed performance testing of the 2002 basecase simulation, the CAMx modeling system was exercised with a 2009 On-the-Books (OTB) emissions control scenario aimed at assessing the effects of future year emission control strategies on ozone in the St. Louis Nonattainment Area (NAA). The projected 8-hour ozone design values (using observed 2000-2004 5-year baseline 8-hour ozone design values) in the St. Louis NAA for the 2009 OTB emission scenario

were all below 85 ppb, thereby demonstrating attainment. However, the projected 2009 design value for one St. Louis NAA monitor (Orchard Farm) was very nearly 82 ppb and therefore, a weight of evidence determination was completed to provide additional confidence in the study results. Note, the CMAQ modeling system never was able to meet the model performance evaluation goals using the final basecase inventory and was discarded from further consideration due to lack of acceptable performance.

Based on the model's response to sensitivity analyses, the final attainment demonstration, and an Ozone Source Apportionment Technology (OSAT) scenario, elevated ozone concentrations in St. Louis are responsive to NOx emission control. Upwind and local NOx emission control are beneficial to reduce ozone in the area and necessary to demonstrate attainment in St. Louis.

The weight of evidence analyses lead to a determination that the St. Louis area will be in attainment of the NAAQS by 2010. Every one of the supplemental analyses performed was consistent in predicting attainment for St. Louis; not a single study suggested that the St. Louis area will not reach attainment by 2010. Therefore, the evidence for attainment was overwhelming and conclusive.

2.0 INTRODUCTION

2.1 BACKGROUND AND PURPOSE

On April 15, 2004, U.S. EPA designated portions of the St. Louis metropolitan area, including counties in both Missouri and Illinois, as nonattainment for the 8-hour ozone National Ambient Air Quality Standard (NAAQS). These designations became effective on June 15, 2004. Nine counties in the St. Louis area are designated as "moderate" nonattainment for this new 8-hour standard (based on 2001-2003 observed ozone data). In Missouri, they are St. Louis City, Franklin, Jefferson, St. Charles, and St. Louis Counties. In Illinois, the nonattainment counties are Jersey, Madison, Monroe, and St. Clair.

For "moderate" nonattainment areas, U.S. EPA established a deadline of June 15, 2007, for states to develop and adopt SIPs, and June 15, 2010, for areas to attain the 8-hour ozone standard. The June 2007 8-hour ozone SIP must include a demonstration that the St. Louis nonattainment area (NAA) will achieve the 8-hour ozone standard by 2010. An important component of this attainment demonstration is the use of photochemical grid models to project future-year ozone air quality. On April 15, 2004, U.S. EPA issued Phase I of its implementation rule for the 8-hour ozone NAAQS. This rule provides for classification of nonattainment areas for the 8-hour ozone standard, and describes U.S. EPA's policy regarding revocation of the 1-hour ozone NAAQS, attainment dates, and timing of emissions reductions necessary to demonstrate attainment. Phase II of the Implementation Rule was released in late 2005 and addressed mandatory control measures, interstate transport, attainment demonstrations, reasonable further progress, conformity, reasonable available control measures, NOx exemptions, and new source review (70 FR 71612-71705, Nov. 29, 2005).

One of the primary goals of the St. Louis 8-hour ozone and $PM_{2.5}$ modeling study was to develop photochemical modeling data bases and allied analysis tools necessary to reliably simulate the processes responsible for 8-hour ozone exceedances in the region. This was done to develop realistic emissions reduction strategies for inclusion in the St. Louis ozone SIP due by June 2007. This Technical Support Document (TSD) describes the modeling activities performed by the Missouri Department of Natural Resources (MDNR), Illinois Environmental Protection Agency (IEPA) and the St. Louis Modeling and Data Analysis Workgroup (MDAW) as well as the contractors for the study (ENVIRON/Alpine Geophysics) for the 8-hr ozone attainment demonstration for the St. Louis NAA. The MDAW consists of experienced air quality modelers at four (4) 'modeling hubs': MDNR, IEPA, EPA Region VII and Ameren that performed much of the St. Louis ozone modeling, with assistance from ENVIRON/Alpine. Collectively, the MDAW modeling hubs conducted the episodic 8-hour ozone modeling for St. Louis. Both the Missouri Department of Natural Resources, Air Pollution Control Program and the Illinois Environmental Protection Agency, Bureau of Air expressed a strong desire to work cooperatively with affected parties in the development and implementation of reliable, effective and equitable 8-hour ozone control strategies for the St. Louis metropolitan area. Both agencies have maintained the authority and flexibility to promulgate plans and necessary rules, given the dictates of the rulemaking process in each state.

2.2 STATE AGENCY ORGANIZATIONS AND WORK GROUPS

The states of Missouri and Illinois determined the committee structure described below that was used to manage the development and evaluation of control strategies, research, modeling, and other activities:

- **State Air Agencies:** Responsible for providing policy direction and guidance, selecting achievable emissions strategies, and resolving disputes as they arose. The state air agencies met as appropriate to oversee the progress of the effort. The Missouri Air Conservation Commission has final authority to adopt Missouri's control plan. Similarly, the Illinois Pollution Control Board has the final authority to adopt control requirements in Illinois.

  Participants: Air Directors from Missouri DNR and Illinois EPA.

- **Modeling and Data Analysis Workgroup (MDAW):** Responsible for the planning and management of the technical work necessary to demonstrate attainment, including emissions, meteorological, and photochemical modeling. The Modeling Workgroup contained four (4) modeling hubs (MDNR, IEPA, EPA Region VII and Ameren) that each assumed primary responsibility for the treatment of one meteorological episode for ozone. The Workgroup was also responsible for contractor selection, data analysis, source apportionment, coordination and communication of model results to AQAC, the Control Strategy Development Workgroup, and the state agency air directors. The Modeling and Data Analysis Workgroup met on a regular basis to coordinate the development and performance of technical activities. Meetings were open to stakeholders and representatives from local agencies having the technical expertise to contribute to work activities.

  Participants: IEPA, MDNR, U.S. EPA Region VII, U.S. EPA Region V, and East-West Gateway. Local organizations, stakeholders, and academics that were able to contribute technical capabilities or resources were also invited to participate.

- **Air Quality Advisory Committee (AQAC):** Served as a forum for communication and outreach between local governmental agencies, stakeholders, the Modeling and Data Analysis Workgroup, Control Strategy Development Workgroup, and the state agency air directors. The AQAC met on a regular basis, and was also responsible for identifying emissions control options for evaluation by the Control Strategy Development Workgroup, for developing conformity budgets, and preparing conformity demonstrations that are consistent with the 8-hour ozone SIPs. The Modeling and Data Analysis Workgroup, the Control Strategy Development Workgroup, and, when possible, the state agency air directors, were present at the meetings to report on activities, and to solicit input on control strategy recommendations.

  Participants: East West Gateway, MDNR, IEPA, U.S. EPA Regions 5 and 7, St. Louis County, St. Louis City, Federal Highway Administration, Missouri Department of Highway and Transportation (MDHT), Illinois Department of Transportation (IDOT), Federal Highway Administration (FHWA), Environmental Groups, Industry, and other local representatives.

- **Control Strategy Development Workgroup (CSDW):** Responsible for the identification and technical evaluation of control strategies needed to demonstrate attainment of the 8-hour ozone standards, and meet other regulatory requirements (e.g. contingency measure identification). The Control Strategy Development Workgroup was also responsible for coordination and communication of strategies and technical information to AQAC, the Modeling and Data Analysis Workgroup, and the State Agency Air Directors. The Control Strategy Development Workgroup met on a regular basis to coordinate the performance of technical activities. Meetings were open to stakeholders and representatives from local agencies having the technical expertise to contribute to work activities.

  Participants: IEPA, MDNR, U.S. EPA Region VII, U.S. EPA Region V, East-West Gateway. Local organizations, stakeholders, and academics that were able to contribute technical capabilities or resources were also invited to participate.

2.3 OVERVIEW OF APPROACH

2.3.1 Modeling Protocol

The St. Louis 8-Hour Ozone Study meteorological, emissions and air quality modeling followed the procedures outlined in the Modeling Protocol (ENVIRON and Alpine Geophysics, 2005). The Modeling Protocol describes the overall modeling activities performed by all the participants in the project. Its main function was to serve as a means for planning and communicating how the modeled attainment demonstration would be performed. The protocol guided the technical details of the modeling study and provided a formal framework within which the scientific assumptions, operational details, commitments and expectations of the various participants were communicated explicitly. The modeling protocol also set forth means for resolution of potential differences of technical and policy opinion to be worked out openly and within prescribed time and budget constraints.

2.3.2 Model Selection

The model selection methodology for the St. Louis ozone modeling rigorously adhered to EPA's guidance for regulatory modeling in support of ozone and fine particulate attainment demonstrations (EPA, 1991; 1999; 2005; 2006). Unlike previous ozone modeling guidance, the agency now recommends that models be selected for SIP studies on a 'case-by-case' basis with appropriate consideration being given to the candidate model's:

> Technical formulation, capabilities and features,
> Pertinent peer-review and performance evaluation history,
> Public availability, and
> Demonstrated success in similar regulatory applications.

Detailed discussion of the selection process for each model component may be found in the Modeling Protocol. Here follows a brief summary of each of the model components and a description of how it fits into the St. Louis 8-hour ozone modeling.

- **MM5:** The Mesoscale Meteorological Model (MM5) is a nonhydrostatic, prognostic meteorological model routinely used for urban- and regional-scale photochemical, fine particulate, and regional haze regulatory modeling studies (Dudhia, 1993; Seaman, 2000).

Developed in the 1970s, the MM5 modeling system maintains its status as a state-of-the-science model through enhancements provided by a broad user community worldwide (Stauffer and Seaman, 1990; Xiu and Pleim, 2000; Byun et al., 2005a,b). MM5 is used nearly exclusively for regulatory air quality applications in the U.S. In recent years, the modeling system has been successfully applied in continental-scale annual simulations.

- **SMOKE**: The Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system is an emissions modeling system that generates hourly, gridded, speciated emission inputs of mobile, nonroad, area, point, fire, and biogenic emission sources for photochemical grid models (Coats, 1995; Houyoux et al., 2000). As with most 'emissions models', SMOKE is principally an *emission processing system* and not a true *emissions modeling system* in which emissions estimates are simulated from 'first principles'. This means that, with the exception of mobile and biogenic sources, its purpose is to provide an efficient, modern tool for converting emissions inventory data into the formatted emission files required by an air quality simulation model. For mobile sources, SMOKE actually simulates emissions rates based on input mobile-source activity data, emission factors and outputs from transportation travel-demand models.

- **EMS**: The Emissions Modeling System-2003 (EMS-2003) is an emissions processing and modeling system with core functionality---spatial allocation, temporal allocation, and speciation of emissions---effectively the same as the SMOKE modeling system. Emissions inventory data representing point, area, fire, nonroad, mobile, and biogenic emissions are processed to produce inputs that are properly formatted for acceptance by an air quality simulation model. Only mobile and biogenic emissions are obtained from 'fundamental' calculations or 'first principles', the remaining emissions categories are input as pre-determined estimates that are 'reduced' through processing to the required level of resolution. The software was primarily used to create Electrical Generating Unit (EGU) emission estimates, and to provide supporting quality assurance/quality control checks.

- **CAMx:** The Comprehensive Air Quality Model with Extensions (CAMx) modeling system is a state-of-science 'One-Atmosphere' photochemical grid model capable of addressing ozone, particulate matter (PM), visibility and acid deposition at regional scale for periods up to one year (ENVIRON, 2006). CAMx is a publicly available open-source computer modeling system for the integrated assessment of gaseous and particulate air pollution. Built on today's understanding that air quality issues are complex, interrelated, and reach beyond the urban scale, CAMx is designed to (a) simulate air quality over many geographic scales, (b) treat a wide variety of inert and chemically active pollutants including ozone, inorganic and organic $PM_{2.5}$ and PM_{10} and mercury and toxics, (c) provide source-receptor, sensitivity, and process analyses and (d) be computationally efficient and easy to use. The U.S. EPA has approved the use of CAMx for numerous ozone and PM State Implementation Plans throughout the U.S. and has used this model to evaluate regional mitigation strategies.

- **CMAQ:** EPA's Models-3/Community Multiscale Air Quality (CMAQ) modeling system is also 'One-Atmosphere' photochemical grid model capable of addressing ozone, particulate matter (PM), visibility and acid deposition at regional scale for periods up to one year (Byun and Ching, 1999). The CMAQ modeling system was designed to approach air quality as a whole by including state-of-the-science capabilities for modeling multiple air quality issues, including tropospheric ozone, fine particles, toxics, acid deposition, and visibility degradation. CMAQ was also designed to have multi-scale capabilities so that separate

models were not needed for urban and regional scale air quality modeling. The CMAQ modeling system contains three types of modeling components: (a) a meteorological module for the description of atmospheric states and motions, (b) an emission models for man-made and natural emissions that are injected into the atmosphere, and (c) a chemistry-transport modeling system for simulation of the chemical transformation and fate.

The MM5 meteorological model was applied to generate the meteorological fields used with the SMOKE emissions and CMAQ/CAMx air quality models. The MM5 meteorological modeling was conducted in a similar fashion as was done for the Central Regional Air Planning Association (CENRAP) visibility modeling (Johnson, 2004). These simulations used the Pleim-Xiu PBL scheme (Xiu and Pleim, 2000), the Kain-Fritsch II cumulus parameterization for the 36 and 12 km domains (Kain and Fritsch, 1993), the RRTM radiation scheme (Mlawer et al. 1997) and the Reisner I mixed phase moist physics parameterization (Reisner et al., 1998). Model-ready emissions inputs were generated by processing emissions inventories developed by CENRAP (Strait, Roe and Vuckovich, 2004; Reid et al., 2004a,b) and the Midwest RPO (MRPO) using the SMOKE emissions modeling system. In the first phase of the St. Louis Modeling, EPA's Models-3 Community Multiscale Air Quality (CMAQ; Byun and Ching, 1999) modeling system and the Comprehensive Air-quality Model with extensions (CAMx; ENVIRON, 2006) air quality models were both applied. The application of the CMAQ/CAMx air quality models benefited from the extensive testing and evaluation conducted by CENRAP (Morris et al., 2005c), Visibility Improvement State and Tribal Association of the Southeast (VISTAS) (ENVIRON et al., 2003b,c,d; Morris et al., 2004a,b,c; 2005a,b) and MRPO (Baker, 2004). The CMAQ/CAMx model application followed the relevant guidance documents (EPA, 1991; 1999; 2001; 2003a, b; 2005; 2006). Note: As with all long-term modeling projects conducted for St. Louis, there was a consistent effort to use the most up-to-date scientific algorithms in each modeling system. For example, several different versions of CAMx were used in the base-case evaluation process (v4.11, v4.20, and v4.30). It was the intention of the modeling hubs to use the most technically defensible tools for the model performance and attainment demonstration exercises.

2.3.3 Modeling Domains

The 36 km continental U.S. horizontal domain for each of the models was identical to those used by Western Regional Air Partnership (WRAP), CENRAP, and VISTAS Regional Planning Organizations (RPOs). The CMAQ/CAMx air quality modeling domain is nested within the MM5 domain. The selection of the MM5 domain is described by Johnson (2004). Figure 2-1 displays the nested 36/12/4 km domains established by the MDNR for photochemical modeling and emissions modeling of the three summer 2002 8-hour ozone episodes.

During the course of the photochemical analyses, the modeling team decided to utilize a smaller 4km grid than the one described above for sensitivity testing purposes. This was done to maximize the amount of modeling work that could be accomplished given the computing resources available during the analyses. This smaller 4km grid was more narrowly focused around the St. Louis area and provided much shorter run times in CAMx to allow for more efficient processing of the sensitivity analyses. When evaluating the final model performance and proceeding with the future year analyses, the larger of the 4km grids was used to minimize affects from the 12km to 4km grid transition in St. Louis. In order to use the MM5 outputs for the smaller 4km domain, MM5CAMx had to be re-run for each episode and the SMOKE emission output had to be "windowed" out to allow for input to CAMx. Figure 2-2 displays the

revised domains utilized in the study.

Both MM5 and CMAQ/CAMx employed the RPO unified grid definition for the 36 km continental domain for the ozone modeling. The RPO unified grid consists of a Lambert-Conformal map projection using the projection parameters listed in Table 2-1.

The MM5 36 km grid includes 164 cells in the east-west direction and by 128 cells in the north-south direction. The CMAQ/CAMx 36 km grid includes 148 cells in the east-west direction and 112 cells in the north-south direction. Because the MM5 model is also nested within the Eta model, there is a possibility of boundary effects near the MM5 boundary that occur as the Eta meteorological variables are simulated by MM5 and are forced into dynamic balance with MM5's meteorological fields. Thus, a larger MM5 domain was selected to provide a buffer of 6 grid cells around each boundary of the CMAQ/CAMx 36 km domain. This was designed to eliminate any errors in the meteorology from boundary effects in the MM5 simulation at the interface of the MM5 and Eta models. The buffer region used here complies with the EPA suggestion of a buffer of at least 3-6 grid cells at each boundary (EPA, 2006).

Table 2-2 lists the number of rows and columns and the definition of the X and Y origin (i.e., the southwest corner) for the 36/12/4 km domains used by MM5, SMOKE and CMAQ/CAMx. In Table 2-2, "Dot" refers to the grid mesh defined at the vertices of the grid cells while "Cross" refers to the grid mesh defined by the grid cell centers. Thus, the dimension of the dot mesh is equal to the dimension of the cross mesh plus one.

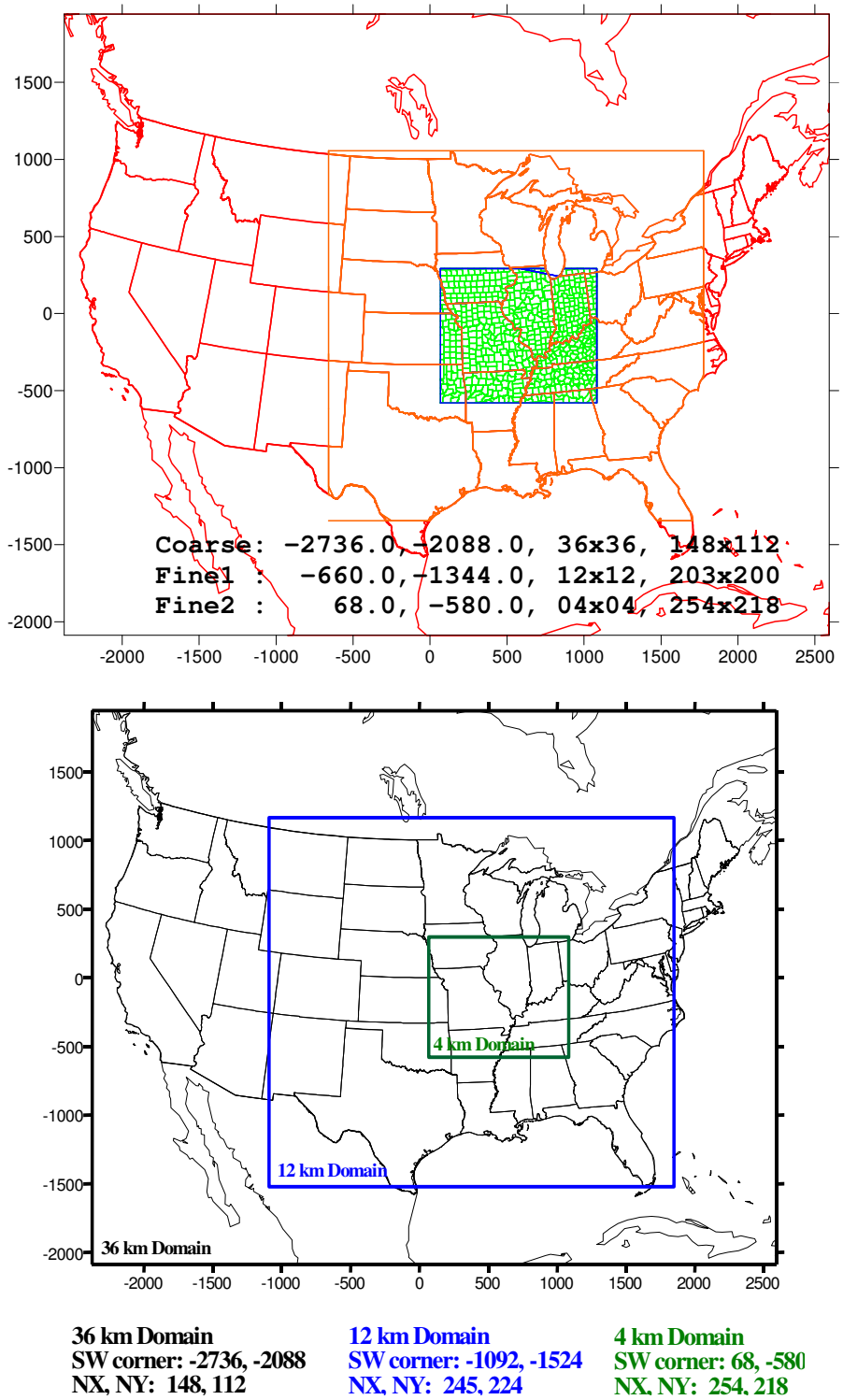


Figure 2-1. Nested 36/12/4 km St. Louis modeling domains for photochemical (top) and emissions (bottom) modeling.

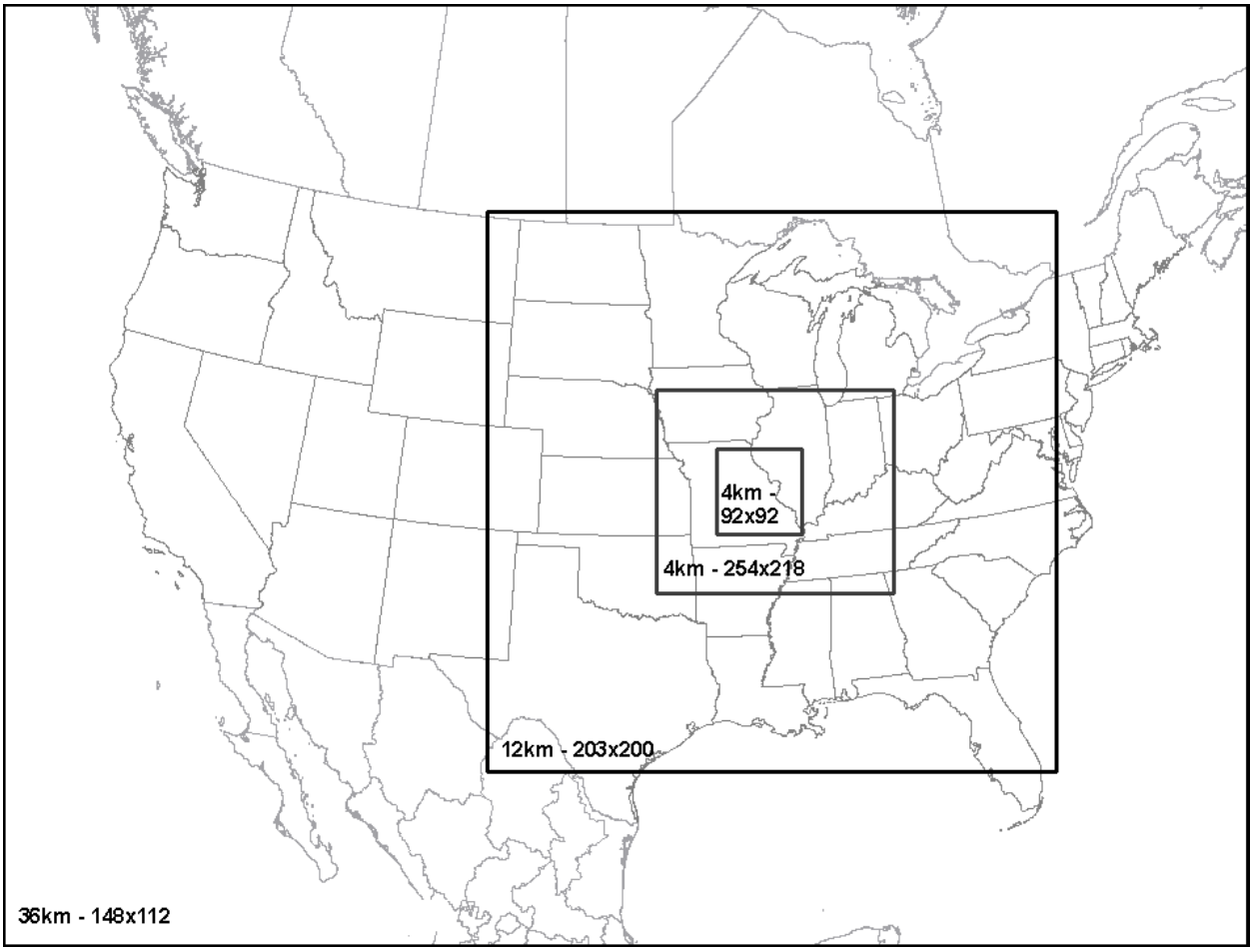


Figure 2-2. Revised Nested 36/12/4 km St. Louis modeling domains for photochemical modeling.

Table 2-1. RPO Unified Grid Projection Definition

Parameter	Value
Projection	Lambert-Conformal
Alpha	33 degrees
Beta	45 degrees
x center	-97 degrees
y center	40 degrees

Table 2-2. Grid Definitions for MM5, SMOKE/EMS, and CMAQ/CAMx

Model	Columns dot(cross)	Rows dot(cross)	Xorigin (meters)	Yorigin (meters)
MM5				
36 km grid	165 (164)	129 (128)	-2952000	-2304000
12 km grid	265 (264)	241 (240)	-1188000	-1620000
4 km grid	271 (270)	235 (234)	24000	-600000
SMOKE/EMS				
36 km grid	(148)	(112)	-2736000	-2088000
12 km grid	(245)	(224)	-1092000	-1524000
4 km grid	(254)	(218)	68000	-580000
CMAQ/CAMx				
36 km grid	(148)	(112)	-2736000	-2088000
12 km grid	(203)	(200)	-660000	-1344000
4 km grid	(254)	(218)	68000	-580000
small 4km grid	(92)	(92)	320000	-328000

2.3.4 Vertical Structure of Modeling Domain

The CMAQ/ CAMx model vertical structure is primarily defined by the vertical grid used in the MM5 modeling. The MM5 model employed a terrain-following coordinate system defined by pressure, and had 34 vertical layers that extend from the surface upward to 100 mb. CAMx and CMAQ were applied with exactly the same vertical layer structure. A layer averaging scheme was adopted for CMAQ/CAMx to reduce the computational burden of the CMAQ and CAMx simulations. The effects of layer averaging were evaluated by WRAP and VISTAS and were found to have a relatively minor effect on the model performance metrics when both the 34 layer (no layer averaging) and 19 layer (layers averaged) CMAQ model simulations were compared to ambient monitoring data (Morris et al., 2004a). For the St. Louis ozone modeling, 16 vertical layers were used. Table 2-3 details the mapping from the 34 vertical layers used by MM5 to the 16 vertical layers used by CMAQ and CAMx in the St. Louis study.

Table 2-3. Vertical Layer Definition for MM5 Simulations (left-most columns) and Approach for Reducing CMAQ/CAMx Layers by Collapsing Multiple MM5 Layers (right columns)

MM5					CMAQ/CAMx			
Layer	Sigma	Pres (mb)	Height (m)	Depth (m)	Layer	Pres (mb)	Height (m)	Depth (m)
34 (top)	**0.000**	**100**	**18123**	**2856**	**16**	**100**	**18123**	**7987**
33	0.050	145	15267	2097				
32	0.100	190	13170	1659				
31	0.150	235	11510	1374				
30	**0.200**	**280**	**10136**	**1173**	**15**	**280**	**10136**	**3106**
39	0.250	325	8963	1024				
28	0.300	370	7938	909				
27	**0.350**	**415**	**7030**	**817**	**14**	**415**	**7030**	**2866**
26	0.400	460	6213	742				
25	0.450	505	5471	680				
24	0.500	550	4791	627				
23	**0.550**	**595**	**4163**	**582**	**13**	**595**	**4163**	**1635**
22	0.600	640	3581	543				
21	0.650	685	3038	509				
20	**0.700**	**730**	**2528**	**386**	**12**	**730**	**2528**	**664**
19	0.740	766	2142	278				
18	**0.770**	**793**	**1864**	**269**	**11**	**793**	**1864**	**443**
17	0.800	820	1596	174				
16	**0.820**	**838**	**1421**	**171**	**10**	**838**	**1421**	**338**
15	0.840	856	1251	167				
14	**0.860**	**874**	**1083**	**164**	**9**	**874**	**1083**	**324**
13	0.880	892	920	161				
12	**0.900**	**910**	**759**	**79**	**8**	**910**	**759**	**158**
11	0.910	919	680	78				
10	**0.920**	**928**	**601**	**78**	**7**	**928**	**601**	**155**
9	0.930	937	524	77				
8	**0.940**	**946**	**447**	**76**	**6**	**946**	**447**	**152**
7	0.950	955	371	75				
6	**0.960**	**964**	**295**	**75**	**5**	**964**	**295**	**149**
5	0.970	973	220	74				
4	**0.980**	**982**	**146**	**37**	**4**	**982**	**146**	**37**
3	**0.985**	**987**	**109**	**37**	**3**	**987**	**109**	**37**
2	**0.990**	**991**	**73**	**36**	**2**	**991**	**73**	**36**
1	**0.995**	**996**	**36**	**36**	**1**	**996**	**36**	**36**
0 (ground)	**1.000**	**1000**	**0**	**0**	**0**	**0**	**0**	**0**

2.3.4.1 Air Quality Data

Data from ambient monitoring networks for both gas and aerosol species were used in the model performance evaluation. In the model performance evaluation presented in this TSD, the focus is on the evaluation of modeled surface layer ozone within the St. Louis NAA. Figure 2-3 displays the locations of monitoring sites in the St. Louis area including monitors outside the current NAA.

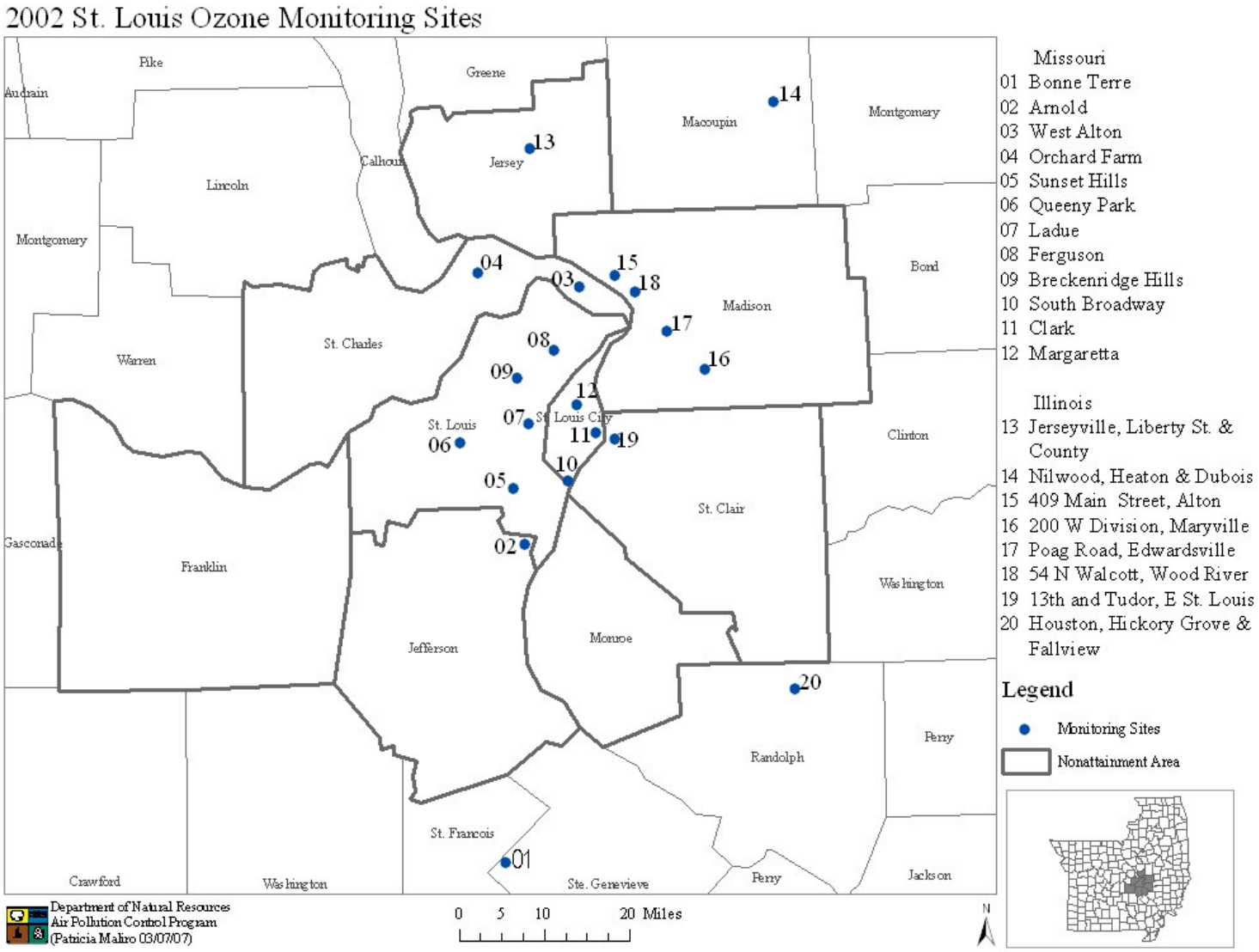


Figure 2-3. Ozone monitoring sites in the St. Louis Area

2.3.4.2 Ozone Column Data

Additional data used in the air quality modeling include the Total Ozone Mapping Spectrometer (TOMS) data. TOMS data are available for 24-hour average time periods, and are obtained from http://toms.gsfc.nasa.gov/eptoms/ep.html. The TOMS data are used in the CMAQ (JPROC) and CAMx (TUV) radiation models to calculate photolysis rates. The TOMS data were completely missing for the period of 3 August through 12 August, 2002, as well as on 10 June, 2002. In addition, 2 August and 18-19 November, 2002 had partially missing data.

The CAMx TUV processor allows for the use of monthly average data, so that option was used and the missing data ignored. The CMAQ JPROC processor does not allow for the use of monthly average data so the data from 1 August was used for 2 August through 7 August, and the data from 13 August was used for 8 August through 12 August. Data from 9 June was used for 10 June. Data from 17 November was used for 18 November, and data from 20 November was used for 19 November.

2.3.4.3 Initial and Boundary Conditions Data

For the episodic ozone simulations, the MDAW modeling hubs utilized a nominal 48-72 hour spin up period to initialize the simulations. The CENRAP annual CMAQ results were used for Initial Concentrations (ICs) for the CMAQ and CAMx episodic simulations. The CMAQ and CAMx boundary conditions were based on results from a 2002 GEOS-CHEM global climate model simulation (Jacob, 1999). The 2002 GEOS-CHEM model output has been processed to define day-specific high time resolved (i.e., 3-hourly) CMAQ and CAMx boundary conditions for 2002.

2.3.5 Episode Selection

The methodology for episode selection for the St. Louis 8-hour ozone modeling adhered to the criteria set forth by EPA in their guidance document for regulatory modeling in support of ozone, $PM_{2.5}$ and regional haze analyses (EPA, 1991; 1999; 2005; 2006). In general, EPA recommends the following main criteria for selecting time periods to model for 8-hour ozone:

- The time periods selected should represent a variety of meteorological conditions. 8-hour ozone should exceed 85 ppb at multiple monitors.
- Model episodes with observed ozone close to the area design value (~90 ppb).
- Model time periods with robust observational databases.
- Model a sufficient number of days to ensure a robust Relative Response Factor (RRF) for each monitor (minimum 5 days, 10-16 days preferred).

EPA recognized that some of these criteria may be in conflict with each other and acknowledged that some secondary criteria may help resolve the issue. Some additional considerations for selection are: choosing time periods that have been previously modeled successfully in other demonstrations, selecting time periods drawn from the period upon which the baseline design value was calculated (i.e., 2000-2004), choosing episodes as close to the NAAQS on as many days are possible, and including weekend days if the area commonly has violations then.

The St. Louis Ozone Technical Group accounted for these criteria when choosing the appropriate time periods to model. The group also recognized other key state-specific considerations in the selection process, such as constraints due to limited regulatory timeframe, human resources, and computing capacity.

In accordance with the guidance, episode selection focused on the key years surrounding the calculation of the area's baseline design value. Particularly, the years 2001-2003 were examined in order to determine appropriate representative time periods to model. Below is a brief summary of the elevated ozone time period specifics for 2001 – 2003 as it recorded by the 17 urban area monitors in and around St. Louis.

2001 Ozone Season: 14 8-hour ozone exceedance days, 12 single-day events, one 2-day event, weak multiple-monitor days (no days > 4 monitors exceeding).

2002 Ozone Season: 32 exceedance days, 5 single days, but significant multi-day events, wide breadth of meteorology, many multiple-monitor days (17 days > 4 monitors exceeding).

2003 Ozone Season: 11 exceedance days, four single-day events, two 2-day events, one 3-day event (6 days > 4 monitors exceeding).

In order to affirm that the episode selection represented a variety of meteorological conditions associated with high ozone events, MDNR's July 2003 Technical Support Document for Determination of Nonattainment Boundaries in Missouri for the 8-hr Ozone National Ambient Air Quality Standard was reviewed (Bennett, Froning, Mefrakis 2003). A summary of the different meteorological regimes identified for St. Louis is below.

Meteorological Regime #1

Synoptic features

Regime #1 occurs as a high pressure area develops over the Ohio River Valley forcing any lingering frontal boundaries to be pushed out of the region. As the day wears on, the center of the high pressure system migrates to the northeast and establishes itself over the New England states. Frontal boundaries typically remain to the northwest with their area of influence limited to the High Plains.

Surface features

The presence of the high pressure center over the Ohio River valley during the morning hours often leads to calm, potentially haze conditions. As the high pressure center migrates eastward, the surface wind speeds increase slightly, but remain below ten knots. In most instances the predominant wind direction is from the southeastern quadrant. Slight variations in the position of the high pressure center determine if the winds are from the east-southeast, southeast, or south-southeast.

Meteorological Regime #2

Synoptic Features

Regime #2 occurs as a high pressure area over the New England states retreats southward over the Mid-Atlantic states. The frontal boundary positioned over the High Plains in Regime #1 continues to move toward the Midwest as the afternoon high pressure center drifts off the eastern seaboard. Depending on the strength of the area of high pressure, the frontal boundary may continue its southeasterly path,

or it may become stationary along the Missouri/Iowa border

Surface features

The surface conditions occurring during the 2nd regime are not as consistent as those associated with the first. The largest contributor to this variation in wind direction is often due to the proximity of the frontal boundary to the St. Louis metropolitan area. The predominant wind direction is often from the southwest with wind speeds less than ten knots. Again, a.m. calms are common. As frontal boundaries approach, the winds may shift to the southeast or north. With few exceptions, the winds remain at speed less than ten knots.

Meteorological Regime #3

Synoptic Features

Regime #3 occurs as the stationary front positioned along the Missouri/Iowa border, as seen in Regime #2, becomes mobile and continues its southerly advance though the State of Missouri. As the front approaches the St. Louis and Kansas City regions, early morning precursor emissions and/or ozone are forced southward causing higher concentrations of ozone to the south of each metropolitan area. The timing and intensity of the frontal boundary determines which sites report elevated concentrations.

Surface Features

The surface conditions occurring during this regime do not follow a consistent pattern due to the proximity of the frontal boundary to the St. Louis metropolitan area. Hazy conditions are often reported prior to the passage of a cold front with calm, variable winds common. As frontal boundaries approach, the winds may shift to the southeast or north. With few exceptions, the winds remain at speeds less than ten knots.

Meteorological Regime #4

Synoptic Features

Regime #4 occurs as a high pressure area develops over the State of Iowa and migrates southward over Missouri. Further tracking of the high pressure center indicates that it will continue to move eastward over Illinois and Indiana. No predominate frontal systems are present within the region.

Surface Features

The presence of the high pressure center over the midsection of the United States during the morning hours often leads to calm, potentially hazy conditions. As the high pressure center migrates eastward into Illinois and Indiana, the surface wind speeds increase slightly, but remain below ten knots. In most instances the predominant wind direction is from the northeast quadrant. Slight variations in the position of the high pressure center determine the pattern of the surface flow.

Meteorological Regime #5

Synoptic Features

Regime #5 occurs less frequently than previous regimes as a high pressure areas develop over Canada and the Northern New England states. A frontal boundary will approach and pass through the State of Missouri and will remain to the east over the Ohio River Valley as a second boundary approaches from the West.

Surface Features

The presence of multiple frontal boundaries in the region typically leads to little or

no formation of ozone. However, on the days with reported ozone exceedances, the frontal systems were in close proximity to one another and often trapped pollutants between their boundaries. With little or no precipitation reported and sunny skies, the ozone precursors had little chance for dilution and were available for ozone production.

Meteorological Regime #6

Synoptic Features

Regime #6 resulted in a high pressure buildup over West Virginia as a stationary front remained in an east/west configuration along the I-70 corridor. The frontal boundary advanced and retreated across the immediate area causing ozone episodes with significant differences in ozone maximums from day to day depending on what air mass was over each metropolitan area.

Surface Features

The presence of the frontal boundary to the north or the south of the city caused the wind speeds and directions to vary from day to day depending upon the air mass over the region.

Meteorological Regime #7

Synoptic Features

Regime #7 occurs when an area of strong high pressure develops over the Eastern United States. Depending on the strength of the high pressure region, centers may develop over Missouri and Illinois. The strongest subsidence regions remain over the East Coast. The St. Louis region was the only area within the State of Missouri that reported ozone exceedances during this meteorological regime.

Surface Features

The presence of the high pressure centers throughout the region leads to calm conditions during the morning hours allowing precursor emissions to remain in the urban core. As the high pressure centers migrate and/or weaken as the day continues, the ozone plume will begin to migrate in the direction of the surface flow. The wind directions vary under this regime and are extremely dependent upon the development and position of individual high pressure centers.

The meteorological conditions associated with Regimes #2, #4, and #7 resulted in the most severe 8-hour ozone concentrations within the St. Louis area. Each of these meteorological regimes resulted in days exceeding 110 parts per billion based upon the 8-hour average. Regime's #1 and #3 were the next most severe, with concentrations exceeding 100 parts per billion at several ambient air quality sites. Both regimes #6 and #7 remained below 100 parts per billion.

In addition to reviewing the severity of ozone concentrations under certain meteorological conditions, the likelihood that ozone concentrations in excess of the 8-hour ozone standard would occur was also evaluated. Regime's #1 and #2 occurred most frequently and often were associated with the same episode. Regimes #3, #4, and #7 also occurred on a regular basis, with Regime #3 ending ozone episodes with the passage of a frontal system that ushered in new, cleaner air masses.

Balancing the existing capabilities of the technical group and the necessity to develop a robust modeling demonstration, the 2002 time period offered the best candidate ozone events. By

limiting the modeling to a particular year, it allowed for a significantly streamlined database acquisition process without compromising episode quality or quantity per guidance recommendations. Listed in Table 2-4 are the 8-hour exceedance days from the summer 2002 ozone season in the St. Louis area. Highlighted in shaded, bolded text are the exceedance days selected to model.

Table 2-4. 2002 8-Hour Ozone Exceedance Days in the St. Louis Area

06/08/2002	**07/16/2002**
06/19/2002	07/20/2002
06/20/2002	07/25/2002
06/21/2002	**07/30/2002**
06/22/2002	**08/01/2002**
06/23/2002	**08/02/2002**
07/02/2002	**08/03/2002**
07/03/2002	**08/04/2002**
07/04/2002	08/09/2002
07/05/2002	08/10/2002
07/07/2002	09/01/2002
07/08/2002	09/06/2002
07/09/2002	09/07/2002
07/13/2002	09/08/2002
07/14/2002	09/09/2002
07/15/2002	09/14/2002

Note: Shaded, bolded text indicates days chosen for modeling.

For this study, 21 of the 32 exceedance days (and necessary ramp-up days) in 2002 were modeled. Of the 5 multi-day episodes of three or more consecutive days, four of them are captured in the modeling. The meteorology during the September 6-9, 2002 timeframe bears a striking resemblance to the weather conditions prevalent during the high ozone stretch in early July, thus it was removed from consideration to avoid duplication or overweighting from a particular meteorological regime.

The meteorological regimes identified previously are summarized as follows:

Regime #1 *June 19-21*, August 9, September 1
Regime #2 *June 22-23, July 8-9,* July 25, *August 1-2*, August 10, September 14
Regime #3 *July 5*, July 20
Regime #4 *July 13-16*
Regime #5 *July 30*
Regime #6 *August 2-4*
Regime #7 *July 2-4*, September 7-9

All the meteorological regimes are contained in the episodes selected with the most frequent regimes represented by more than one episode. The selection of these episodes assures that we have a variety of meteorological conditions that are conducive to elevated 8-hour ozone formation in the St. Louis area.

Below is a brief description of the air quality and meteorology from the episode days selected in the attainment demonstration modeling. See Appendix A for more detailed air quality and meteorological information for the chosen modeled days.

6/19/02-6/23/02: A high-pressure center at the 500-millibar level persisted over the State of Missouri for the entirety of the review period with surface high pressure evident over the Ohio River Valley and New England states at the onset of the episode. The presence of the surface high over the New England states resulted in calm, hazy conditions across the region during the morning hours, with light southeasterly flow apparent by the mid-afternoon hours on June 19 and 20, 2002. Elevated ozone concentrations were reported at West Alton (93 ppb – 8 hour), Jerseyville (91 ppb), Orchard Farm (86 ppb) and Alton (87 ppb) on June 19th. The highest 8-hour concentrations on June 20th were again north of the downtown area and the maximum was monitored at Jerseyville (100 ppb). The back trajectory analysis indicates that on June 19, 2002 little transport occurred from areas outside the non-attainment area. As the 500-millibar high pressure center intensified and the air mass became more stagnant by June 21, 2002, the ozone concentrations across the region increased with a southerly push still evident as maximum ozone concentrations of 110 ppb and 100 respectively were reported at Jerseyville and West Alton. The back trajectory analysis indicates that transport from the Gulf Coast states is occurring and corresponds to the southerly push that was noted on the meteorological charts. On June 22, 2002 a weak frontal boundary was located over the Great Lakes region with high pressure continuing to dominate the East Coast with the center over the mid-Atlantic states. Early morning conditions continued to be calm, with haze reported at several National Weather Service sites. Higher ozone concentrations continued on June 22nd continued to occur with maximum concentrations reported at Orchard Farm (111 ppb), Jerseyville (109 ppb), and West Alton (111 ppb). Transport from the Tennessee and Ohio River Valley's is evident based upon the back trajectory analysis that was conducted for the 22nd and 23rd of June. Widespread rainfall associated with a low pressure center over Florida and Georgia brought the June episode to an end.

7/2/02-7/16/02: Long-term elevated ozone period, essentially 3 different episodes with one to two days break for air-mass change. July 2- July 5 was dominated by low wind speeds, variable wind directions in St. Louis, moderate stagnation, and upper-level winds from south to southeast. Weak high pressure drifted from KY to northern AL during the 4-day stretch. Daily peak 8-hour ozone ranged from 92 ppb on July 2 (1 site exceeding) to 109 ppb on July 5 (6 sites exceeding). A front in the area on July 6 marked the transition to the 2nd elevated period. A fast moving high pressure migrated from Michigan to South Carolina over the 3 days of July 7-July 9. For the period, back trajectories indicated transport of ozone into the St. Louis area from the east/northeast. Winds backed to southwesterly by July 9 as a cold front approached from the northwest and monitors on the Illinois side were high. On July 7, transport from the northeast was evident southwesterly winds. Daily 8-hour ozone peaks were 93 ppb on July 7 (4 sites exceeding), 119 ppb on July 8 (13 sites), and 90 ppb on July 9 (1 site over). From July 10-12, a low pressure system and cold front cleaned out the air mass, but a new high pressure system migrating out of Canada moved slowly from northern MN on July 13 to southern Alabama on July 16, resulted in a significant ozone episode in St. Louis. Transport indicated incoming ozone from the IN, OH, MI area. Daily peaks ranged from 89 ppb (3 sites exceeding) of July 13 to 114 ppb (145 sites exceeding) on July 15. Though high pressure was still in place in the deep-south, daily localized rainfall in St. Louis air-shed on July 17th and 18th effectively suppressed ozone formation.

7/30/02-8/4/02: A 500 mb high pressure centered itself over the central plains during this period, with a weak surface high residing in the southeast early on, then another surface high pressure area strengthening from MI to VA as the episode progressed. A weak frontal boundary near St. Louis during the August 2-4 timeframe likely muted the intensity of the exceedances, but did result in highly variable wind directions day to day. Daily 8-hour ozone peaks were 93 ppb on July 30 (1 site over), then a 1 day break on July 31, followed by 96 ppb on August 1 (3 sites), 85 ppb on August 2 (1 site), 99 ppb on August 3 (7 sites), and 98 ppb on August 4 (6 sites exceeding). Backward trajectories indicate long term transport from the southwest until August 3rd, then an air-mass origination from the Ohio River Valley on August 4th. Ozone levels remained high but just below 85 ppb on August 5th. A strong cold frontal passage ended the episode on August 6.

The technical group determined that modeling this selection of episodes provides a full range of the typical or historical ozone conducive meteorology in St. Louis, including modeling full synoptic cycles of some of the longer term elevated ozone event from the summer of 2002. The quantity of days modeled also provided the necessary robustness (for each monitor) to draw conclusions from the EPA recommended RRF test with reasonable confidence.

2.3.6 Conceptual Model

The conceptual model is designed to provide an explanation of events that transpired to cause high ozone during these modeling time periods. Typically, it includes a discussion of meteorology, emissions, and transported ozone and precursors into the metropolitan area. As discussed previously in Episode Selection, there are several types of synoptic weather patterns associate with high ozone in St. Louis. Most of the local surface weather patterns are calm or light winds in the morning hours and continued calm or a "push" to the suburban areas in the afternoon resulting in high 8-hour concentrations.

The following is a description of the conceptual model for 8-hour ozone exceedance days within all three ozone episodes evaluated in the attainment demonstration analyses:

<u>June 19-23, 2002</u>

As discussed previously in Section 2.3.5, there was a high pressure center at the 500-millibar level that remained over the state of Missouri throughout this episode. This in conjunction with surface high pressure over the Ohio River Valley and Great Lakes Region translate to Meteorological Regime #1 in St. Louis for June 19-21.

On June 19th, the surface winds were light and predominantly from the south-southeast and south over the course of the day. The 72-hour back trajectory for June 19th entering St. Louis demonstrates low-wind speed conditions and limited transport of ozone and precursors from eastern Tennessee and Kentucky along with southern Illinois and Missouri. As expected the highest 8-hour ozone concentrations were found north of the metropolitan area at Jerseyville (91 ppb) along with exceedances at Orchard Farm, West Alton, and Alton. In addition, there was an exceedance at the Houston, IL (86 ppb) monitor to the south and east of the metropolitan area. These high concentrations are likely due to large proximate NOx source impacts on the monitor and/or near-field transport from the south or south-southeast. The other upwind monitors for this day (Bonne Terre, Arnold) were 70-75 ppb (max 8-hour average).

Surface wind conditions on June 20th were again from the south and south-southeast. The 72-hour back trajectories indicate potential transport from the south and south-southeast (eastern Tennessee, Kentucky, Mississippi). Again, the highest 8-hour concentrations were downwind of the urban core at Jerseyville (100 ppb) with exceedances at West Alton, Orchard Farm, Alton, Breckenridge Hills, and Nilwood. The wind directions were consistent and the highest 1-hour value was monitored at Jerseyville (115 ppb) at 5:00 PM with the highest 1-hour concentrations at West Alton, Orchard Farm, and Alton earlier (2:00-3:00 PM). This is indicative of persistent flow within the region and transport of the morning urban emission plume into the suburban and rural areas in the early/late afternoon hours. Maximum 8-hour upwind monitor concentrations on this day were between 58 and 69 ppb.

The 500-millibar high pressure center over Missouri intensified and the air mass became more stagnant on June 21st. As expected, the early morning surface winds slowed down further on this day and were variable, but remained from the south as the day progressed. In addition, a weak front was located over Iowa and the Great Lakes. The back trajectories again illustrated transport from the south and south-east (more easterly on this day). The highest 1-hour concentrations were downwind of the area at Jerseyville (119 ppb at 4:00 PM), but the sites closer to the downtown experienced 1-hour concentrations over 100 ppb at 11:00 AM and continued into the early afternoon. There were many concentrations that exceeded the 8-hour standard on this day. The maximum was observed at Jerseyville 110 ppb, with West Alton (100 ppb), Orchard Farm and Breckenridge Hills (96 ppb), Ferguson (95 ppb), Alton (94 ppb), Sunset Hills (90 ppb), Nilwood (89 ppb), Maryville (88 ppb), Arnold and Margaretta (85 ppb) also experiencing concentrations over the standard. Maximum upwind concentrations were 75-80 ppb. The more stagnant air mass around the metropolitan area contributed to more sites and overall higher concentrations on this day than previous days in this episode.

June 22nd and 23rd were characterized in Section 2.3.5 as being from meteorological regime #2 with surface high pressure centered over the Mid-Atlantic states with the frontal boundary remaining over the Great Lakes region. June 22nd was predominated by hazy conditions over much of the Midwest and East. The surface winds were very light and variable during the morning hours with calms reported. Winds were more easterly than previous days, but still remained from the southeast throughout the afternoon hours. The back trajectories for June 22nd were more easterly from Kentucky and southern Illinois. All sites within the St. Louis area monitored concentrations over the 8-hour standard with the maximums occurring north and west of the urban core (West Alton and Orchard Farm – 111 ppb). The maximum 1-hour concentration at Orchard Farm was 125 ppb at 2:00 PM. This day was the highest monitored day in the June 2002 episode. This day can be characterized as a high regional event with concentrations over the 8-hour ozone standard in most of the Midwestern United States along with the very light and variable winds in the morning hours contributing allowing a buildup of precursors that were later slowly pushed to the north and west resulting in very high concentrations throughout the entire area. The maximum 8-hour "upwind" concentrations on this day were above 90 ppb.

Surface winds were again light and variable in the morning hours on June 23rd. Late morning and early afternoon winds were similar to June 21st (southerly). Back trajectories illustrated transport from the Ohio River Valley. The maximum 8-hour average concentration was 101 ppb at Orchard Farm. Jerseyville, West Alton, Queeny Park, Arnold, Alton, Sunset Hills, Ferguson, Ladue, Maryville, Edwardsville, Wood River, and Margaretta monitored concentrations over the standard. Two separate 1-hour ozone peaks were observed at the Orchard Farm and Jerseyville

monitors on this day (early peak at 11:00 AM-12:00 PM and late peak at 4:00 PM-5:00 PM). This episode ends on June 24th due to late afternoon and evening rain showers in and around the St. Louis area.

July 2-5

The first portion of the July 2-5, 2002 episode was characterized as Meteorological Regime #7 in Section 2.3.5. This regime develops with strong high pressure over the eastern United States. Strong subsidence remains over the east coast and high pressure centers can develop over Missouri and Illinois. Surface wind conditions are dependent on the location of the high pressure centers and are typically light and variable in the morning hours.

Surface high pressure was located over southern Illinois on July 2nd with light and variable surface winds in the morning with a south-southeasterly flow in the afternoon. The maximum 8-hour concentration was 88 ppb at the Orchard Farm monitor with elevated 1-hour concentrations also observed at West Alton and Jerseyville. The 72-hour back trajectories for July 2nd illustrated transport from the south-southwest (southern Missouri and western Arkansas). Cloud cover on this day may have led to somewhat reduced ozone concentrations. Maximum 8-hour upwind concentrations were below 60 ppb.

The high pressure over the central/eastern United States remained on July 3rd with light and variable surface winds throughout the day. Back trajectories indicated stagnation around the St. Louis area. The maximum 8-hour concentration was observed at West Alton (90 ppb) with the maximum 1-hour concentration at the Ferguson monitor (107 ppb). It appears that the ozone plume did not extend much beyond the suburban area during this day. Morning clouds in the St. Louis area may have somewhat limited ozone formation on this day. Maximum 8-hour upwind concentrations were between 60-70 ppb.

Surface high pressure was located directly over Missouri on July 4th with light and variable winds in the morning and a westerly/northerly push by the afternoon. Back trajectories were indicative of stagnation around the St. Louis area. Maximum 8-hour concentrations were observed at Ladue (103 ppb) with higher concentrations measured in the southern half of the monitoring network. Bonne Terre monitored a maximum 8-hour concentration of 90 ppb. Maximum 8-hour upwind concentrations in the northern part of the area were around 65 ppb. Also, a frontal boundary was present over Iowa in the afternoon.

The front approached from the north on July 5th and light/variable winds continued. Back trajectories still demonstrated stagnation with influence from the east (Illinois, Indiana). Again, the maximum 1-hour and 8-hour concentrations were seen in the south-western portions of the St. Louis area (Sunset Hills – 128 ppb 1-hour and 109 ppb 8-hour). Concentrations over the 8-hour NAAQS were observed at Queeny Park, Ladue, West Alton, S. Broadway, Margaretta, and Arnold. Upwind, maximum 8-hour concentrations were near 70 ppb.

The frontal passage on July 6th caused reduced ozone concentrations, but the maximum 8-hour concentration was still 84 ppb at Sunset Hills.

July 7-9

A surface wind shift is evident on July 7th with early morning winds light and from the south with a switch to northeast in the late morning and early afternoon hours. A surface high was located over the Great Lakes region on this day. Back trajectories illustrate transport around that high pressure center from the northern Ohio River Valley. Maximum 1-hour concentrations were observed early (10:00 AM) at West Alton -- 111 ppb with a substantive decrease in concentration over the next few hours. 1-hour and 8-hour concentrations increase back over the urban core and the highest 8-hour concentration was monitored at the Sunset Hills monitor (93 ppb). Several sites exceeded the 8-hour standard on this day including: Ladue, Queeny Park, and Margaretta. Maximum 8-hour upwind concentrations (north of the area) were near 70 ppb.

The surface high migrated to the south and east over the Mid-Atlantic states and a frontal boundary was observed over the High Plains on July 8th (Meteorological Regime #2). Light and variable surface winds (southerly component) switched to southwesterly and westerly after noon and continued until the early evening hours. Back trajectories on this day illustrate transport from the north and east (Illinois, Indiana). As with July 7th, the suburban sites to the north (Orchard Farm, West Alton, and Alton) all monitored higher 1-hour concentrations at 10:00-11:00 AM than the typical mid-to-late afternoon. The highest 1-hour and 8-hour concentrations were monitored at Maryville (135 ppb and 119 ppb). This day recorded the highest monitored concentrations in the July 2002 episode. Several other sites monitored exceedances of the 8-hour standard: Margaretta (111 ppb), Ferguson (110 ppb), Edwardsville (104 ppb), E. St. Louis (102 ppb), West Alton (99 ppb), Breckenridge Hills (94 ppb), South Broadway (93 ppb), Maryville (92 ppb), Orchard Farm (91 ppb), Ladue (87 ppb), Clark (86 ppb), and Sunset Hills (85 ppb). Maximum 8-hour upwind concentrations (south of the area) were 76-77 ppb.

The front over Iowa progressed south toward St. Louis on July 9th and some rain showers developed during the day mitigating ozone production. Light and variable winds during the early morning give way to westerly surface flow in the late morning that continues with increased speed into the evening. Back trajectories reflect limited transport into the area. Only one monitor recorded an 8-hour exceedance on this day (Maryville - 90 ppb). After the front passed, "clean air" arrived from the north and ended this portion of the episode. It is interesting to note that Bonne Terre observed two 1-hour concentrations over 100 ppb on the morning of July 10th (carry-over from the previous episode days).

July 13-16

This portion of the episode was identified as Meteorological Regime #4 in Section 2.3.5. This regime has a surface high pressure center over Iowa with light surface winds from the northeast. Back trajectories for July 13th show influence from the high pressure center and illustrate transport from the northern Ohio River Valley. High 1-hour and 8-hour concentrations were observed over the southern portion of the monitoring network with the maximum at Sunset Hills (8-hour 89 ppb). Exceedances were also monitored at Arnold (88 ppb), Ladue (86 ppb), and Bonne Terre (85 ppb). As expected, the Bonne Terre concentrations become elevated after the near-metro sites. Maximum 8-hour upwind concentrations (north) were 76-77 ppb.

The high pressure center remained over Iowa and surface winds were variable in the morning hours and transitioned to the northeast in the late morning and early afternoon. Back trajectories again illustrated transport from Illinois, Indiana, and Ohio. Highest 1-hour and 8-hour

concentrations were again in the southern portion of the monitoring network. Sunset Hills monitored the maximum 8-hour ozone concentration at 97 ppb. The Arnold and Bonne Terre monitors also monitored 1-hour concentrations over 100 ppb. 8-hour exceedances were monitored at Arnold, Bonne Terre, Sunset Hills, Ladue, S. Broadway, Margaretta, West Alton, E. St. Louis, and Alton. Maximum 8-hour upwind concentrations were near 80 ppb.

The high pressure center moved south over northeast Missouri and surface winds were very light and variable on July 15th (the entire day). Back trajectories still exhibited transport from Illinois and Indiana. This day was dominated by the stagnant air near the high pressure center and ozone built-up around the entire metropolitan area. Sunset Hills and Margaretta both monitored one-hour concentrations above 120 ppb at 2:00 PM. Nearly all urban and suburban sites monitored 8-hour exceedances on this day (Wood River, Bonne Terre, Houston, Jerseyville, and Nilwood were the only sites not to monitor over 85 ppb). Maximum 8-hour background concentrations were 75-83 ppb around the metropolitan area. On this day, emissions were not pushed out of the urban center and resulted in high concentrations throughout the area.

The high pressure center migrated over into central Illinois on the 16th and surface winds were again light, but with a late morning/early afternoon push from the south. Limited transport from the east due to the migration of the surface high was prevalent in the back trajectories. The highest concentrations were monitored at the West Alton and Alton locations (93 and 90 ppb – 8 hour). There were also exceedances at Orchard Farm, Jerseyville, and Arnold. The higher values at Arnold are likely due to precursor carry-over to the south of the area from the previous day being blown back over the monitor on the 16th. Upwind concentrations around 70 ppb were observed. This is a "normal" high ozone day for St. Louis (light winds in the morning with a southerly push around noon.

Localized rainfall in St. Louis on July 17th and 18th suppressed ozone formation and ended this extended period of high ozone.

<u>July 30 and August 1-4</u>

A 500 mb high pressure system centered itself over the central plains during this episode. July 30th was a mild ozone exceedance day with only one 8-hour exceedance at Queeny Park (90 ppb). Transport was indicated by the back trajectories from the southwest (southwestern Missouri, Oklahoma and Texas). Winds were variable in the morning and shifted to the northeast around noon (contributing to the exceedance at Queeny Park). Widely scattered rain showers were prevalent on this day around the St. Louis area.

July 31st had sustained winds higher than the previous day and following days from the south and was not an exceedance day in this episode. The highest 8-hour concentration was 78 ppb at Orchard Farm.

A weak frontal boundary approached from the north on August 1st and a surface high pressure center developed over the West Virgina. Winds were from the south, southeast, and southwest during the day. The highest 8-hour concentrations were observed at Wood River (92 ppb), West Alton (88 ppb), and Alton (85 ppb) on the 1st. Back trajectories again illustrated transport from the southwest. Background concentrations were observed near 50 ppb for 8-hour averages.

High pressure was still located over West Virginia on August 2nd, with the frontal boundary near the St. Louis area pushed past the metropolitan area (Meteorological Regime #6). This caused a wind shift to the north and northwest in the late afternoon. Winds were highly variable on this day due to the frontal passage. Back trajectories show transport from southwest Missouri, Oklahoma, and Texas. The maximum concentrations happened as the front passed and precursors were pushed to the south. Arnold was the only site that observed an 8-hour exceedance (85 ppb), but Arnold, Sunset Hills, and S. Broadway all monitored 1-hour concentrations over 100 ppb. Background concentrations were still generally low (50-60 ppb) on August 2nd.

The frontal boundary retreated back to the north of St. Louis on August 3rd with high pressure remaining over the eastern seaboard. The "old", dirty airmass returned to the area and caused a sharp rise in monitored concentrations. Light and variable winds in the morning were predominant with the south-southeasterly flow during the late morning and early afternoon. Back trajectories again show transport from the southwest. The highest 1-hour and 8-hour concentrations were monitored at West Alton (99 ppb – 8 hour), Alton, and Orchard Farm. Background concentrations were monitored around 60 ppb in the area.

The front remains to the north on August 4th with high pressure remaining over West Virginia. Variable winds on this day contributed to higher concentrations in the urban core than on previous days. The highest observed concentrations were detected at Margaretta (116 ppb – 1 hour and 98 ppb – 8 hour). Other exceedances were monitored at Edwardsville, Maryville, Alton, and Ladue. Background concentrations near 70 ppb were again observed.

2.3.7 Emissions Input Preparation and QA/QC

The purpose of the emissions processing is to format the emission inventory for the photochemical model. Specifically, the emission inventory is allocated:

- Temporally – to account for seasonal, day of week and hour of day variability,
- Spatially – to reflect the geographic distributions of emissions, and
- Chemically – to account for the chemical composition of VOC and NOx emissions in terms of the Carbon Bond 4 (CB4) chemical mechanism.

Three sets of emissions inputs were prepared for the St. Louis 8-hour ozone modeling study—the 2002 model validation inventory, the 2002 typical emissions inventory, and the 2009 on-the-books inventory. The 2002 model validation inventory was used in the model performance evaluation. It includes day- and hour-specific continuous emissions monitoring (CEM) data for Electric Generating Units (EGUs). The 2002 typical emissions inventory is similar to the validation inventory except that it does not include day- and hour-specific CEM data. The typical emissions inventory was used as the basis for applying growth and control factors and calculating RRFs. Lastly, the 2009 on-the-books inventory accounts for emissions growth and incorporates federal, state, and local controls implemented between 2002 and 2009.

The process of producing a model-ready inventory is iterative, with data corrections or improvements invariably leading to a succession of more refined modeling inventories. The St. Louis modeling commenced with Base 1 and concluded with Base 4, and the latter reflects processing of Midwest RPO inventory updates through the Base K inventory as well as CENRAP inventory updates through the Base B inventory. Section 3 of this document describes the

preparation of the Base 4 model-ready emissions inputs in greater detail. Below is a summary of the most significant changes from the Base 1 through the final Base 4 versions of the modeling inventories.

Base 1 Modeling Emissions Inventory

- CENRAP Base A inventory for all source categories plus CEM data for all CENRAP EGUs
- MRPO Base I inventory for all categories
- Initial draft link-based VMT from EW Gateway

Base 2 Modeling Emissions Inventory

- CENRAP Base B inventory for all source categories (no changes to CEM data)
- Corrected MO statewide recreational marine emissions in the offroad inventory
- MRPO Base J inventory for all categories except onroad mobile
- Draft link-based VMT from EW Gateway received Aug 2005 (~84 million DVMT total in counties covered by network)

Base 3 Modeling Emissions Inventory

- Draft MRPO Base K emissions for aircraft, commercial marine, locomotives for MRPO states (categories were missing from MRPO Base J)
- "Final" link-based VMT from EW Gateway received Oct 2005 (~70 million DVMT total)

Base 3b Modeling Emissions Inventory

- Corrected point source stack parameters in MRPO states
- Refined criteria for elevated and plume-in-grid (PiG) sources and set PiG sources consistently across all episodes
- Reran biogenics and onroad mobile for July episode using "Base 2" meteorological inputs

Base 4 Modeling Emissions Inventory

- MRPO Base K inventory for all categories except onroad mobile
- Added portable fuel containers (gas cans) to MO area inventory statewide
- Corrected aircraft refueling emissions at Lambert International Airport (applied a 90% control factor)
- Corrected VOC emissions at a point source in Arkansas -- 52,000 tons/yr changed to 52 tons/yr

An important part of this process is the quality control checks integral to the emissions modeling software that generate warning or error messages on suspect or incorrect records because of data that is missing, “out-of-bounds,” duplicative, lacking matching cross-reference data, or is otherwise deficient. In addition, programs external to the emissions modeling systems for generating data summaries, graphical depictions of emissions data, and other data-probing or analyses were relied upon extensively in the processing of inventories to assure the highest quality emission inputs are being used for photochemical modeling. Illinois and Missouri, both separately and jointly, conducted quality assurance checks on their respective state inventories.

Additionally, ENVIRON conducted independent assessments of the inputs and outputs to the emissions model.

2.3.8 Meteorological Input Preparation and QA/QC

Meteorological data were generated using the MM5 prognostic meteorological model. Episodic MM5 runs at 5-day increments on the 36/12/4 km domains were performed by the four MDAW modeling hubs, with a minimum 12 hour spin up period used for each episode. The following table illustrates the physics options selected for the 36/12/4km MM5 analyses. An example of the configure.user files and mm5.deck files are included in Appendix B.

Physics Options	Selection	Configure.user file
Moisture	Mixed Phase (Reisner 1)	IMPHYS = 5,5,5 (MPHYSTBL=0)
Cumulus Parameterization	Kain-Fritsch 2 (36/12km), None (4km)	ICUPA=8,8,1
Planetary Boundary Layer	Pleim-Xiu	IBLTYP=7,7,7
Radiation	RRTM	FRAD=4,4,4
Land Surface Model	Pleim-Xiu	ISOIL=3
Shallow Convection	No	ISHALLO=0,0,0
Nudging	Sfc = Varies Analysis = Yes	FDDAGD=1

The MDAW Modeling Hubs processed the MM5 data using the MCIP and MM5CAMx processors to generate meteorological inputs for the CMAQ and CAMx models, respectively. The outputs from this processing were used by the Modeling Hubs to perform base case modeling using both the CAMx and CMAQ models.

The MDNR, IEPA, and Ameren modeling staff reviewed the performance of the meteorological output using METSTAT. As with the inventory discussion, the process of producing model-ready meteorological can be iterative. In this study after several rounds of sensitivity analyses, the modeling team discovered the July 2002 episode was dramatically underpredicting ozone. Based on the METSTAT outputs for the Base 1 meteorological files and a substantive ozone underprediction, a strong temperature bias in the 4km grid (model underprediction) for this episode was discovered that was not present in the other two episodes.

Based on recommendations from ENVIRON, a sensitivity analysis was completed on the MM5 4-kilometer domain that evaluated the use of:

1) 3-D analysis nudging (FDDA) to the 4 km grid for MXRATIO, temperature, and winds.
2) No nudging in planetary boundary layer for temperature or MXRATIO, but included for winds (i.e. surface analysis nudging).

The results of this sensitivity were evaluated along with the original performance using METSTAT and the resulting photochemical analysis. The changes in the mm5.deck file are included in Appendix B along with the other MM5 input files. As can be seen in the METSTAT results, this sensitivity provided enhanced performance for the 4-km temperature field and,

ultimately, improved photochemical model underprediction for this episode. Therefore, the final basecase modeling analyses (emissions and photochemical) were performed with this Base 2 meteorological dataset for the July 2002 episode. Both sets of METSTAT results (Base 1 and Base 2) are included in Appendix B along with the other two episodes' results.

In addition to the METSTAT analyses detailed in Appendix B, ENVIRON performed some additional quality assurance/quality control measures for this study:

- Analyses of the MM5 data to assure that it had been transferred correctly.
- Evaluation of upper-air MM5 meteorological estimates by comparison them to upper-air observations and satellite images.
- Comparison of the MDAW modeling hub's 2002 36 km MM5 simulation with the ones generated by WRAP and VISTAS.

2.3.9 Air Quality Model Input Preparation and QA/QC

Key aspects of QA for the CMAQ and CAMx input and output data included the following:

- Verification that correct configuration and science options were used in compiling and running each module in the CMAQ and CAMx modeling systems, where these included (for CMAQ) the MCIP, JPROC, ICON, BCON and the CCTM.
- Verification that the correct configuration and science options were used in running each model in the CAMx modeling system where these included MM5CAMx, TUV, land use, CAMx, and the CMAQ-to-CAMx emissions and IC/BC processors.
- Verification that correct input data sets were used when running each model.
- Evaluation of CMAQ and CAMx results to verify that model output was reasonable and consistent with general expectations.
- Processing of ambient monitoring data for use in the model performance evaluation.
- Evaluation of the CMAQ and CAMx results against concurrent observations and each other.
- Backup and archiving of critical model input data.

During the processing of the MM5 data for use into CAMx, there are two different options for computing vertical turbulent diffusivity when using the MM5 options chosen for the St. Louis study: (1) the O'Brien scheme (OB70) and (2) the CMAQ scheme. Each of these schemes was utilized in the early photochemical analyses to determine the better fit for this exercise. The minimum Kv value (Kz_min) was set at 0.1 m^2/s for OB70 and 1.0m^2/s for CMAQ. The modeling group performed all the Base 1, 2, and 3 runs with both sets of meteorological inputs. After establishing that the CMAQ scheme was slightly superior to the OB70 scheme based on model performance in the small 4km domain, the remaining photochemical analyses were developed with the CMAQ-processed dataset.

In addition to this choice and based on recommendations from ENVIRON, a program called kvpatch was utilized to better represent mixing over the urbanized area. This program applies minimum Kv values to layers below a user-defined height based on input landuse fields and maximum Kv within that depth. The kvpatch program was utilized for both the OB70 and CMAQ diffusitivity schemes with improved results from both when compared to the original scenarios. However, once the decision was made to pursue the CMAQ scheme, two versions of this program were run: kvpatch and super-kvpatch for one of the episodes (June 2002). The

super-kvpatch version utilized a value of 2.0 m^2/s over urban land use areas, while the kvpatch version utilized a value of 1.0 m^2/s. The user-defined height was chosen as the default (100 meters) for all these sensitivities. This last sensitivity illustrated that the kvpatch program and not the super-kvpatch program should be used for the final basecase analyses.

The most critical element for CMAQ and CAMx simulations was the QA/QC of the meteorological and emissions input files, which is discussed above. The major QA issue specifically associated with the air quality model simulations was verification that the correct science options were specified in the model itself and that the correct input files were used when running the model. For CMAQ modeling, MDNR employed a system of naming conventions using environment variables in the compile and run scripts that guarantee that correct inputs and science options are used. Similar procedures were used in CAMx modeling using file and directory naming conventions. A redundant naming system was employed so that the names of key science options or inputs are included in the name of the CMAQ and CAMx executable program, in the name of the CMAQ and CAMx output files, and in the name of the directory in which the files were located. This was accomplished by using the environment variables in the scripts to specify the names and locations of key input files.

A second key QA procedure was to avoid "recycling" run scripts, i.e., the original run scripts and directory structures that were used in performing a model simulation were preserved.

The MDAW modeling hubs and ENVIRON also performed a post-processing QA of the CMAQ and CAMx output files similar to that described for the emissions processing. Animated graphic files were generated using PAVE, and were viewed to search for unexpected patterns in the CMAQ and CAMx output files. In the case of model sensitivity studies, the animated graphic files were prepared as difference plots for the sensitivity case minus the base case. This was done to screen for errors in the emissions inputs. Finally, 24-hour average plots were produced for each day of the CMAQ and CAMx simulations. This provided a summary that was useful for quickly comparing various model simulations. A table detailing all the scenarios completed is included in Appendix D along with example run scripts for the photochemical models.

2.3.10 Base Case Modeling and Model Performance Evaluation

The St. Louis 8-hr Ozone Modeling Study simulated three high 8-hour ozone episodes from the summer of 2002. The three episodes were: June 10-24, July 2-16, and July 29-August 5, 2002. During Phase I of the St. Louis 8-hour ozone modeling, both the CAMx and CMAQ models were used to simulate these three episodes, and model performance was evaluated following EPA Guidance (EPA 2006) augmented by other recommendations (e.g., Boylan, 2004; McNally and Tesche, 1994; Pun, Chen and Seigneur, 2004; and Morris et al., 2005a, b).

Initially, the four MDAW Modeling Hubs performed ozone modeling on the 36/12/4 km grid using both the CAMx and CMAQ models with the Base 1 2002 base case emissions for the June, July and July/August ozone episodes. CMAQ and CAMx were applied using the exact same horizontal and vertical structure using the Carbon Bond IV chemical mechanism (Gery et al., 1989). The ozone performance of both models during the Phase I modeling was characterized by a general underestimation bias. The underestimation bias in CMAQ was more severe, so, given the time constraints imposed by the SIP deadline, the primary focus was placed on the CAMx model, in order to diagnose the causes of its underestimation bias to improve performance for the 8-hour ozone attainment demonstration. <u>NOTE: the final basecase evaluation results using</u>

CMAQ are included in Appendix D. As can be seen, the CMAQ results illustrate dramatic underprediction when compared to the CAMx results. Therefore, the CMAQ modeling analyses were not conducted for the attainment demonstration analyses due to poor model performance.

The modeling group performed several iterations of photochemical analyses including the various emissions scenarios (Base 1, 2, 3, 3b, and 4), CAMx model versions (v4.11s, v4.20, and v4.30), vertical diffusivity schemes (CMAQ, OB70, with and without kvpatch), 4 km domain sizes, photochemical mechanisms (CAMx Mech3, Mech4_CF, and Mech4_None), different meteorological modeling inputs, and Plume-in-grid treatment of large point sources. Many of these sensitivity combinations were performed on all three ozone episodes, but several were attempted only on one or two episodes. Each analysis provided useful information with respect to the air quality model's response to emission changes and the model's performance was tracked to identify the set of options that provided the best performance. The results of these analyses are included in tables for each episode in Appendix D.

In addition to the myriad sensitivity analyses discussed above, ENVIRON was tasked with performing other separate sensitivity analyses. These included investigating the possibility that the model's exaggerated ozone suppression in the St. Louis urban core may be due to insufficient vertical mixing. A summary of their analysis and findings is provided below.

ENVIRON - *Analysis of the first round of CAMx modeling of the three episodes showed that part of the ozone underprediction could be attributed to the model's tendency to overstate the ozone suppression in the St. Louis urban core. In addition, the modeled ozone formation occurred too slowly, so that peaks occur further downwind from the St. Louis urban core in the model than observed. The magnitudes and the timing of the modeled peaks, however, were comparable to observations.*

Several potential causes of these ozone performance issues were evaluated. Ozone formation that occurs too slowly may be caused by an insufficient free radical supply. This may due to several factors. One possibility is insufficient sunlight to generate radicals vital for ozone formation. Incoming solar radiation may be overly attenuated if the meteorological model has a bias toward excessive cloudiness. The MM5 cloud fields were compared to satellite imagery during the June and July episodes, and the observed and modeled cloud fields were found to agree reasonably well; this suggests that the MM5 cloud field is not the cause of the delayed ozone formation.

NOx is emitted into the model layers near the surface, and if the vertical mixing in the model is more subdued than in the real world, NOx concentrations in the near surface layers will be unrealistically high in the model. This can cause excessive titration of ozone, leading to ozone suppression. It is also possible that the reactivity of emitted VOCs in the emissions inventory is understated or that the VOC inventory (mobile sources in particular) is simply underestimated. A series of sensitivity tests was performed to evaluate these hypotheses.

First, the chemical mechanism used in the initial basecase I modeling, CAMx Mechanism 3, was replaced with CAMx Mechanism 4, and Episode 2 was rerun; the two Episode 2 simulations were identical except for the choice of chemical mechanism. CAMx Mechanism 3 uses the OTAG (Ozone Transport Assessment Group) version of the CB4 (Carbon Bond 4) mechanism with updated PAN chemistry and revised radical and isoprene reactions. CAMx Mechanism 4 gas-phase chemistry is based on an updated version of the CB4 Mechanism that was developed by

extending the inorganic reactions in the OTAG version of the CB4 mechanism (Yarwood et al. 2005). The use of CAMx Mechanism 4 improved the normalized bias by 2-5 percentage points. This is likely due to renoxification through HNO_3, which is the reaction of gaseous NO with HNO_3 on surfaces to form NO_2 and HONO. Removal of HNO_3 via deposition is therefore not a permanent sink, but represents a pathway through which NOx can be cycled back into the atmosphere, and possibly increase ozone production. Reactions for renoxification through HNO_3 are present in Mechanism 4, but not Mechanism 3.

A second set of sensitivity studies examined the effect of increasing the vertical diffusivity (K_v). K_v is not calculated within MM5, but is determined within the meteorological preprocessor MM5CAMx. K_v values near the ground were modified because the MM5 tends to underestimate real world near-surface mixing of trace gases. In the original St. Louis CAMx application, land-use dependant minimum K_v values were applied in the surface layer. Then, in each vertical column, the maximum diffusivity encountered in the lowest 100 meters was applied to all layers below 100 meters. In the sensitivity test, the minimum K_v value was increased from 1.0 $m^2 s^{-1}$ to 2.0 $m^2 s^{-1}$. This change improved model performance slightly, reducing the mean normalized bias during Episode 2 by ~2 percentage points.

Next, the model's sensitivity to changes in VOC and NOx emissions was explored, with the intent of determining the cause of the exaggerated ozone suppression in the urban core. In the first emissions sensitivity test, biogenic isoprene emissions were increased throughout the 4-km domain by a factor of 1.5 in order to determine whether underestimation of biogenic VOCs might be the cause of the excessive ozone suppression near the downtown St. Louis. There was some improvement (a 3-5 percentage point increase in the normalized bias) in the June episode. During periods of southerly winds during the June episode (e.g. June 21), air rich in biogenic emissions was advected toward the downtown St. Louis, supplying additional VOCs to the St. Louis NAA. However, increasing the biogenic isoprene had little effect during the July episode.

As a result of this sensitivity test, the biogenic and mobile emissions were recalculated using MM5 temperatures adjusted to correct a known bias (see Section 2.3.8) in the modeled temperature fields.

Several other emissions tests were carried out that did not have a significant effect on model performance. Anthropogenic NOx emissions were reduced by 25%. This had a small effect on the normalized bias (<±2% change), with urban ozone increases offset by rural ozone reductions. A 50% increase in non-isoprene (i.e., anthropogenic) VOC emissions resulted in only a minor improvement in performance (<1% change in normalized bias). Finally, a test in which NOx was reduced by 25% and non-isoprene VOCs increased by 50% did not have a significant impact on performance.

As a result of all these sensitivity analyses and model performance evaluations, the final 2002 Base Case episodic simulations were carried out using CAMx version 4.30, Mechanism 4 with no PM chemistry, the minimum K_v set to 1.0 m^2/s using the CMAQ kv scheme with the kvpatch adjustment, Plume-in-Grid treatment for large sources, and Base 4 emissions.

An operational evaluation of model performance of the final 2002 episodic CAMx simulation was carried out according to EPA Guidance (EPA 2006). Although on many days model performance was characterized by an under-prediction bias, the model performance was found to exhibit sufficient skill in meeting most performance goals that it could be used to project future-

year ozone air quality and 8-hour ozone attainment for St. Louis, recognizing the inherent uncertainties in atmospheric modeling process. The model performed best during the periods of high ozone that are critical to the attainment demonstration. The method of performing the attainment test (EPA 2006) effectively removed from consideration the low ozone days on which the model's performance issues were most in evidence.

2.3.11 Future-Year Modeling and Modeled Attainment Demonstration

Future-year modeling for ozone was performed with CAMx for 2009. The 2002 emissions were projected to 2009 assuming growth and currently on-the-book (OTB) controls. These growth and control factors were developed by the contracting team. Regional growth and control factors developed by EPA for the Clean Air Interstate Rule (CAIR) and by the various RPOs were used, and were enhanced with information specific to the St. Louis area. The control factors reflect federally promulgated Maximum Achievable Control Technology (MACT) standards, New Source Performance Standards, implementation of the NOx SIP Call, and court settlements (consent decrees) reached with refineries and ethanol producers.

The St. Louis future-year modeling used the 2002 MM5 meteorological conditions. That is, the meteorological conditions for the 2009 future-year were assumed to the same as for 2002. This allowed for the comparison of the changes in 8-hr ozone concentrations in the study area from the current (2002) to future-year due to changes in emissions. This means that the effects of climate change, land use variations and climatic variations were not be accounted for in the future-year meteorological inputs.

The St. Louis modeling results were used to demonstrate attainment of the 8-hour ozone standards. The procedures for performing a modeled ozone attainment demonstration are outlined in EPA's 8-hour ozone modeling guidance (EPA, 2006) and are discussed in Section 4. These procedures involve the use of the model in a relative sense to scale the observed 8-hour ozone design value based on the relative changes in the modeled 8-hour ozone concentration between the current-year (2002) and future-year (2009).

In the St. Louis Nonattainment Area, there are 8 monitoring sites for which the current year (2002) design values exceeded the 8-hour ozone NAAQS (85.0 ppb or higher). The projected design values for 2009 using the modeling results show that no monitor exceeds 85 ppb, so that all St. Louis monitors are projected to attain the 8-hour standard. *The attainment test using the St. Louis modeling results suggested that on-the-books controls are sufficient for the St. Louis area to pass the modeled attainment demonstration test.*

2.3.12 Weight of Evidence (WOE) Analysis

EPA guidance states that if there is a future design value between 82-87 ppb at one or more sites/grid cells, then "a weight of evidence demonstration should be conducted to determine if aggregate supplemental analyses support the modeled attainment test" (EPA 2006). In fact, EPA suggests that a weight of evidence (WOE) always be performed to corroborate the modeled attainment demonstration test. In a WOE determination, results from several types of air quality analyses are considered and the results reviewed for consistency with the conclusion of the modeled attainment test regarding the likelihood that the proposed control strategy will result in a NAA meeting the NAAQS. The credibility of each type of analysis used in the WOE determination must be assessed and finally, a conclusion reached regarding the likelihood of

attainment.

The trends in air quality and emissions, corroborative modeling analyses, and additional modeling metrics all support the conclusion of the CAMx modeled attainment demonstration that the St. Louis NAA will be attainment by 2010. Every one of the analyses presented was consistent in predicting attainment for St. Louis; not a single component of the weight of evidence determination suggested that the St. Louis area will be out of attainment in 2010. Thus, the evidence that the St. Louis NAA will reach attainment of the ozone NAAQS by 2010 is overwhelming and conclusive.

3.0 EMISSIONS MODELING

This section describes the preparation of the 36/12/4 km emissions inputs for the June 10-24, July 2-16 and July 29-August 5, 2002 episodes. Three separate sets of CAMx-ready Base 4 emissions files were prepared—the 2002 model validation inventory, the 2002 typical emissions inventory, and the 2009 on-the-books inventory. The emissions modeling projection and grid structure are described in Figure 2-1 and Tables 2-1 and 2-2.

In building the Base 4 inventory for St. Louis ozone modeling, the best available emissions datasets were obtained from RPOs that are developing comprehensive inventories for their member states and tribes for regional haze purposes. Most notably, the St. Louis Base 4 inventory incorporated the Base B inventory generated by CENRAP and the Base K inventory from the MRPO.

Emissions for each major source group (e.g., mobile, off-road mobile, area, point, and biogenic) were processed separately and merged together to create model-ready emissions files. Emissions for all source categories were processed for each day in the three ozone episodes.

MDNR, IEPA, and ENVIRON/Alpine collaborated on preparing the emissions. IEPA used EMS-2003 to process the emissions for electric generating units (EGUs) for the MRPO states plus Minnesota.[1] ENVIRON/Alpine generated biogenic and onroad mobile emissions, and MDNR prepared emissions for the remainder of the source categories. Both ENVIRON/Alpine and MDNR used SMOKE v. 2.1 as their emissions processing tool. MDNR, IEPA, and ENVIRON/Alpine were all involved in quality-assuring the raw emissions inputs as well as the gridded, model-ready emissions files.

Tables 3-1 and 3-2 present summaries of anthropogenic NOx and VOC emissions in the St. Louis nonattainment counties for 2002 and 2009. The emissions in these tables are based on the 2002 typical and 2009 on-the-books inventories for a weekday in the June episode (Wednesday, June 19). Additional emissions summaries and details of the emissions preparation are included in Sections 3.1 through 3.4. NOTE: due to rounding, the sum of the individual entries may differ slightly from the totals shown in the emission summary tables.

1 Minnesota, though a CENRAP member state, was actively involved with the MRPO in reviewing and revising its inventory beyond CENRAP's contractor-supported base year inventory. Minnesota gave approval to the MRPO for using these updates in their emissions processing, and this lead was generally followed for Minnesota's emissions for the St. Louis study.

Table 3-1. Summary of Weekday NOx Emissions from the 2002 Base 4 Typical and 2009 On-the-Books Inventories for St. Louis Nonattainment Counties

County	Area NOx (tpd)		Offroad Mobile NOx (tpd)		Onroad Mobile NOx (tpd)		Non-EGU Point NOx (tpd)		EGU Point NOx (tpd)		Total: All Source Categories NOx (tpd)	
	2002	2009	2002	2009	2002	2009	2002	2009	2002	2009	2002	2009
Missouri												
Franklin	1.7	1.8	4.8	3.8	15.1	7.7	0.1	0.1	24.2	28.1	46.0	41.6
Jefferson	1.4	1.5	5.3	5.4	17.7	9.6	15.4	18.3	10.6	15.2	50.4	50.0
St Charles	2.4	2.5	7.1	7.7	23.5	12.8	1.2	1.2	44.9	21.9	79.1	46.1
St Louis	9.9	10.2	31.5	31.6	97.4	52.7	2.3	2.3	23.1	17.9	164.1	114.8
St Louis City	4.0	4.4	12.0	10.5	26.4	14.4	5.4	5.1	0.0	0.0	47.9	34.5
MO NAA Subtotal	**19.4**	**20.4**	**60.8**	**59.1**	**180.1**	**97.2**	**24.4**	**27.1**	**102.8**	**83.1**	**387.4**	**286.9**
Illinois												
Jersey	0.1	0.1	2.6	2.4	1.7	1.0	0.0	0.0	0.0	0.0	4.4	3.5
Madison	0.7	0.8	15.6	13.1	24.2	11.7	29.7	25.7	13.9	9.5	84.1	60.8
Monroe	0.1	0.1	5.5	4.2	3.8	1.9	0.1	0.1	1.7	0.0	11.2	6.4
St Clair	0.5	0.6	10.8	8.8	23.6	11.4	3.3	4.7	0.4	0.0	38.6	25.5
IL NAA Subtotal	**1.4**	**1.5**	**34.5**	**28.5**	**53.3**	**26.1**	**33.1**	**30.5**	**15.9**	**9.6**	**138.3**	**96.2**
NAA Totals	**20.8**	**21.9**	**95.3**	**87.6**	**233.4**	**123.3**	**57.4**	**57.6**	**118.7**	**92.7**	**525.7**	**383.1**

Table 3-2. Summary of Weekday VOC Emissions from the 2002 Base 4 Typical and 2009 On-the-Books Inventories for St. Louis Nonattainment Counties

County	Area VOC (tpd)		Offroad Mobile VOC (tpd)		Onroad Mobile VOC (tpd)		Non-EGU Point VOC (tpd)		EGU Point VOC (tpd)		Total: All Source Categories VOC (tpd)	
	2002	2009	2002	2009	2002	2009	2002	2009	2002	2009	2002	2009
Missouri												
Franklin	3.9	4.2	2.7	3.3	5.3	3.7	1.9	1.9	0.8	0.8	14.5	14.0
Jefferson	8.7	9.0	4.0	4.5	8.3	4.7	1.7	1.7	0.4	0.5	23.1	20.4
St Charles	9.1	10.1	7.2	7.2	11.4	6.5	3.0	3.1	0.6	0.6	31.3	27.4
St Louis	36.2	39.2	27.5	20.3	49.3	28.0	13.2	13.4	0.2	0.3	126.4	101.3
St Louis City	13.4	14.1	5.6	4.1	14.5	8.3	11.1	10.8	0.0	0.0	44.6	37.2
MO NAA Subtotal	**71.4**	**76.6**	**46.9**	**39.4**	**88.9**	**51.2**	**30.8**	**30.9**	**1.9**	**2.3**	**239.9**	**200.3**
Illinois												
Jersey	2.2	2.2	0.5	0.5	1.1	0.5	0.1	0.0	0.0	0.0	3.8	3.2
Madison	13.8	13.3	4.4	3.3	11.3	5.5	11.0	7.9	0.3	0.2	40.8	30.1
Monroe	2.3	2.3	0.6	0.5	2.0	1.0	0.1	0.0	0.1	0.0	5.1	3.9
St Clair	11.6	11.0	3.4	2.4	11.7	5.7	3.7	3.9	0.0	0.0	30.5	22.9
IL NAA Subtotal	**29.9**	**28.8**	**9.0**	**6.5**	**26.1**	**12.7**	**14.9**	**11.9**	**0.4**	**0.2**	**80.2**	**60.1**
NAA Totals	**101.3**	**105.4**	**55.9**	**45.9**	**115.0**	**63.9**	**45.7**	**42.7**	**2.3**	**2.5**	**320.1**	**260.4**

3.1 2002 BASE 4 MODEL VALIDATION EMISSIONS INVENTORY

The 2002 Base 4 model validation inventory was used for the CAMx model performance evaluation. Because this inventory is used to calibrate the CAMx model, the intent is to include episode-specific emissions to the greatest extent possible. In particular, day- and hour-specific CEM data were incorporated for point sources where available.

3.1.1 2002 Base 4 Model Validation Inventory Data Sources

3.1.1.1 All Point Sources Except EGUs in Midwest RPO and Minnesota

For the majority of point sources in the modeling domain, MDNR obtained emissions inventory files in SMOKE's inventory data analyzer (IDA) format from the RPOs. In order to facilitate future-year emissions processing, each of the IDA files was separated into EGUs, defined as sources included in the Integrated Planning Model (IPM), and non-EGUs, defined as sources not included in IPM. Because 2009 output from IPM was used for future-year emissions for EGUs, extracting these sources before applying growth and control factors to the non-EGUs ensured that EGU emissions were not double-counted in 2009. The EGUs and non-EGUs were separated using a crosswalk obtained from the MRPO that linked inventory identifiers (state and county codes, facility IDs, emission unit IDs, process IDs, and Source Classification Codes (SCCs)) to the corresponding identifiers used in the IPM model.

The emissions contained in the IDA files, which were primarily annual values, were supplemented with day- and hour-specific CEM data for EGUs where available. NOx emissions based on CEM data were used for EGUs in the CENRAP states; CO, VOC, and NOx based on CEM data were used for EGUs in the VISTAS states. It is important to note that emissions are not double-counted when both annual and hourly emissions inputs are used with SMOKE. SMOKE selects the emissions value representing the most specific time period for any given source, i.e., hourly emissions are selected over annual emissions where available.

For the MRPO states and Minnesota, non-EGU point source inventory files were obtained from the MRPO in the National Emissions Inventory format (NIF). The NIF files were converted to SMOKE-compatible formats. MDNR compared the MRPO emissions generated using SMOKE to Base K emissions reports posted on the Lake Michigan Air Directors Consortium (LADCO) emissions modeling webpage (http://www.ladco.org/tech/emis/basek/BaseK_Reports.htm). Results most comparable to LADCO's were achieved by using a combination of IDA-formatted files and files in SMOKE's day-specific format (ptday). This was done by converting annual emissions records in the original NIF files to the IDA format and converting the summer day emissions records to the ptday format. When an IDA file is used in conjunction with a ptday file, SMOKE selects the emissions value representing the most specific time period for any given source, i.e., daily emissions are selected over annual emissions.

In addition to the traditional point sources, CENRAP, WRAP, and VISTAS provided a set of files containing emissions and plume rise data for prescribed burns and wildfires that could be temporally and spatially resolved. These fires were processed as point sources within the SMOKE modeling system. None of these large fires occurred within Missouri or Illinois during the ozone modeling episodes.

Table C-1 in Appendix C provides greater detail about each of the raw point source inventory input files used in MDNR's SMOKE processing, including the geographic coverage of the inventory, the pollutants included, the source of the original inventory data files, and a summary of any modifications made to the original files for the St. Louis modeling effort.

There are two separate emissions input files required for the CAMx model—low-level or surface emissions and elevated emissions. In the St. Louis modeling, elevated sources were specified as those with a plume rise greater than or equal to 40 meters (131.2 feet) and NOx emissions greater than or equal to 1.25 tons/day. Plume-in-grid (PiG) sources were sources with NOx emissions greater than or equal to 5.5 tons/day and located in Illinois or Missouri. The same elevated and PiG selection criteria were used for non-EGU and EGU point sources. In a few instances, manual edits were made to the elevated point source files generated by SMOKE to ensure that the same sources were flagged for PiG treatment in all episodes.

Annual and daily emissions were disaggregated to hourly values using EPA default temporal profiles cross-referenced by SCC. The default temporal profiles were supplemented for Illinois and Missouri point sources with monthly profiles at the emission unit level based on seasonal throughput percentage. In addition, for EGUs in CENRAP, monthly, day of week, and hourly temporal profiles were created by Pechan under contract to CENRAP based on three-year average CEM data (2001-2003). EPA default speciation profiles were used to disaggregate the inventory species into the CB4 species (e.g., VOC into PAR, OLE, XYL, ISOP, and others). Documentation of EPA's temporal and speciation profiles and associated cross reference files is available on the Emissions Modeling Clearinghouse website, http://www.epa.gov/ttn/chief/emch/index.html.

3.1.1.2 EGU Point Sources in the Midwest RPO and Minnesota

Unit-specific EGU temporal profiles based on median monthly CEM heat input data for the years 2000-2003 were developed by the MRPO that account for monthly and day-of-week variations in emissions. The Midwest RPO provided this inventory refinement in the form of NIF-formatted hourly EGU emissions records that were directly readable by EMS. IEPA processed the EGU files for the MRPO states and Minnesota for the 4, 12, and 36 km modeling domains. The low-level and elevated point source emission files were subsequently forwarded to MDNR for merging with other emissions datasets.

3.1.1.3 Area Sources

For the majority of area sources in the modeling domain, MDNR obtained emissions inventory files in SMOKE's IDA format from the RPOs. For the MRPO states and Minnesota, area source inventory files were obtained from the MRPO in NIF format and converted to SMOKE-compatible formats. The emissions results generated using SMOKE for the MRPO states were compared to the Base K inventory reports posted on LADCO's emissions modeling webpage (http://www.ladco.org/tech/emis/basek/BaseK_Reports.htm). Results most comparable to LADCO's were achieved using a combination of IDA-formatted files and SMOKE's EMS-95 format. The annual emissions contained in the original NIF files were converted to IDA, and the typical ozone season day emissions records were converted to SMOKE's EMS-95 format. As opposed to daily emissions values contained in an IDA-formatted file, SMOKE does not "annualize" daily emissions contained in EMS-95 formatted file by multiplying the value by 365 before applying monthly temporal profiles. The EMS-95 formatted files were processed

separately and merged with the rest of the area source emissions.

Table C-2 in Appendix C provides detail about each inventory file used in MDNR's area source SMOKE processing, including the geographic coverage, the pollutants included, the source of the original file, and any revisions made to the original files for the St. Louis modeling. The table also indicates which area source inventory files include agricultural and other prescribed burning activities, which are particularly significant in Kansas and Oklahoma.

EPA default gridding surrogates were used to disaggregate county-level emissions to the grid-cell level. The gridding surrogates were obtained from the CHIEF website (http://www.epa.gov/ttn/chief/emch/spatial/newsurrogate.html) and windowed to be consistent with the dimensions of the St. Louis emissions modeling domains. The original surrogates were developed for the 36 km, 12 km, 4 km grid cell sizes for the RPO modeling domain on a Lambert Conformal projection consistent with the St. Louis modeling projection. They were developed based on data from the 2000 census, National Land Cover Characteristics Data, and other spatial sources to produce approximately 65 spatial surrogates. Gridding surrogates for the 12 km and 4 km domains were not available for Canadian, Mexican, and offshore (Gulf of Mexico) area source inventories. Therefore, these area source inventories were only processed for the 36 km domain as noted in Table C-2.

EPA's default temporal and speciation profiles were used in the processing of area sources. Documentation of EPA's temporal and speciation profiles and associated cross reference files is available on the Emissions Modeling Clearinghouse website, http://www.epa.gov/ttn/chief/emch/index.html**.**

3.1.1.4 Offroad Mobile Sources

For the majority of the modeling domain, MDNR obtained offroad mobile emissions inventory files in IDA format from the regional planning organizations (RPOs). For the MRPO states and Minnesota, offroad inventory files were obtained from the MRPO in NIF format and converted to SMOKE's IDA format.

In order to facilitate future-year emissions processing, SCCs included in EPA's NONROAD model were separated from aircraft, locomotive, and commercial marine vessel SCCs, which are not covered by NONROAD. Because 2009 output from the EPA's NONROAD model was used for future-year emissions, extracting the NONROAD model SCCs before applying growth and control factors to aircraft, locomotive, and commercial marine vessel SCCs ensured that no offroad mobile emissions were double-counted in the 2009 inventory.

Table C-3 in Appendix C provides detail about each inventory file used in MDNR's 2002 offroad mobile source SMOKE processing, including the geographic coverage, the pollutants included, the source of the original file, and any revisions made to the original files for the St. Louis study.

Similar to the area sources, EPA's default temporal and speciation profiles and gridding surrogates were used to process the offroad mobile sources. Because 12 km and 4 km gridding surrogates were not available for Canadian and Mexican offroad mobile source inventories, these inventories were only processed for the 36 km domain as noted in Table C-3. Documentation of EPA's temporal and speciation profiles, gridding surrogates, and associated cross reference files

is available on the Emissions Modeling Clearinghouse website, http://www.epa.gov/ttn/chief/emch/index.html**.**

3.1.1.5 Onroad Mobile Sources

The category of on-road mobile source emissions includes emissions from vehicles certified for highway use – cars, trucks, and motorcycles. Emissions from these vehicles were estimated within the SMOKE model, which relies upon MOBILE6 to generate emission factors. For eight St. Louis non-attainment area counties with a transportation network modeled by the East West Gateway, detailed emissions were estimated using link-level inputs within SMOKE. For the rest of the counties in each domain, county-level VMT data were obtained from the CENRAP Base B modeling effort and the MWRPO Base I inventory for input to SMOKE.

The East West Gateway provided link-level congested speed and VMT data representing typical weekday travel in 2002 in the eight St. Louis non-attainment area counties listed in Table 3-3. For each link, the dataset included congested speed and VMT for the morning peak (6 a.m. – 9 a.m.), afternoon peak (2 p.m. – 7 p.m.), mid-day (9 a.m. – 2 p.m.) and night-time (7 p.m. – 6 a.m.) travel periods.

Table 3-3. Counties with Link-based VMT and Speed Data from East West Gateway

County	State	FIPS
Franklin	MO	29071
Jefferson	MO	29099
St. Charles	MO	29183
St. Louis	MO	29189
St. Louis City	MO	29510
Madison	IL	17119
Monroe	IL	17133
St. Clair	IL	17163

East West Gateway provided the final 2002 dataset on October 14, 2005. Although link-specific speed and VMT were available in the dataset by time of day, SMOKE v. 2.1 does not support link-specific speed and temporal profiles. Therefore, MDNR derived speed and temporal profiles by county and road type from the East West Gateway data. Hourly temporal profiles were calculated by dividing the VMT for each travel period by the number of hours in the period. The hourly values were then averaged by county and road type. Similarly, hourly speed profiles were created by assigning the speed for the period to each hour in the period and averaging the resulting hourly profiles by county and road type.

For the link-based processing within SMOKE, MDNR provided seasonal MOBILE6 input files for Jefferson, St. Charles and St. Louis Counties, as well as for the City of St. Louis. For these four counties, a simplified minimum and maximum temperature of 74 and 97 degrees Fahrenheit, respectively, was specified in the MOBILE6 input file. Separate monthly MOBILE6 input files for Franklin County Missouri were obtained from the CENRAP Base B modeling effort. For the three Illinois counties, MOBILE6 input files came from the MWRPO Base I inventory via Alpine Geophysics. Table C-4 in Appendix C provides

specific information on all data sources and final model-ready files used for link-based processing of mobile emissions in SMOKE.

County-based processing was divided into multiple regions due to computer constraints. The regions were as follows:

- WRAP/Mexico/Canada
- CENRAP_1 [mbv1] (Arkansas, Iowa, Louisiana, Texas)
- CENRAP_2 [mbv2] (Kansas, Minnesota, Nebraska, Oklahoma)
- CENRAP_3 [mbv3] (Missouri)
- MWRPO
- VISTAS/MANE-VU

Daily meteorological data, including surface temperature, barometric pressure, and water vapor mixing ratios extracted from gridded MM5 output were provided to SMOKE as daily MCIP files for each domain. SMOKE uses the gridded meteorology data to create 24-hour temperature and relative humidity profiles for each county in the inventory. The Base 2 meteorological inputs were used for the July 2-16 episode.

Table C-5 in Appendix C provides specific information on data sources and final model-ready files used for all county-based processing of mobile emissions in SMOKE. Note that for the 2002 model validation inventory, pre-computed emissions were used for WRAP/Mexico/Canada. For the 2002 typical inventory, WRAP emissions were separated out from that group and calculated within SMOKE using county-based inputs, leaving non-US areas (Mexico/Canada) as a separate group. In all other respects, the onroad mobile emissions in the 2002 model validation and 2002 typical inventories were identical. For all groups except CENRAP_3 (Missouri) and the Illinois counties in MWRPO, SMOKE was configured to average meteorological data over all counties sharing a reference county and over each week within an episode. For Missouri and Illinois, meteorological data was kept as county- and hour-specific.

3.1.1.6 Biogenic Sources

Biogenic emissions were prepared for the 36-km, 12-km, and 4-km modeling grids using the Biogenic Emission Inventory System (BEIS) model v. 3.09 within SMOKE. These emissions were calculated for each episode day for each of the domains. SMOKE biogenic processing relies upon the BEIS3 emissions model, and requires domain definition, land use, and meteorological input files. Input files for land use were based on EPA's Biogenics Emissions Landuse Database version 3 (BELD3) data. Daily meteorological data, including wind speed, humidity, and temperature extracted from MM5 output were provided to SMOKE as daily MCIP files for each domain. Alpine Geophysics performed all the biogenic data processing. The biogenic emissions for the July 2-16 episode were generated using the Base 2 meteorological inputs.

3.1.2 2002 Model Validation Inventory Emissions Summaries

Tables 3-4 through 3-6 summarize weekday (Wednesday, June 19), Saturday (June 22), and Sunday (June 23) emissions in the St. Louis nonattainment counties by source type for NOx, VOC, and CO, respectively. Because onroad mobile, EGU point, and biogenic emissions from the model validation inventory exhibit considerable variation from day to day, additional

summaries of these emissions for every day in the ozone episodes are included in Table 3-7 (onroad mobile NOx), Table 3-8 (onroad mobile VOC), Table 3-9 (onroad mobile CO), Table 3-10 (biogenic VOC), and Table 3-11 (EGU point source NOx).

All emission estimates in the following tables reflect gridded, temporalized, model-ready emissions in tons per day (tpd). Tables C-8 through C-10 in Appendix C contain additional NOx, VOC, and CO emissions summaries of the 2002 Base 4 model validation inventory by state for every state in the 36 km modeling domain.

Table 3-4. 2002 Base 4 Model Validation Inventory – Weekday, Saturday, Sunday NOx Emissions for St. Louis Nonattainment Area Counties by Source Type

County	Area NOx (tpd)			Offroad Mobile NOx (tpd)			Onroad Mobile NOx (tpd)			Non-EGU Point NOx (tpd)			EGU Point NOx (tpd)		
	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun
Missouri															
Franklin	1.7	1.7	1.6	4.8	4.5	4.5	15.1	7.0	6.1	0.1	0.1	0.0	20.5	20.2	19.8
Jefferson	1.4	1.4	1.3	5.3	5.1	5.1	17.7	8.5	7.3	15.4	15.3	15.2	12.6	14.4	13.3
St Charles	2.4	2.3	2.2	7.1	6.5	6.4	23.5	11.4	9.7	1.2	1.0	0.9	44.4	42.5	42.9
St Louis	9.9	9.3	8.8	31.5	29.9	29.6	97.4	49.5	41.7	2.3	1.8	1.5	35.6	39.6	38.0
St Louis City	4.0	3.8	3.6	12.0	11.6	11.6	26.4	13.7	11.5	5.4	5.1	5.0	0.0	0.0	0.0
MO NAA Subtotal	**19.4**	**18.3**	**17.6**	**60.8**	**57.7**	**57.1**	**180.1**	**90.0**	**76.3**	**24.4**	**23.3**	**22.7**	**113.1**	**116.6**	**114.0**
Illinois															
Jersey	0.1	0.1	0.1	2.6	2.4	2.3	1.7	1.6	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Madison	0.7	0.7	0.7	15.6	15.1	14.9	24.2	12.3	10.7	29.7	23.1	22.9	13.9	7.9	7.9
Monroe	0.1	0.1	0.1	5.5	5.3	5.2	3.8	2.0	1.8	0.1	0.0	0.0	1.7	0.0	0.0
St Clair	0.5	0.5	0.5	10.8	10.3	10.2	23.6	12.4	10.8	3.3	0.8	0.8	0.4	0.0	0.0
IL NAA Subtotal	**1.4**	**1.4**	**1.4**	**34.5**	**33.0**	**32.7**	**53.3**	**28.3**	**24.9**	**33.1**	**23.9**	**23.7**	**15.9**	**7.9**	**7.9**
NAA Totals	**20.8**	**19.7**	**18.9**	**95.3**	**90.7**	**89.8**	**233.4**	**118.3**	**101.2**	**57.4**	**47.2**	**46.3**	**129.1**	**124.5**	**121.9**

Table 3-5. 2002 Base 4 Model Validation Inventory – Weekday, Saturday, Sunday VOC Emissions for St. Louis Nonattainment Area Counties by Source Type

County	Area VOC (tpd)			Offroad Mobile VOC (tpd)			Onroad Mobile VOC (tpd)			Non-EGU Point VOC (tpd)			EGU Point VOC (tpd)		
	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun
Missouri															
Franklin	3.9	3.9	3.9	2.7	2.5	2.4	5.3	3.6	3.2	1.9	1.0	0.5	0.8	0.8	0.8
Jefferson	8.7	8.7	8.7	4.0	3.5	3.3	8.3	5.5	4.8	1.7	1.3	1.1	0.4	0.4	0.4
St Charles	9.1	9.1	9.1	7.2	6.1	5.9	11.4	7.5	6.6	3.0	0.8	0.2	0.6	0.6	0.6
St Louis	36.2	35.8	35.7	27.5	21.3	20.1	49.3	32.6	28.7	13.2	6.8	2.5	0.2	0.2	0.2
St Louis City	13.4	13.2	13.1	5.6	4.4	4.3	14.5	9.6	8.5	11.1	9.2	8.7	0.0	0.0	0.0
MO NAA Subtotal	**71.4**	**70.6**	**70.4**	**46.9**	**37.7**	**36.1**	**88.9**	**58.7**	**51.9**	**30.8**	**19.2**	**12.9**	**1.9**	**1.9**	**1.9**
Illinois															
Jersey	2.2	2.2	2.2	0.5	0.5	0.5	1.1	1.1	1.0	0.1	0.1	0.1	0.0	0.0	0.0
Madison	13.8	13.8	13.8	4.4	4.2	4.2	11.3	8.1	7.2	11.0	8.6	8.1	0.3	0.2	0.2
Monroe	2.3	2.3	2.3	0.6	0.6	0.6	2.0	1.4	1.3	0.1	0.0	0.0	0.1	0.0	0.0
St Clair	11.6	11.6	11.6	3.4	3.3	3.3	11.7	8.4	7.5	3.7	2.8	1.7	0.0	0.0	0.0
IL NAA Subtotal	**29.9**	**29.9**	**29.9**	**9.0**	**8.5**	**8.5**	**26.1**	**19.0**	**17.0**	**14.9**	**11.5**	**9.8**	**0.4**	**0.2**	**0.2**
NAA Totals	**101.3**	**100.5**	**100.3**	**55.9**	**46.2**	**44.5**	**115.0**	**77.6**	**68.8**	**45.7**	**30.7**	**22.7**	**2.3**	**2.1**	**2.1**

Table 3-6. 2002 Base 4 Model Validation Inventory – Weekday, Saturday, Sunday CO Emissions for St. Louis Nonattainment Area Counties by Source Type

County	Area CO (tpd)			Offroad Mobile CO (tpd)			Onroad Mobile CO (tpd)			Non-EGU Point CO (tpd)			EGU Point CO (tpd)		
	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun
Missouri															
Franklin	6.4	6.4	6.4	22.8	18.3	17.6	70.6	48.7	44.8	0.1	0.0	0.0	6.5	6.5	6.5
Jefferson	15.6	15.6	15.5	46.4	35.9	34.2	107.0	69.8	63.6	2.8	2.7	2.7	3.0	3.0	3.0
St Charles	1.2	1.2	1.1	79.9	61.0	57.9	142.2	92.5	84.8	0.9	0.5	0.3	2.7	2.7	2.7
St Louis	5.3	5.0	4.9	426.5	313.6	296.1	583.9	386.3	351.1	5.9	4.4	4.0	1.6	1.6	1.6
St Louis City	1.8	1.7	1.7	93.0	68.5	65.6	160.0	106.2	95.9	3.4	3.2	3.1	0.0	0.0	0.0
MO NAA Subto0tal	**30.3**	**29.9**	**29.6**	**668.6**	**497.4**	**471.4**	**1,063.6**	**703.5**	**640.3**	**13.0**	**10.8**	**10.1**	**13.7**	**13.7**	**13.7**
Illinois															
Jersey	0.1	0.1	0.1	4.4	3.7	3.7	10.4	11.0	10.4	0.0	0.0	0.0	0.0	0.0	0.0
Madison	0.6	0.6	0.6	54.9	51.1	50.9	145.0	107.0	98.7	53.5	52.0	51.9	5.5	1.5	1.5
Monroe	0.1	0.1	0.1	5.8	5.2	5.1	24.2	17.8	16.4	0.2	0.1	0.1	0.9	0.0	0.0
St Clair	0.6	0.6	0.6	45.3	42.1	41.9	144.5	107.1	98.4	5.1	2.9	2.8	0.2	0.0	0.0
IL NAA Subtotal	**1.4**	**1.4**	**1.4**	**110.4**	**102.1**	**101.6**	**324.2**	**242.9**	**223.9**	**58.8**	**55.0**	**54.8**	**6.6**	**1.5**	**1.5**
NAA Totals	**31.7**	**31.3**	**31.0**	**779.0**	**599.6**	**573.1**	**1,387.7**	**946.3**	**864.1**	**71.8**	**65.8**	**64.9**	**20.3**	**15.2**	**15.2**

Table 3-7. 2002 Base 4 Model Validation Inventory – Daily Onroad Mobile NOx Emissions for St. Louis Nonattainment Area Counties

Date	Missouri Nonattainment Counties NOx (tpd)					MO NAA Subtotals NOx (tpd)	Illinois Nonattainment Counties NOx (tpd)				IL NAA Subtotals NOx (tpd)	NAA Totals NOx (tpd)
	Franklin	Jefferson	St Charles	St Louis	St Louis City		Jersey	Madison	Monroe	St Clair		
Sat, 6/15	7.30	8.83	11.73	50.56	14.03	92.46	1.62	12.98	2.17	13.10	29.87	122.33
Sun, 6/16	6.08	7.03	9.43	40.37	11.21	74.12	1.50	10.93	1.81	10.91	25.15	99.27
Mon, 6/17	16.36	19.09	25.31	105.17	28.64	194.57	1.77	26.20	4.25	25.69	57.90	252.47
Tue, 6/18	15.77	18.49	24.32	102.14	27.84	188.55	1.72	25.26	4.05	24.73	55.77	244.32
Wed, 6/19	15.13	17.67	23.46	97.37	26.45	180.08	1.69	24.17	3.85	23.63	53.34	233.42
Thus, 6/20	15.23	18.15	24.09	100.10	27.09	184.66	1.75	24.05	3.87	23.50	53.17	237.83
Fri, 6/21	15.40	18.39	24.35	102.20	27.77	188.10	1.82	24.42	3.94	23.94	54.12	242.22
Sat, 6/22	6.95	8.50	11.37	49.52	13.67	90.01	1.57	12.32	2.05	12.37	28.31	118.32
Sun, 6/23	6.08	7.30	9.71	41.73	11.52	76.33	1.49	10.75	1.81	10.83	24.88	101.22
Mon, 6/24	15.40	18.03	24.02	98.41	26.59	182.45	1.64	23.84	3.83	23.27	52.58	235.03
Tue, 7/02	15.00	18.18	24.25	101.30	27.47	186.19	1.67	24.00	3.85	23.44	52.96	239.16
Wed, 7/03	14.32	17.51	23.20	96.43	26.17	177.63	1.63	22.94	3.69	22.47	50.74	228.37
Thus, 7/04	4.91	6.17	8.18	35.46	9.81	64.53	1.39	8.94	1.48	9.00	20.82	85.35
Fri, 7/05	15.05	18.12	24.01	98.54	26.70	182.43	1.73	23.78	3.85	23.29	52.64	235.07
Sat, 7/06	6.55	8.18	10.84	46.91	13.04	85.52	1.50	11.75	1.95	11.82	27.01	112.54
Sun, 7/07	5.80	7.17	9.28	40.70	11.33	74.28	1.45	10.54	1.76	10.58	24.33	98.61
Mon, 7/08	15.38	18.38	24.42	101.11	27.43	186.72	1.66	24.38	3.95	23.87	53.86	240.59
Tue, 7/09	15.11	18.44	24.25	101.90	27.85	187.56	1.62	24.18	3.89	23.72	53.42	240.97
Wed, 7/10	14.30	17.45	23.07	95.25	25.76	175.83	1.59	22.80	3.63	22.21	50.22	226.05
Thus, 7/11	14.99	18.17	24.08	100.01	27.14	184.40	1.75	24.83	3.91	24.02	54.51	238.90
Fri, 7/12	15.19	18.23	24.00	100.40	27.28	185.11	1.81	24.64	3.95	24.13	54.53	239.64
Sat, 7/13	7.00	8.51	11.28	49.08	13.53	89.39	1.57	12.48	2.07	12.49	28.61	118.01
Sun, 7/14	5.94	6.92	9.24	39.22	10.78	72.09	1.47	10.42	1.74	10.39	24.01	96.11
Mon, 7/15	15.32	17.98	23.97	98.68	26.65	182.59	1.69	24.47	3.90	23.75	53.80	236.39
Tue, 7/16	14.90	18.02	23.86	98.64	26.67	182.10	1.63	23.78	3.81	23.25	52.47	234.57
Mon, 7/29	14.95	18.00	23.87	97.81	26.47	181.11	1.62	23.63	3.76	22.99	51.99	233.10
Tue, 7/30	15.17	18.25	24.37	101.62	27.56	186.97	1.66	24.12	3.85	23.51	53.14	240.11
Wed, 7/31	14.65	17.72	23.60	98.86	26.79	181.61	1.65	23.53	3.77	23.06	52.02	233.63
Thus, 8/01	15.03	18.28	24.18	101.17	27.49	186.14	1.76	24.40	3.93	23.89	53.99	240.13
Fri, 8/02	14.60	17.91	23.76	98.65	26.82	181.74	1.74	23.21	3.73	22.82	51.50	233.24
Sat, 8/03	6.61	8.13	10.82	46.25	12.72	84.53	1.49	11.42	1.90	11.42	26.23	110.76
Sun, 8/04	5.67	6.88	9.08	38.95	10.77	71.34	1.41	9.93	1.68	9.99	23.01	94.35
Mon, 8/05	15.10	18.10	23.97	99.29	27.06	183.52	1.64	23.85	3.86	23.46	52.81	236.32

Table 3-8. 2002 Base 4 Model Validation Inventory – Daily Onroad Mobile VOC Emissions for St. Louis Nonattainment Area Counties

Date	Missouri Nonattainment Counties VOC (tpd)					MO NAA Subtotals VOC (tpd)	Illinois Nonattainment Counties VOC (tpd)				IL NAA Subtotals VOC (tpd)	NAA Totals VOC (tpd)
	Franklin	Jefferson	St Charles	St Louis	St Louis City		Jersey	Madison	Monroe	St Clair		
Sat, 6/15	3.46	5.45	7.48	32.54	9.60	58.53	1.01	7.68	1.36	7.98	18.03	76.56
Sun, 6/16	3.03	4.84	6.66	28.76	8.47	51.76	0.91	6.80	1.18	7.00	15.89	67.65
Mon, 6/17	5.81	8.83	12.17	52.25	15.37	94.42	1.11	12.54	2.23	12.98	28.87	123.29
Tue, 6/18	5.43	8.46	11.66	50.23	14.79	90.57	1.10	11.87	2.07	12.22	27.26	117.83
Wed, 6/19	5.26	8.32	11.45	49.32	14.52	88.86	1.06	11.33	2.00	11.73	26.13	114.99
Thus, 6/20	5.80	8.89	12.24	52.69	15.51	95.12	1.24	12.83	2.27	13.20	29.54	124.66
Fri, 6/21	5.71	8.54	11.75	50.65	14.91	91.56	1.28	12.64	2.24	13.10	29.26	120.82
Sat, 6/22	3.55	5.46	7.49	32.57	9.60	58.68	1.07	8.07	1.42	8.39	18.96	77.64
Sun, 6/23	3.19	4.84	6.65	28.73	8.46	51.86	0.99	7.22	1.27	7.48	16.95	68.81
Mon, 6/24	5.77	8.87	12.22	52.47	15.43	94.75	1.12	12.53	2.20	12.99	28.84	123.60
Tue, 7/02	5.44	8.48	11.66	50.26	14.80	90.63	1.21	12.52	2.18	12.87	28.78	119.41
Wed, 7/03	5.27	8.32	11.45	49.34	14.52	88.89	1.21	12.11	2.14	12.55	28.01	116.90
Thus, 7/04	2.69	4.36	5.98	26.00	7.67	46.69	1.00	6.35	1.12	6.61	15.09	61.78
Fri, 7/05	5.73	8.88	12.23	52.50	15.44	94.78	1.25	12.96	2.30	13.42	29.93	124.71
Sat, 7/06	3.45	5.47	7.51	32.65	9.62	58.69	1.09	8.10	1.43	8.42	19.04	77.73
Sun, 7/07	3.11	4.84	6.66	28.76	8.47	51.84	1.02	7.22	1.26	7.46	16.96	68.80
Mon, 7/08	5.75	8.85	12.19	52.35	15.40	94.54	1.24	13.11	2.32	13.47	30.14	124.68
Tue, 7/09	5.65	8.47	11.66	50.24	14.79	90.81	1.26	12.81	2.26	13.31	29.64	120.45
Wed, 7/10	5.18	8.33	11.47	49.43	14.54	88.96	1.09	11.62	2.06	12.09	26.86	115.82
Thus, 7/11	5.39	8.90	12.24	52.73	15.51	94.76	1.12	12.02	2.15	12.58	27.87	122.63
Fri, 7/12	5.17	8.55	11.78	50.70	14.92	91.12	1.15	11.75	2.09	12.21	27.20	118.32
Sat, 7/13	3.34	5.46	7.49	32.58	9.61	58.49	1.00	7.70	1.35	7.94	17.99	76.48
Sun, 7/14	2.98	4.85	6.66	28.79	8.48	51.77	0.94	6.81	1.20	7.05	16.00	67.76
Mon, 7/15	5.53	8.87	12.21	52.43	15.42	94.45	1.16	12.44	2.18	12.79	28.57	123.02
Tue, 7/16	5.24	8.49	11.69	50.39	14.83	90.64	1.13	11.80	2.09	12.24	27.26	117.89
Mon, 7/29	5.51	8.87	12.23	52.49	15.43	94.53	1.12	12.67	2.20	13.00	28.98	123.52
Tue, 7/30	5.48	8.47	11.66	50.25	14.79	90.66	1.17	12.40	2.18	12.78	28.52	119.18
Wed, 7/31	5.30	8.31	11.43	49.26	14.51	88.80	1.16	12.13	2.13	12.54	27.95	116.76
Thus, 8/01	5.68	8.88	12.23	52.65	15.49	94.93	1.26	13.02	2.30	13.48	30.06	124.99
Fri, 8/02	5.55	8.56	11.78	50.74	14.93	91.56	1.28	12.56	2.24	13.03	29.11	120.67
Sat, 8/03	3.48	5.47	7.52	32.68	9.63	58.78	1.06	7.96	1.41	8.27	18.69	77.47
Sun, 8/04	3.13	4.85	6.67	28.81	8.48	51.94	0.99	7.26	1.29	7.59	17.13	69.07
Mon, 8/05	5.83	8.86	12.21	52.40	15.41	94.70	1.18	13.08	2.31	13.60	30.17	124.86

Table 3-9. 2002 Base 4 Model Validation Inventory – Daily Onroad Mobile CO Emissions for St. Louis Nonattainment Area Counties

Date	Missouri Nonattainment Counties CO (tpd)					MO NAA Subtotals CO (tpd)	Illinois Nonattainment Counties CO (tpd)				IL NAA Subtotals CO (tpd)	NAA Totals CO (tpd)
	Franklin	Jefferson	St Charles	St Louis	St Louis City		Jersey	Madison	Monroe	St Clair		
Sat, 6/15	46.5	68.7	91.3	383.2	105.2	695.0	10.4	99.1	16.7	99.3	225.5	920.5
Sun, 6/16	41.9	64.3	85.5	354.6	96.5	642.8	9.6	90.0	15.0	89.5	204.1	846.8
Mon, 6/17	78.6	111.4	148.7	610.2	167.0	1,115.9	11.0	161.6	27.4	161.7	361.8	1,477.6
Tue, 6/18	72.5	106.8	143.2	587.3	160.9	1,070.7	10.8	152.8	25.0	151.1	339.6	1,410.3
Wed, 6/19	70.6	107.0	142.2	583.9	160.0	1,063.6	10.4	145.0	24.2	144.5	324.2	1,387.7
Thus, 6/20	80.2	114.6	152.2	625.3	171.7	1,144.0	12.2	171.9	28.5	169.5	382.1	1,526.1
Fri, 6/21	77.8	108.2	144.0	592.7	162.7	1,085.3	12.5	166.3	27.5	164.9	371.3	1,456.5
Sat, 6/22	48.7	69.8	92.5	386.3	106.2	703.5	11.0	107.0	17.8	107.1	242.9	946.3
Sun, 6/23	44.8	63.6	84.8	351.1	95.9	640.3	10.4	98.7	16.4	98.4	223.9	864.1
Mon, 6/24	79.9	116.0	153.9	634.3	173.2	1,157.3	11.3	169.4	28.0	168.7	377.3	1,534.6
Tue, 7/02	77.6	108.4	143.3	590.8	162.0	1,082.1	12.0	169.1	27.5	166.7	375.2	1,457.3
Wed, 7/03	76.1	106.9	142.4	585.9	160.4	1,071.7	12.1	165.8	27.4	164.4	369.6	1,441.3
Thus, 7/04	39.5	57.3	75.9	316.7	86.9	576.3	10.7	88.2	14.7	88.4	202.1	778.4
Fri, 7/05	84.0	115.9	154.4	633.2	172.8	1,160.3	12.4	180.3	30.0	178.8	401.5	1,561.8
Sat, 7/06	50.4	70.9	94.5	393.9	107.7	717.4	11.4	111.1	18.5	111.1	252.1	969.6
Sun, 7/07	46.4	64.2	86.4	354.6	96.5	648.1	10.6	100.1	16.7	99.7	227.1	875.3
Mon, 7/08	82.7	113.6	151.5	621.5	170.1	1,139.3	12.2	178.3	29.5	175.6	395.6	1,534.9
Tue, 7/09	79.1	107.2	143.4	588.9	161.2	1,079.8	12.5	170.0	28.0	168.6	379.0	1,458.8
Wed, 7/10	73.3	108.6	144.3	596.1	163.1	1,085.4	10.9	154.7	25.9	154.7	346.2	1,431.5
Thus, 7/11	73.5	115.3	152.3	629.9	172.2	1,143.2	10.6	153.2	26.1	155.9	345.8	1,489.1
Fri, 7/12	70.5	109.4	146.4	598.6	163.8	1,088.8	11.0	150.5	25.4	150.7	337.7	1,426.4
Sat, 7/13	46.4	69.9	92.8	387.4	106.5	703.0	10.3	99.8	16.7	99.3	226.0	928.9
Sun, 7/14	43.0	65.0	86.2	358.4	97.7	650.3	10.1	91.7	15.5	92.2	209.4	859.7
Mon, 7/15	77.6	115.8	153.0	629.3	172.3	1,148.1	11.5	164.5	27.1	162.7	365.8	1,513.9
Tue, 7/16	73.4	109.9	146.2	604.3	165.4	1,099.1	11.3	155.9	25.8	155.1	348.1	1,447.2
Mon, 7/29	80.0	116.4	154.9	636.2	173.3	1,160.9	11.4	175.9	28.6	173.2	389.2	1,550.0
Tue, 7/30	77.6	107.8	142.8	589.9	161.8	1,080.0	11.6	165.6	27.3	163.8	368.4	1,448.4
Wed, 7/31	75.2	105.8	140.2	578.2	158.9	1,058.3	11.5	161.6	26.6	160.0	359.7	1,418.0
Thus, 8/01	81.4	113.6	151.0	621.3	170.1	1,137.5	12.3	174.4	28.8	172.6	388.1	1,525.7
Fri, 8/02	81.3	110.5	146.9	603.0	164.8	1,106.4	12.9	171.5	29.1	172.5	386.0	1,492.4
Sat, 8/03	51.3	71.1	95.1	398.0	109.0	724.5	11.3	111.3	18.8	111.7	253.1	977.5
Sun, 8/04	47.5	65.0	87.1	359.9	98.0	657.5	10.7	104.3	17.5	104.8	237.4	894.9
Mon, 8/05	85.4	114.6	153.1	626.6	170.8	1,150.4	12.0	181.5	30.1	180.2	403.8	1,554.3

Table 3-10. 2002 Base 4 Model Validation Inventory – Daily Biogenic VOC Emissions for St. Louis Nonattainment Area Counties

Date	Missouri Nonattainment Counties VOC (tpd)					Illinois Nonattainment Counties VOC (tpd)				NAA Totals VOC (tpd)	Rest of MO VOC (tpd)	Rest of IL VOC (tpd)
	Franklin	Jefferson	St Charles	St Louis	St Louis City	Jersey	Madison	Monroe	St Clair			
Sat, 6/15	101.2	80.9	12.3	9.6	5.9	23.2	32.1	20.8	13.3	299.3	5,548.6	1,900.8
Sun, 6/16	87.5	71.2	11.9	9.5	5.0	19.4	28.8	18.9	13.3	265.5	4,874.0	1,780.3
Mon, 6/17	93.9	75.1	12.1	9.7	5.8	22.3	31.5	19.7	13.2	283.3	5,187.4	2,048.3
Tue, 6/18	103.7	87.2	12.6	10.1	6.2	24.6	36.9	22.6	14.6	318.4	6,060.0	2,325.5
Wed, 6/19	107.5	82.1	13.0	10.4	5.7	22.3	30.3	19.8	14.2	305.4	6,737.1	2,382.0
Thus, 6/20	149.8	121.4	18.0	14.4	8.8	37.0	50.5	31.8	19.6	451.3	8,564.4	3,453.7
Fri, 6/21	171.5	138.4	19.1	15.4	10.5	41.2	57.5	35.6	21.0	510.1	9,136.4	3,673.5
Sat, 6/22	168.6	134.5	19.6	15.8	10.5	42.6	57.8	36.4	21.6	507.4	9,100.3	3,774.8
Sun, 6/23	165.7	134.6	19.7	15.7	10.2	41.1	57.0	35.1	21.5	500.7	8,844.2	3,643.7
Mon, 6/24	143.5	113.6	18.0	14.1	8.2	36.5	47.1	29.2	19.2	429.3	8,033.6	3,400.4
Tue, 7/02	185.0	153.5	21.4	17.1	11.7	49.5	66.0	40.7	23.0	567.7	9,338.1	4,140.4
Wed, 7/03	191.9	151.3	20.8	16.4	11.2	45.8	64.1	37.5	21.9	560.9	8,951.9	4,083.0
Thus, 7/04	164.6	136.3	19.5	15.8	9.9	41.9	60.4	38.7	22.4	509.5	9,420.1	4,042.8
Fri, 7/05	173.9	127.1	20.0	15.7	8.7	38.9	64.3	34.8	22.2	505.5	10,237.6	3,812.7
Sat, 7/06	212.4	169.9	22.2	18.2	11.9	44.3	63.3	42.5	23.7	608.5	10,999.3	3,432.9
Sun, 7/07	188.2	149.8	19.7	16.0	10.8	41.6	57.3	36.9	20.5	540.8	9,965.5	3,527.5
Mon, 7/08	192.3	158.9	21.0	16.6	10.7	46.1	61.6	40.2	21.7	569.1	10,937.9	4,024.6
Tue, 7/09	225.2	198.4	23.6	18.9	14.0	53.7	73.9	50.4	25.5	683.6	12,167.3	3,990.7
Wed, 7/10	129.1	114.0	16.4	13.1	7.7	29.0	43.9	30.2	18.6	402.1	8,287.3	2,729.6
Thus, 7/11	89.6	81.1	14.8	11.8	6.2	20.5	34.8	23.9	16.7	299.3	5,400.2	2,050.4
Fri, 7/12	81.6	59.5	12.5	10.0	4.6	18.3	26.6	16.1	13.4	242.6	4,988.1	2,011.0
Sat, 7/13	107.7	94.1	13.7	11.1	6.8	25.1	37.5	25.2	15.2	336.4	5,692.3	2,271.7
Sun, 7/14	119.0	95.9	14.0	11.3	7.2	28.6	38.5	23.9	15.8	354.2	6,658.5	2,628.2
Mon, 7/15	129.9	103.0	15.6	12.3	7.1	31.9	43.4	26.7	17.0	386.9	6,958.4	2,884.7
Tue, 7/16	113.0	110.7	16.3	13.3	7.5	29.7	44.9	29.1	18.3	382.8	7,406.0	3,153.2
Mon, 7/29	111.7	92.0	18.8	15.3	8.4	31.2	46.5	25.8	20.8	370.5	6,274.5	2,815.1
Tue, 7/30	151.6	120.7	18.7	14.9	9.1	36.7	49.2	30.7	19.5	451.0	8,039.1	3,160.9
Wed, 7/31	143.7	117.2	19.6	15.5	8.9	38.2	52.1	30.4	20.4	446.1	8,321.8	3,366.5
Thus, 8/01	147.9	118.0	19.1	15.3	8.7	38.7	52.5	32.1	20.5	452.8	8,559.6	3,306.4
Fri, 8/02	170.6	141.3	22.4	17.9	9.9	38.6	51.4	35.6	22.9	510.4	8,672.3	3,224.7
Sat, 8/03	174.0	141.1	21.3	16.8	9.4	39.6	51.4	35.8	22.4	511.9	9,463.2	3,352.0
Sun, 8/04	185.3	160.3	21.8	17.5	11.9	43.5	60.6	41.5	23.8	566.3	10,637.6	3,939.2
Mon, 8/05	190.5	153.6	22.7	18.0	11.4	43.5	60.1	39.6	24.4	563.7	10,389.0	3,574.6

Table 3-11. 2002 Base 4 Model Validation Inventory – EGU NOx Emissions by Day

Date	Missouri Nonattainment Counties NOx (tpd)					Illinois Nonattainment Counties NOx (tpd)				NAA Totals NOx (tpd)	Rest of MO NOx (tpd)	Rest of IL NOx (tpd)
	Franklin	Jefferson	St Charles	St Louis	St Louis City	Jersey	Madison	Monroe	St Clair			
Sat, 6/15	19.8	4.7	25.1	0.0	40.0	0.0	7.9	0.0	0.0	97.5	264.8	776.6
Sun, 6/16	18.0	7.8	50.3	0.0	34.1	0.0	7.9	0.0	0.0	118.1	259.0	745.3
Mon, 6/17	19.1	11.7	54.6	0.0	28.6	0.0	13.9	1.7	0.4	130.0	282.3	861.5
Tue, 6/18	19.5	12.9	45.8	0.0	30.1	0.0	13.9	1.7	0.4	124.2	286.7	889.0
Wed, 6/19	20.5	12.6	44.4	0.0	35.6	0.0	13.9	1.7	0.4	129.1	305.1	889.0
Thus, 6/20	22.0	13.8	44.3	0.0	37.6	0.0	13.9	1.7	0.4	133.7	318.6	889.0
Fri, 6/21	21.3	16.4	38.6	0.0	40.2	0.0	13.9	1.7	0.4	132.5	324.2	889.0
Sat, 6/22	20.2	14.4	42.5	0.0	39.6	0.0	7.9	0.0	0.0	124.5	310.6	776.6
Sun, 6/23	19.8	13.3	42.9	0.0	38.0	0.0	7.9	0.0	0.0	121.9	297.3	745.3
Mon, 6/24	22.7	14.7	42.8	0.0	42.2	0.0	13.9	1.7	0.4	138.4	320.4	861.5
Tue, 7/02	22.2	13.6	48.7	0.0	22.1	0.0	13.9	1.7	0.4	122.5	313.1	887.8
Wed, 7/03	21.5	14.4	48.6	0.0	29.4	0.0	13.9	1.7	0.4	129.9	292.8	887.8
Thus, 7/04	21.5	7.2	44.7	0.0	36.7	0.0	13.9	1.7	0.4	126.0	280.4	887.8
Fri, 7/05	22.4	6.8	45.5	0.0	35.2	0.0	13.9	1.7	0.4	125.8	283.2	887.8
Sat, 7/06	21.8	7.1	45.8	0.0	35.4	0.0	7.9	0.0	0.0	117.9	297.4	775.4
Sun, 7/07	14.6	9.4	45.8	0.0	35.9	0.0	7.9	0.0	0.0	113.5	292.9	744.3
Mon, 7/08	14.7	14.8	46.5	0.0	38.7	0.0	13.9	1.7	0.4	130.5	298.2	860.4
Tue, 7/09	15.4	13.5	50.2	0.0	41.5	0.0	13.9	1.7	0.4	136.6	306.3	887.8
Wed, 7/10	15.7	15.8	33.3	0.0	40.1	0.0	13.9	1.7	0.4	120.9	320.5	887.8
Thus, 7/11	14.6	16.4	26.2	0.0	34.6	0.0	13.9	1.7	0.4	107.7	320.6	887.8
Fri, 7/12	15.7	10.9	25.7	0.0	37.6	0.0	13.9	1.7	0.4	105.8	313.9	887.8
Sat, 7/13	14.4	15.4	32.8	0.0	34.7	0.0	7.9	0.0	0.0	105.2	297.1	775.4
Sun, 7/14	12.9	16.7	121.0	0.0	27.9	0.0	7.9	0.0	0.0	186.4	288.7	744.3
Mon, 7/15	16.1	14.2	73.6	0.0	34.7	0.0	13.9	1.7	0.4	154.5	313.1	860.4
Tue, 7/16	16.6	14.5	46.5	0.0	38.1	0.0	13.9	1.7	0.4	131.7	332.9	887.8
Mon, 7/29	29.3	14.1	44.8	0.0	40.5	0.0	13.9	1.7	0.4	144.7	329.5	860.4
Tue, 7/30	26.8	13.0	41.5	0.0	39.7	0.0	13.9	1.7	0.4	136.9	336.5	887.8
Wed, 7/31	26.9	6.4	43.0	0.0	41.3	0.0	13.9	1.7	0.4	133.6	335.7	887.8
Thus, 8/01	27.5	7.1	43.4	0.0	43.8	0.0	13.9	1.7	0.4	137.8	325.6	887.8
Fri, 8/02	28.1	7.4	42.5	0.0	44.0	0.0	13.9	1.7	0.4	138.0	320.7	887.8
Sat, 8/03	22.8	10.0	44.2	0.0	40.1	0.0	7.9	0.0	0.0	124.9	307.2	775.4
Sun, 8/04	20.8	14.9	45.3	0.0	37.8	0.0	7.9	0.0	0.0	126.7	291.8	744.3
Mon, 8/05	21.1	15.7	43.3	0.0	39.3	0.0	13.9	1.7	0.4	135.3	306.9	860.4

3.2 2002 BASE 4 TYPICAL EMISSIONS INVENTORY

The 2002 typical base case inventory was used as the basis for projecting emissions and for calculating the relative response factors. Day-specific emissions not appropriate for using in future year projections were replaced with average or "typical" emissions for certain types of sources. Specifically, day- and hour-specific CEM data used for EGU point sources were replaced with typical emissions for those facilities. For all other source categories, including non-EGU point, area, offroad mobile, onroad mobile, and biogenic, 2002 typical emissions were identical to the 2002 model validation emissions. Tables C-1 through C-6 in Appendix C document which SMOKE input files were used to develop the 2002 typical inventory.

Tables 3-12 through 3-14 summarize the 2002 NOx, VOC, and CO typical emissions for a weekday (Wednesday, June 19), Saturday (June 22), and Sunday (June 23) by source type for the

St. Louis nonattainment area. All emission estimates in the following tables reflect gridded, temporalized, model-ready emissions in tons per day (tpd). Appendix C contains additional emissions summaries: Tables C-14 and C-15 summarize typical 2002 NOx emissions for all Missouri and Illinois EGUs at the facility level, and Tables C-16 and C-17 summarize NOx and VOC emissions by facility for non-EGU point sources in the St. Louis nonattainment counties.

Table 3-12. 2002 Base 4 Typical Inventory – Weekday, Saturday, Sunday NOx Emissions for St. Louis Nonattainment Area Counties by Source Type

County	Area NOx (tpd)			Offroad Mobile NOx (tpd)			Onroad Mobile NOx (tpd)			Non-EGU Point NOx (tpd)			EGU Point NOx (tpd)		
	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun
Missouri															
Franklin	1.7	1.7	1.6	4.8	4.5	4.5	15.1	7.0	6.1	0.1	0.1	0.0	24.2	24.2	24.2
Jefferson	1.4	1.4	1.3	5.3	5.1	5.1	17.7	8.5	7.3	15.4	15.3	15.2	10.6	10.6	10.6
St Charles	2.4	2.3	2.2	7.1	6.5	6.4	23.5	11.4	9.7	1.2	1.0	0.9	44.9	44.9	44.9
St Louis	9.9	9.3	8.8	31.5	29.9	29.6	97.4	49.5	41.7	2.3	1.8	1.5	23.1	23.1	23.1
St Louis City	4.0	3.8	3.6	12.0	11.6	11.6	26.4	13.7	11.5	5.4	5.1	5.0	0.0	0.0	0.0
MO NAA Subtotal	**19.4**	**18.3**	**17.6**	**60.8**	**57.7**	**57.1**	**180.1**	**90.0**	**76.3**	**24.4**	**23.3**	**22.7**	**102.8**	**102.8**	**102.8**
Illinois															
Jersey	0.1	0.1	0.1	2.6	2.4	2.3	1.7	1.6	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Madison	0.7	0.7	0.7	15.6	15.1	14.9	24.2	12.3	10.7	29.7	23.1	22.9	13.9	7.9	7.9
Monroe	0.1	0.1	0.1	5.5	5.3	5.2	3.8	2.0	1.8	0.1	0.0	0.0	1.7	0.0	0.0
St Clair	0.5	0.5	0.5	10.8	10.3	10.2	23.6	12.4	10.8	3.3	0.8	0.8	0.4	0.0	0.0
IL NAA Subtotal	**1.4**	**1.4**	**1.4**	**34.5**	**33.0**	**32.7**	**53.3**	**28.3**	**24.9**	**33.1**	**23.9**	**23.7**	**15.9**	**7.9**	**7.9**
NAA Totals	**20.8**	**19.7**	**18.9**	**95.3**	**90.7**	**89.8**	**233.4**	**118.3**	**101.2**	**57.4**	**47.2**	**46.3**	**118.7**	**110.7**	**110.7**

Table 3-13. 2002 Base 4 Typical Inventory – Weekday, Saturday, Sunday VOC Emissions for St. Louis Nonattainment Area Counties by Source Type

County	Area VOC (tpd)			Offroad Mobile VOC (tpd)			Onroad Mobile VOC (tpd)			Non-EGU Point VOC (tpd)			EGU Point VOC (tpd)		
	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun
Missouri															
Franklin	3.9	3.9	3.9	2.7	2.5	2.4	5.3	3.6	3.2	1.9	1.0	0.5	0.8	0.8	0.8
Jefferson	8.7	8.7	8.7	4.0	3.5	3.3	8.3	5.5	4.8	1.7	1.3	1.1	0.4	0.4	0.4
St Charles	9.1	9.1	9.1	7.2	6.1	5.9	11.4	7.5	6.6	3.0	0.8	0.2	0.6	0.6	0.6
St Louis	36.2	35.8	35.7	27.5	21.3	20.1	49.3	32.6	28.7	13.2	6.8	2.5	0.2	0.2	0.2
St Louis City	13.4	13.2	13.1	5.6	4.4	4.3	14.5	9.6	8.5	11.1	9.2	8.7	0.0	0.0	0.0
MO NAA Subtotal	**71.4**	**70.6**	**70.4**	**46.9**	**37.7**	**36.1**	**88.9**	**58.7**	**51.9**	**30.8**	**19.2**	**12.9**	**1.9**	**1.9**	**1.9**
Illinois															
Jersey	2.2	2.2	2.2	0.5	0.5	0.5	1.1	1.1	1.0	0.1	0.1	0.1	0.0	0.0	0.0
Madison	13.8	13.8	13.8	4.4	4.2	4.2	11.3	8.1	7.2	11.0	8.6	8.1	0.3	0.2	0.2
Monroe	2.3	2.3	2.3	0.6	0.6	0.6	2.0	1.4	1.3	0.1	0.0	0.0	0.1	0.0	0.0
St Clair	11.6	11.6	11.6	3.4	3.3	3.3	11.7	8.4	7.5	3.7	2.8	1.7	0.0	0.0	0.0
IL NAA Subtotal	**29.9**	**29.9**	**29.9**	**9.0**	**8.5**	**8.5**	**26.1**	**19.0**	**17.0**	**14.9**	**11.5**	**9.8**	**0.4**	**0.2**	**0.2**
NAA Totals	**101.3**	**100.5**	**100.3**	**55.9**	**46.2**	**44.5**	**115.0**	**77.6**	**68.8**	**45.7**	**30.7**	**22.7**	**2.3**	**2.1**	**2.1**

Table 3-14. 2002 Base 4 Typical Inventory – Weekday, Saturday, Sunday CO Emissions for St. Louis Nonattainment Area Counties by Source Type

County	Area CO (tpd)			Offroad Mobile CO (tpd)			Onroad Mobile CO (tpd)			Non-EGU Point CO (tpd)			EGU Point CO (tpd)		
	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun
Missouri															
Franklin	6.4	6.4	6.4	22.8	18.3	17.6	70.6	48.7	44.8	0.1	0.0	0.0	6.5	6.5	6.5
Jefferson	15.6	15.6	15.5	46.4	35.9	34.2	107.0	69.8	63.6	2.8	2.7	2.7	3.0	3.0	3.0
St Charles	1.2	1.2	1.1	79.9	61.0	57.9	142.2	92.5	84.8	0.9	0.5	0.3	2.7	2.7	2.7
St Louis	5.3	5.0	4.9	426.5	313.6	296.1	583.9	386.3	351.1	5.9	4.4	4.0	1.6	1.6	1.6
St Louis City	1.8	1.7	1.7	93.0	68.5	65.6	160.0	106.2	95.9	3.4	3.2	3.1	0.0	0.0	0.0
MO NAA Subtotal	**30.3**	**29.9**	**29.6**	**668.6**	**497.4**	**471.4**	**1,063.6**	**703.5**	**640.3**	**13.0**	**10.8**	**10.1**	**13.7**	**13.7**	**13.7**
Illinois															
Jersey	0.1	0.1	0.1	4.4	3.7	3.7	10.4	11.0	10.4	0.0	0.0	0.0	0.0	0.0	0.0
Madison	0.6	0.6	0.6	54.9	51.1	50.9	145.0	107.0	98.7	53.5	52.0	51.9	5.5	1.5	1.5
Monroe	0.1	0.1	0.1	5.8	5.2	5.1	24.2	17.8	16.4	0.2	0.1	0.1	0.9	0.0	0.0
St Clair	0.6	0.6	0.6	45.3	42.1	41.9	144.5	107.1	98.4	5.1	2.9	2.8	0.2	0.0	0.0
IL NAA Subtotal	**1.4**	**1.4**	**1.4**	**110.4**	**102.1**	**101.6**	**324.2**	**242.9**	**223.9**	**58.8**	**55.0**	**54.8**	**6.6**	**1.5**	**1.5**
NAA Totals	**31.7**	**31.3**	**31.0**	**779.0**	**599.6**	**573.1**	**1,387.7**	**946.3**	**864.1**	**71.8**	**65.8**	**64.9**	**20.3**	**15.2**	**15.2**

3.3 2009 BASE 4 ON-THE-BOOKS EMISSIONS INVENTORY

The 2009 Base 4 on-the-books inventory accounts for countywide or statewide economic growth and local, state, and federal control measures implemented between 2002 and 2009.

3.3.1 2009 Base 4 On-the-Books Inventory Data Sources

3.3.1.1 All Point Sources Except EGUs in Midwest RPO and Minnesota

The growth and control factors were prepared by Alpine Geophysics by consolidating the best available growth factors from CENRAP, EPA in its latest release of the Economic Growth Analysis System (EGAS) Beta v. 5.0, VISTAS, and EPA growth factors as used in the most recent CAIR projection inventories. In addition, the latest growth and control factors from the MRPO Base K modeling were converted to SMOKE-ready format by ENVIRON and applied to the MRPO states and Minnesota.

The control factors for non-EGU point sources account for Maximum Available Control Technology (MACT) standards and the NOx SIP Call for industrial boilers and cement kilns. Two modifications were made to the control packet provided by Alpine for Missouri non-EGUs. One change was the removal of the NOx SIP Call control for Missouri cement kilns because these sources are not expected to implement additional NOx controls as a result of this rule after the 2002 base year. The other was revision was the removal of controls associated with the St. Louis SIP industrial surface coating rule because this rule was in place prior to 2002 and is reflected in the base year emissions inventory.

The 2002 non-EGU point source emissions were projected to 2009 by applying growth and control factors within SMOKE. The exception was for non-EGU point sources in Illinois; because SMOKE does not properly project emissions that are in the day-specific or ptday format, growth and control factors were applied to Illinois non-EGU point source emissions outside the SMOKE system using relational database software. The 2009 emissions for the Illinois sources were then processed separately within SMOKE and merged with the other 2009 datasets. Table C-1 in Appendix C documents the non-EGU point source files that were grown and controlled within the SMOKE system, and Table C-6 provides detail about the non-EGU point source files processed for 2009 directly. Note that 2002 emissions for point source fires and offshore point sources located in the Gulf of Mexico were held constant for this study.

For Illinois non-EGU point sources, the provisions of recent consent decrees, preliminary NOx RACT control levels in the Metro-East counties (Madison, Monroe, and St. Clair), a proposed expansion of the Conoco-Phillips Refinery (as well as post-2002 sources not in the Base Year inventory), and the recently permitted Prairie State Generating Station (Washington County, Illinois) were incorporated.

The proposed Illinois NOx RACT control measures are part of a planned statewide NOx rulemaking; however, these controls were only modeled for the Illinois counties in the St. Louis nonattainment area. There are seven primary process source types and source categories targeted: industrial, commercial and institutional (ICI) boilers; process heaters; aluminum melting; glass melting; iron and steel manufacturing; cement kilns; and, lime kilns. Emission limits for combustion sources at aluminum melting plants and iron and steel manufacturing facilities, as well as ICI boilers and process heaters, are generally represented by an emission rate expressed as a “lb/mmbtu” limit and reflect the fuel type, firing configuration, and type of control equipment. For glass melting furnaces, lime kilns, and cement kilns, the emission limit is expressed as “lb/ton” of glass, lime, or clinker produced. In certain situations, a limit may be expressed as a percentage reduction of actual emissions based upon a mode of operation (i.e. 30% reduction for combustion tuning). Sources for which a percentage reduction limit was

considered applicable (e.g. catalytic cracker), were modeled conservatively by assuming the least amount of emission reduction for the range of possible percentage reductions (e.g. modeling 5% when the range is 5 – 35%). The Conoco-Phillips inventory includes a level of uncertainty in the company-supplied information as to whether certain sources will be operational in 2009. The decision by IEPA staff to include these sources in the 2009 modeling inventory is viewed as an attempt to conservatively represent the facility's emissions.

All facilities that were reported as out-of business subsequent to 2002 were removed from the 2009 inventory. The newly permitted Holcim cement kiln in Ste. Genevieve was added to the 2009 inventory.

The Ford-Hazelwood facility was held at constant 2002 emissions levels. Based on a review of emissions reported on EIQs from 2002 through 2005, VOC emissions for this facility have decreased annually as follows: 2002 – 929.8 tons/year, 2003 – 974.3 tons/year, 2004 – 791.3 tons/year, and 2005 – 309.9 tons/year. In addition, a letter was received from Ron Brasher, Site Manager, stating that the St. Louis Assembly Plant is no longer in production mode, with no production scheduled for the foreseeable future. The department's Air Pollution Control Program believes that the trend of decreasing emissions, along with the plant's "idle mode" status are sufficient justification to hold emissions for this facility constant rather than applying growth through 2009. The letter from Ron Brasher, dated May 22, 2006, is included in Appendix C.

A draft of the 2009 point source emissions inventory was posted on the project website for stakeholder review and comment. Comments received from Anheuser-Busch and Daimler-Chrysler based on more recent emissions data and internal growth information were incorporated. The letter sent to facilities on March 15, 2006 to solicit their input on the draft 2009 inventory, and the response letter from Anheuser-Bush, dated April 11, 2006, are included in Appendix C. The future-year emissions for Chrysler-Fenton and Chrysler-South were based on telephone conversations with Terry Tecklenberg, Daimler-Chrysler Paint Operations Specialist, in April 2006 and a review of the 2004 and 2005 EIQs for these facilities.

Emissions for JW Aluminum (510 0118, formerly Alumax) were held constant at 2002 levels. Subsequent to the 2002 base year, JW Aluminum switched to a solvent with a lower VOC content and requested to bank the resulting VOC emission reductions in accordance with Missouri's emissions banking and trading rule, 10 CSR 10-6.410, Emissions Banking and Trading. In 2002, VOC emissions for this facility were 6.1 tons/day. The total VOC emissions for this facility after the implementation of the new solvent are estimated to be 1.6 tons/day (the new permit limit of 600 tons/year divided by 365 days). The VOC emission reduction credits on a daily basis are approximately 4.5 tons/day (approved credits of 1,655 tons/year divided by 365 days), which is equal to the difference between 6.1 tons/day and 1.6 tons/day. The credits were reflected in the 2008 RFP inventory by setting the 2008 VOC emissions for this facility equal to the 2002 levels of 6.1 tons/day. See the emission reduction credit approval letter in Appendix C.

IPM model output for 2009 was used for EGU point sources. The proprietary IPM model has been used by the EPA to simulate electrical power generation and electrical power distribution scenarios based upon "least-cost" assumptions for future years and, simultaneously, generate estimates of pollutant emissions associated with these scenarios. The IPM run was conducted by ICF under contract to the RPOs. This run corresponds with the "VISTASII_PC_1f" modeling run. This run specifically addressed the emission reductions to be realized through

implementation of the Clean Air Interstate Rule (CAIR) assuming all states participate in the EPA's trading program, Acid Rain Program (Title IV – Phases I and II), NOx SIP Call, and state and local regulations, while incorporating unit-level updates provided by power company stakeholders. Alpine Geophysics prepared the SMOKE IDA-formatted file for this IPM run. Table C-6 in Appendix C provides more information about the 2009 EGU emissions input file.

3.3.1.2 EGU Point Sources in the Midwest RPO and Minnesota

The MRPO provided output from the 2009 "on-the-books" RPO IPM run ("VISTASII_PC_1f") in the form of model-ready, NIF-formatted files available for direct processing with the EMS-2003 software. As with the 2002 baseyear inventory, unit-specific CEM-based (heat input) temporal adjustments were made to the EGU emissions that account for monthly and day-of-week variations. These adjustments replaced the use of national default temporal profiles. The IPM-derived emissions were processed for each day of the three modeling episodes and for all modeling grids.

3.3.1.3 Area Sources

2002 area source emissions were projected to 2009 by applying growth and control factors within SMOKE. The growth and control factors were prepared by Alpine by consolidating growth factors from CENRAP, EPA in its latest release of the Economic Growth Analysis System (EGAS) Beta v. 5.0, VISTAS, and EPA growth factors as used in the most recent CAIR projection inventories. The control factors reflect New Source Performance Standards (NSPS) for residential wood combustion and Stage II vapor recovery controls, including onboard vapor recovery. Table C-2 in Appendix C lists the area source files that were grown and controlled in the 2009 inventory. Note that 2002 emissions for offshore area sources located in the Gulf of Mexico were held constant through 2009 for this study.

3.3.1.4 Offroad Mobile Sources

EPA's draft NONROAD2004 model was used to generate 2009 emissions for these categories. MRPO completed the runs for each month in 2009 and provided the monthly emissions data in NIF format. MDNR converted the NIF files to IDA format. Separate IDA formatted files were prepared for each month by "annualizing" the monthly emissions (dividing the monthly totals by the number of days in the month and multiplying by 365). Table C-7 documents the offroad mobile sources that were processed for 2009 directly.

For aircraft, locomotives, and commercial marine vessels, which are not included in EPA's NONROAD model, the 2002 emissions were projected to 2009 by applying growth and control factors within SMOKE. The growth and control factors were provided by Alpine Geophysics. The control factors reflect federal locomotive and commercial marine vessel engine standards. Table C-3 in Appendix C lists the offroad mobile emissions that were grown and controlled within the SMOKE system.

3.3.1.5 Onroad Mobile Sources

Processing of the on-road mobile inventory for 2009 was similar to 2002, in that detailed emissions were estimated using link-level inputs within SMOKE for eight St. Louis non-attainment area counties with a transportation network modeled by the East West Gateway. For

the rest of the counties in each domain, county-level SMOKE inputs were used. In all cases, speed and temporal profiles remained the same for both 2002 and 2009.

The link-level VMT activity from East West Gateway for 2002 was forecast to 2009 using SCC-based growth factors provided by Alpine Geophysics. As noted in the documentation,[2] the factors were based on linear growth rates for each state, county, and vehicle type as derived from VMT data assembled by EPA for their most recent CAIR rulemaking. The procedures were originally developed during EPA's Tier 2 Tailpipe regulatory modeling analysis and refined through the Heavy Duty Diesel rule. The growth factors varied only by vehicle type (not road type), and were the same for all counties with link-level data. Tables 3-15 and 3-16 compare the 2002 and 2009 VMT by vehicle type in the eight St. Louis non-attainment area counties. Table 3-17 shows the growth factors. As a result of the variation in growth factors by vehicle type, new 2009 profiles for the fraction of each vehicle type by road type in each county (VMTMIX) had to be generated.

New MOBILE6 files were used for 2009 link-based processing in SMOKE. In all five Missouri counties, 100% of vehicles were assumed to be covered by a basic I/M performance standard in 2009. A simplified minimum and maximum temperature of 74 and 97 degrees Fahrenheit, respectively, was stipulated. In Metro East counties, reformulated gasoline was newly specified in 2009. In addition, the assumption for I/M programs was that 90% of VMT was covered in Madison and St. Clair counties, and 20% of VMT in Monroe was covered. To implement these assumptions within SMOKE, the link-based VMT was split into three separate inventory (MBINV) files:

- 100% of 2009 VMT in all five Missouri counties (Missouri scenario)
- 90% of 2009 VMT from Madison & St. Clair and 20% of 2009 VMT from Monroe (Illinois I/M scenario)
- 10% of 2009 VMT from Madison & St. Clair and 80% of 2009 VMT from Monroe (Illinois no-I/M scenario)

Through the use of different reference counties for the various I/M and no-I/M scenarios, all three inventory files were processed in SMOKE. All vehicles in the Missouri-side St. Louis non-attainment area counties should have the same basic I/M performance standard in 2009, although Franklin county used a different set of MOBILE6 input files in the final run. Table 2-18 provides a summary of key differences between the 2002 and 2009 MOBILE6 input file specifications for the eight link-based St. Louis non-attainment area counties. Table C-4 in Appendix C includes specific information on all data sources and final model-ready files used for link-based processing of 2002 and 2009 mobile emissions in SMOKE.

The county-based VMT activity for the remainder of each modeling domain was forecast to 2009 using the county- and SCC-based growth factors provided by Alpine Geophysics. Along with the growth factors, Alpine Geophysics also provided a complete new set of MOBILE6 input files for 2009 and a corresponding new county cross-reference file. Only one other change was made for the 2009 county-based processing compared to the 2002 processing: reformulated gasoline was specified for Jersey county Illinois (17083). Table C-5 in Appendix C provides specific information on data sources and final model-ready files used for all county-based processing of

[2] Alpine Geophysics, 2005. "St. Louis Ozone and PM2.5 Modeling Study: Draft – Task 3 Technical Memorandum Regional and Local Growth Factors." Prepared for the Missouri Department of Natural Resources, May 31, 2005.

2002 and 2009 mobile emissions in SMOKE.

Table 3-15. Comparison of Missouri-side 2002 and 2009 VMT (miles/annual average weekday)

State	FIPS	County	Data	2002	2009	% change
Missouri	029071	Franklin Co	LDGV	1,657,159	1,511,660	-9%
			LDGT1	1,182,056	1,647,313	39%
			LDGT2	461,420	557,395	21%
			HDGV	139,870	169,159	21%
			MC	22,425	27,121	21%
			LDDV	2,661	-	-100%
			LDDT	7,602	7,476	-2%
			HDDV	327,631	396,237	21%
			All vehicles	**3,800,822**	**4,316,361**	**14%**
	029099	Jefferson Co	LDGV	2,141,696	1,953,655	-9%
			LDGT1	1,527,677	2,128,971	39%
			LDGT2	596,335	720,372	21%
			HDGV	180,767	218,620	21%
			MC	28,982	35,050	21%
			LDDV	3,439	-	-100%
			LDDT	9,824	9,662	-2%
			HDDV	423,427	512,093	21%
			All vehicles	**4,912,146**	**5,578,423**	**14%**
	029183	St Charles Co	LDGV	2,914,479	2,658,588	-9%
			LDGT1	2,078,906	2,897,163	39%
			LDGT2	811,509	980,302	21%
			HDGV	245,993	297,504	21%
			MC	39,439	47,698	21%
			LDDV	4,679	-	-100%
			LDDT	13,369	13,149	-2%
			HDDV	576,211	696,870	21%
			All vehicles	**6,684,585**	**7,591,274**	**14%**
	029189	St Louis Co	LDGV	12,428,798	11,337,550	-9%
			LDGT1	8,865,496	12,354,955	39%
			LDGT2	3,460,679	4,180,500	21%
			HDGV	1,049,036	1,268,704	21%
			MC	168,188	203,406	21%
			LDDV	19,954	-	-100%
			LDDT	57,013	56,072	-2%
			HDDV	2,457,253	2,971,802	21%
			All vehicles	**28,506,418**	**32,372,990**	**14%**
	029510	St Louis	LDGV	3,558,158	3,245,752	-9%
			LDGT1	2,538,044	3,537,018	39%
			LDGT2	990,735	1,196,808	21%
			HDGV	300,322	363,209	21%
			MC	48,149	58,232	21%
			LDDV	5,713	-	-100%
			LDDT	16,322	16,053	-2%
			HDDV	703,471	850,777	21%
			All vehicles	**8,160,913**	**9,267,848**	**14%**
Missouri LDGV				22,700,290	20,707,204	-9%
Missouri LDGT1				16,192,179	22,565,421	39%
Missouri LDGT2				6,320,677	7,635,378	21%
Missouri HDGV				1,915,988	2,317,196	21%
Missouri MC				307,183	371,507	21%
Missouri LDDV				36,445	-	-100%
Missouri LDDT				104,130	102,412	-2%
Missouri HDDV				4,487,993	5,427,779	21%
Missouri All vehicles				**52,064,884**	**59,126,895**	**14%**

Table 3-16. Comparison of Illinois-side 2002 and 2009 VMT (miles/annual average weekday)

State	FIPS	County	Data	2002	2009	% change
Illinois	017119	Madison Co	LDGV	4,936,210	4,502,810	-9%
			LDGT1	1,865,044	2,599,125	39%
			LDGT2	636,904	769,380	21%
			HDGV	225,077	272,209	21%
			MC	25,280	30,574	21%
			LDDV	9,786	-	-100%
			LDDT	9,786	9,625	-2%
			HDDV	447,708	541,459	21%
			All vehicles	**8,154,980**	**8,725,182**	7%
	017133	Monroe Co	LDGV	859,025	783,603	-9%
			LDGT1	324,565	452,313	39%
			LDGT2	110,837	133,892	21%
			HDGV	39,169	47,371	21%
			MC	4,399	5,321	21%
			LDDV	1,703	-	-100%
			LDDT	1,703	1,675	-2%
			HDDV	77,913	94,227	21%
			All vehicles	**1,419,172**	**1,518,402**	**7%**
	017163	St Clair Co	LDGV	5,065,054	4,620,342	-9%
			LDGT1	1,913,725	2,666,968	39%
			LDGT2	653,528	789,462	21%
			HDGV	230,952	279,314	21%
			MC	25,940	31,372	21%
			LDDV	10,041	-	-100%
			LDDT	10,041	9,876	-2%
			HDDV	459,394	555,592	21%
			All vehicles	**8,367,841**	**8,952,926**	**7%**
Illinois LDGV				10,860,289	9,906,756	-9%
Illinois LDGT1				4,103,334	5,718,406	39%
Illinois LDGT2				1,401,270	1,692,734	21%
Illinois HDGV				495,199	598,894	21%
Illinois MC				55,620	67,267	21%
Illinois LDDV				21,530	-	-100%
Illinois LDDT				21,530	21,175	-2%
Illinois HDDV				985,015	1,191,278	21%
Illinois All vehicles				**17,941,994**	**19,196,509**	**7%**

Table 3-17 .VMT Growth Factors for St. Louis Non-Attainment Area Counties

Code	Description	2009/2002 VMT growth factor
0100	LDGV: Light Duty Gasoline Vehicles	0.9122
0102	LDGT1: Light Duty Gasoline Trucks 1	1.3936
0104	LDGT2: Light Duty Gasoline Trucks 2	1.2080
0107	HDGV: Heavy Duty Gasoline Vehicles	1.2094
0108	MC: Motorcycles	1.2094
3000	LDDV: Light Duty Diesel Vehicles	0.0000
3006	LDDT: Light Duty Diesel Trucks	0.9835
3007	HDDV: Heavy Duty Diesel Vehicles	1.2094

Table 3-18. Major Differences Between 2002 and 2009 MOBILE6 Settings in Nonattainment Area Counties

County	Parameter	2002 value	2009 value
29099 29183 29189 29510	Diesel sulfur	350	43
	Fuel program	2 S (RFG South)	2 S (RFG South)
	I/M program	Enhanced biennial program with phase-in cutpoints (2 T/O Idle; 2 T/O IM240; 2 T/O GC)	Basic performance standard (T/O Idle; T/O OBD I/M)
29071	Diesel sulfur	390	43
	Fuel program	2 S (RFG South)	2 S (RFG South)
	I/M program	Basic performance standard (T/O Idle; T/O GC)	Basic performance standard (T/O Idle; T/O OBD I/M)
17119 17133 17163	Diesel sulfur	375	15
	Fuel program	1 (Conventional Gas East)	2 S (RFG South)
	I/M program	Enhanced biennial evap and exhaust program (2 T/O Idle; 2 T/O IM240; 2 T/O GC; 2 T/O Evap OBD & GC; 2 T/O OBD I/M)	For Illinois I/M scenario: Onboard diagnostic check only (2 T/O Evap OBD; 2 T/O OBD I/M; HDVs still get 2 T/O Idle & 2 T/O GC)

3.3.1.6 Biogenic Sources

Biogenic emissions used for the 2009 modeling are identical to the 2002 base case modeling inventory.

3.3.2 2009 Base 4 On-the-Books Inventory Emissions Summaries

Tables 3-19 through 3-21 summarize weekday (Wednesday, June 19), Saturday (June 22), and Sunday (June 23) 2009 emissions in the St. Louis nonattainment counties by source type for NOx, VOC, and CO, respectively. Because onroad mobile emissions from the 2009 inventory exhibit considerable variation from day to day, additional summaries of these emissions for every day in the ozone episodes are included in Table 3-22 (onroad mobile NOx), Table 3-23 (onroad mobile VOC), Table 3-24.

All emission estimates in the following tables reflect gridded, temporalized, model-ready emissions in tons per day (tpd). Tables C-11 through C-13 in Appendix C contain additional NOx, VOC, and CO emissions summaries of the 2009 inventory by state and source category for every state in the 36 km modeling domain. In addition, Tables C-14 and C-15 summarize 2002 and 2009 NOx emissions for all EGUs in Missouri and Illinois, and Tables C-16 and C-17 summarize 2002 and 2009 NOx and VOC emissions for non-EGU point sources in the St. Louis nonattainment area.

Table 3-19. 2009 Base 4 On-the-Books Inventory – Weekday, Saturday, Sunday NOx Emissions for St. Louis Nonattainment Area Counties by Source Type

County	Area NOx (tpd)			Offroad Mobile NOx (tpd)			Onroad Mobile NOx (tpd)			Non-EGU Point NOx (tpd)			EGU Point NOx (tpd)		
	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun
Missouri															
Franklin	1.8	1.8	1.7	3.8	3.4	3.4	7.7	3.8	3.4	0.1	0.1	0.0	28.1	24.2	23.5
Jefferson	1.5	1.4	1.4	5.4	5.2	5.2	9.6	4.9	4.3	18.3	18.3	18.2	15.2	13.3	12.9
St Charles	2.5	2.4	2.3	7.7	7.1	7.0	12.8	6.5	5.7	1.2	1.1	0.9	21.9	20.0	21.6
St Louis	10.2	9.6	9.1	31.6	30.8	30.7	52.7	28.5	24.6	2.3	1.9	1.5	17.9	15.9	14.5
St Louis City	4.4	4.1	4.0	10.5	10.3	10.2	14.4	7.9	6.8	5.1	4.8	4.7	0.0	0.0	0.0
MO NAA Subtotal	**20.4**	**19.3**	**18.5**	**59.1**	**56.9**	**56.5**	**97.2**	**51.6**	**44.8**	**27.1**	**26.1**	**25.4**	**83.1**	**73.3**	**72.6**
Illinois															
Jersey	0.1	0.1	0.1	2.4	2.2	2.1	1.0	1.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Madison	0.8	0.8	0.8	13.1	12.6	12.5	11.7	6.0	5.3	25.7	17.6	17.4	9.5	9.0	8.6
Monroe	0.1	0.1	0.1	4.2	4.0	4.0	1.9	1.1	1.0	0.1	0.0	0.0	0.0	0.0	0.0
St Clair	0.6	0.6	0.6	8.8	8.4	8.3	11.4	6.1	5.3	4.7	1.1	1.0	0.0	0.0	0.0
IL NAA Subtotal	**1.5**	**1.5**	**1.5**	**28.5**	**27.2**	**26.9**	**26.1**	**14.1**	**12.5**	**30.5**	**18.6**	**18.4**	**9.6**	**9.0**	**8.7**
NAA Totals	**21.9**	**20.8**	**19.9**	**87.6**	**84.1**	**83.4**	**123.3**	**65.7**	**57.3**	**57.6**	**44.7**	**43.8**	**92.7**	**82.4**	**81.2**

Table 3-20. 2009 Base 4 On-the-Books Inventory – Weekday, Saturday, Sunday VOC Emissions for St. Louis Nonattainment Area Counties by Source Type

County	Area VOC (tpd)			Offroad Mobile VOC (tpd)			Onroad Mobile VOC (tpd)			Non-EGU Point VOC (tpd)			EGU Point VOC (tpd)		
	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun
Missouri															
Franklin	4.2	4.2	4.2	3.3	3.3	3.3	3.7	2.4	2.1	1.9	1.1	0.4	0.8	0.7	0.7
Jefferson	9.0	9.0	9.0	4.5	4.4	4.4	4.7	3.1	2.8	1.7	1.3	1.1	0.5	0.4	0.4
St Charles	10.1	10.0	10.0	7.2	7.0	7.0	6.5	4.3	3.8	3.1	0.8	0.2	0.6	0.6	0.6
St Louis	39.2	38.8	38.7	20.3	19.6	19.6	28.0	18.6	16.5	13.4	6.9	2.5	0.3	0.3	0.3
St Louis City	14.1	13.8	13.7	4.1	3.8	3.8	8.3	5.5	4.9	10.8	9.4	8.9	0.0	0.0	0.0
MO NAA Subtotal	**76.6**	**75.8**	**75.6**	**39.4**	**38.2**	**38.1**	**51.2**	**33.9**	**30.1**	**30.9**	**19.5**	**13.2**	**2.3**	**2.0**	**2.0**
Illinois															
Jersey	2.2	2.2	2.2	0.5	0.4	0.4	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Madison	13.3	13.3	13.3	3.3	3.1	3.1	5.5	3.8	3.4	7.9	5.4	4.9	0.2	0.2	0.2
Monroe	2.3	2.3	2.3	0.5	0.4	0.4	1.0	0.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0
St Clair	11.0	11.0	11.0	2.4	2.3	2.3	5.7	3.9	3.5	3.9	2.8	1.6	0.0	0.0	0.0
IL NAA Subtotal	**28.8**	**28.8**	**28.8**	**6.5**	**6.3**	**6.2**	**12.7**	**8.9**	**8.0**	**11.9**	**8.2**	**6.6**	**0.2**	**0.2**	**0.2**
NAA Totals	**105.4**	**104.6**	**104.4**	**45.9**	**44.5**	**44.3**	**63.9**	**42.8**	**38.0**	**42.7**	**27.7**	**19.7**	**2.5**	**2.2**	**2.2**

Table 3-21. 2009 Base 4 On-the-Books Inventory – Weekday, Saturday, Sunday CO Emissions for St. Louis Nonattainment Area Counties by Source Type

County	Area CO (tpd)			Offroad Mobile CO (tpd)			Onroad Mobile CO (tpd)			Non-EGU Point CO (tpd)			EGU Point CO (tpd)		
	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun	wkday	sat	sun
Missouri															
Franklin	6.8	6.8	6.7	30.5	28.4	28.3	46.0	29.8	27.9	0.1	0.0	0.0	7.1	6.1	5.9
Jefferson	16.4	16.3	16.3	65.4	62.9	62.8	58.0	38.2	35.3	3.4	3.2	3.2	4.0	3.5	3.4
St Charles	1.3	1.2	1.2	113.2	108.0	107.8	77.2	50.7	47.0	1.0	0.5	0.3	2.8	2.6	2.8
St Louis	5.7	5.4	5.2	552.5	518.5	516.9	318.5	212.6	195.5	6.4	4.6	4.2	2.7	2.4	2.2
St Louis City	2.0	1.9	1.8	103.2	90.6	90.1	87.6	58.6	53.6	3.8	3.5	3.5	0.0	0.0	0.0
MO NAA Subtotal	**32.1**	**31.6**	**31.3**	**864.8**	**808.5**	**805.9**	**587.2**	**390.0**	**359.3**	**14.5**	**12.0**	**11.2**	**16.6**	**14.6**	**14.4**
Illinois															
Jersey	0.1	0.1	0.1	4.2	3.6	3.6	5.6	5.2	4.9	0.0	0.0	0.0	0.0	0.0	0.0
Madison	0.7	0.7	0.7	51.3	47.5	47.3	72.0	48.1	44.5	54.4	49.3	49.3	2.0	1.8	1.8
Monroe	0.1	0.1	0.1	5.5	4.9	4.8	13.4	8.9	8.3	0.2	0.1	0.1	0.0	0.0	0.0
St Clair	0.6	0.6	0.6	42.5	39.2	39.1	71.6	48.2	44.5	5.7	3.2	2.9	0.0	0.0	0.0
IL NAA Subtotal	**1.5**	**1.5**	**1.5**	**103.6**	**95.2**	**94.7**	**162.6**	**110.3**	**102.3**	**60.2**	**52.5**	**52.3**	**2.0**	**1.8**	**1.8**
NAA Totals	**33.6**	**33.2**	**32.8**	**968.4**	**903.7**	**900.6**	**749.8**	**500.3**	**461.6**	**74.8**	**64.5**	**63.4**	**18.6**	**16.5**	**16.2**

Table 3-22. 2009 Base 4 On-the-Books Inventory – Daily Onroad Mobile NOx Emissions for St. Louis Nonattainment Area Counties

Date	Missouri Nonattainment Counties NOx (tpd)					MO NAA Totals NOx (tpd)	Illinois Nonattainment Counties NOx (tpd)				IL NAA Totals NOx (tpd)	NAA Totals NOx (tpd)
	Franklin	Jefferson	St Charles	St Louis	St Louis City		Jersey	Madison	Monroe	St Clair		
Sat, 6/15	4.0	5.1	6.8	29.2	8.1	53.2	1.0	6.3	1.1	6.4	14.8	68.0
Sun, 6/16	3.2	4.1	5.5	23.7	6.6	43.2	0.9	5.4	0.9	5.3	12.5	55.7
Mon, 6/17	8.5	10.6	14.0	58.1	15.9	107.2	1.1	12.8	2.2	12.5	28.5	135.6
Tue, 6/18	8.0	10.1	13.2	55.5	15.2	102.0	1.0	12.3	2.1	12.0	27.4	129.4
Wed, 6/19	7.7	9.6	12.8	52.7	14.4	97.2	1.0	11.7	1.9	11.4	26.1	123.3
Thus, 6/20	8.0	9.9	13.1	54.3	14.7	100.0	1.1	11.7	2.0	11.4	26.2	126.2
Fri, 6/21	8.1	10.1	13.3	55.7	15.2	102.3	1.1	11.9	2.0	11.6	26.7	129.0
Sat, 6/22	3.8	4.9	6.5	28.5	7.9	51.6	1.0	6.0	1.1	6.1	14.1	65.7
Sun, 6/23	3.4	4.3	5.7	24.6	6.8	44.8	0.9	5.3	1.0	5.3	12.5	57.3
Mon, 6/24	8.1	9.9	13.1	53.6	14.5	99.2	1.0	11.6	1.9	11.3	25.9	125.1
Tue, 7/02	7.9	9.9	13.1	54.1	14.8	99.9	1.0	11.8	2.0	11.4	26.1	126.0
Wed, 7/03	7.8	9.7	12.8	53.6	14.7	98.7	1.0	11.3	1.9	11.1	25.4	124.1
Thus, 7/04	2.7	3.5	4.7	20.4	5.7	37.1	0.8	4.4	0.8	4.4	10.4	47.5
Fri, 7/05	8.1	9.9	13.0	53.2	14.4	98.8	1.1	11.5	1.9	11.1	25.6	124.4
Sat, 7/06	3.7	4.7	6.2	26.9	7.5	48.9	0.9	5.7	1.0	5.7	13.4	62.3
Sun, 7/07	3.3	4.2	5.5	23.8	6.6	43.3	0.9	5.1	0.9	5.2	12.1	55.5
Mon, 7/08	8.1	10.2	13.3	55.2	15.1	102.0	1.0	12.0	2.0	11.7	26.8	128.7
Tue, 7/09	8.1	10.2	13.0	54.5	14.9	100.6	1.0	11.6	2.0	11.3	25.9	126.5
Wed, 7/10	7.6	9.5	12.5	51.4	14.0	95.0	1.0	11.0	1.9	10.7	24.5	119.5
Thus, 7/11	7.9	9.8	13.0	53.5	14.5	98.8	1.1	11.8	1.9	11.4	26.3	125.0
Fri, 7/12	7.8	9.7	12.9	53.0	14.4	97.9	1.1	11.8	1.9	11.4	26.2	124.0
Sat, 7/13	3.7	4.8	6.4	27.7	7.7	50.3	1.0	6.1	1.1	6.1	14.2	64.5
Sun, 7/14	3.2	4.0	5.4	22.9	6.4	41.8	0.9	5.1	0.9	5.1	12.1	53.8
Mon, 7/15	8.1	9.9	13.3	53.7	14.6	99.5	1.0	11.9	2.0	11.5	26.5	125.9
Tue, 7/16	7.9	9.8	12.9	53.0	14.5	98.0	1.0	11.6	1.9	11.3	25.8	123.8
Mon, 7/29	8.0	9.9	13.0	53.2	14.5	98.5	1.0	11.5	1.9	11.2	25.6	124.1
Tue, 7/30	8.1	9.9	13.3	55.1	15.0	101.4	1.0	11.8	2.0	11.4	26.2	127.5
Wed, 7/31	7.7	9.7	12.9	53.7	14.6	98.6	1.0	11.5	1.9	11.2	25.6	124.2
Thus, 8/01	8.0	10.0	13.2	55.0	15.0	101.2	1.1	11.9	2.0	11.6	26.6	127.8
Fri, 8/02	7.8	9.7	12.9	53.3	14.6	98.3	1.1	11.3	1.9	11.1	25.3	123.7
Sat, 8/03	3.6	4.6	6.2	26.3	7.3	48.0	0.9	5.6	1.0	5.6	13.1	61.0
Sun, 8/04	3.1	4.0	5.3	22.7	6.3	41.5	0.9	4.9	0.9	4.9	11.5	53.0
Mon, 8/05	8.1	9.9	13.1	54.2	14.9	100.2	1.0	11.7	2.0	11.4	26.0	126.2

Table 3-23. 2009 Base 4 On-the-Books Inventory – Daily Onroad Mobile VOC Emissions for St. Louis Nonattainment Area Counties

Date	Missouri Nonattainment Counties VOC (tpd)					MO NAA Totals VOC (tpd)	Illinois Nonattainment Counties VOC (tpd)				IL NAA Totals VOC (tpd)	NAA Totals VOC (tpd)
	Franklin	Jefferson	St Charles	St Louis	St Louis City		Jersey	Madison	Monroe	St Clair		
Sat, 6/15	2.4	3.1	4.3	18.6	5.5	33.9	0.5	3.7	0.7	3.8	8.2	42.0
Sun, 6/16	2.1	2.8	3.8	16.5	4.9	30.1	0.5	3.3	0.6	3.4	7.2	37.3
Mon, 6/17	3.9	5.0	6.9	29.8	8.8	54.4	0.6	6.0	1.1	6.2	13.3	67.8
Tue, 6/18	3.7	4.8	6.6	28.6	8.4	52.1	0.6	5.7	1.1	5.9	12.6	64.7
Wed, 6/19	3.7	4.7	6.5	28.0	8.3	51.2	0.5	5.5	1.0	5.7	12.2	63.3
Thus, 6/20	3.9	5.0	7.0	30.0	8.8	54.7	0.6	6.0	1.1	6.2	13.3	68.0
Fri, 6/21	3.8	4.8	6.7	28.8	8.5	52.6	0.6	5.9	1.1	6.1	13.1	65.7
Sat, 6/22	2.4	3.1	4.3	18.6	5.5	33.9	0.5	3.8	0.7	3.9	8.4	42.3
Sun, 6/23	2.1	2.8	3.8	16.5	4.9	30.1	0.5	3.4	0.6	3.5	7.5	37.6
Mon, 6/24	3.9	5.0	6.9	29.8	8.8	54.5	0.6	5.9	1.1	6.1	13.2	67.7
Tue, 7/02	3.7	4.8	6.6	28.6	8.4	52.2	0.6	5.9	1.1	6.2	13.2	65.4
Wed, 7/03	3.6	4.7	6.5	28.0	8.3	51.1	0.6	5.9	1.1	6.1	13.1	64.2
Thus, 7/04	1.9	2.5	3.4	14.8	4.4	27.0	0.5	3.0	0.6	3.2	6.8	33.8
Fri, 7/05	3.9	5.0	7.0	29.9	8.8	54.6	0.6	6.1	1.1	6.3	13.5	68.1
Sat, 7/06	2.4	3.1	4.3	18.6	5.5	33.9	0.5	3.9	0.7	4.1	8.7	42.6
Sun, 7/07	2.1	2.8	3.8	16.5	4.9	30.1	0.5	3.4	0.6	3.6	7.6	37.7
Mon, 7/08	3.9	5.0	6.9	29.8	8.8	54.5	0.6	6.3	1.2	6.5	14.0	68.5
Tue, 7/09	3.7	4.8	6.6	28.6	8.4	52.2	0.6	6.1	1.2	6.4	13.6	65.8
Wed, 7/10	3.7	4.7	6.5	28.1	8.3	51.2	0.5	5.6	1.1	5.8	12.5	63.7
Thus, 7/11	3.9	5.0	7.0	30.0	8.8	54.7	0.6	5.8	1.1	6.1	13.0	67.7
Fri, 7/12	3.8	4.9	6.7	28.9	8.5	52.7	0.6	5.6	1.1	5.8	12.4	65.1
Sat, 7/13	2.4	3.1	4.3	18.6	5.5	33.9	0.5	3.7	0.7	3.9	8.2	42.1
Sun, 7/14	2.1	2.8	3.8	16.5	4.9	30.1	0.5	3.3	0.6	3.4	7.3	37.4
Mon, 7/15	3.9	5.0	6.9	29.8	8.8	54.5	0.6	6.0	1.1	6.2	13.4	67.9
Tue, 7/16	3.7	4.8	6.6	28.6	8.4	52.2	0.6	5.7	1.1	6.0	12.8	65.0
Mon, 7/29	3.9	5.0	7.0	29.9	8.8	54.6	0.5	5.9	1.1	6.1	13.2	67.7
Tue, 7/30	3.7	4.8	6.6	28.6	8.4	52.1	0.6	5.8	1.1	6.0	12.9	65.0
Wed, 7/31	3.7	4.7	6.5	28.0	8.3	51.1	0.6	5.7	1.1	5.9	12.6	63.7
Thus, 8/01	3.9	5.0	6.9	29.9	8.8	54.7	0.6	6.1	1.2	6.3	13.5	68.2
Fri, 8/02	3.8	4.9	6.7	28.8	8.5	52.6	0.6	5.9	1.1	6.1	13.0	65.7
Sat, 8/03	2.4	3.1	4.3	18.6	5.5	33.9	0.5	3.7	0.7	3.9	8.3	42.2
Sun, 8/04	2.1	2.8	3.8	16.5	4.9	30.1	0.5	3.4	0.6	3.5	7.5	37.6
Mon, 8/05	3.9	5.0	6.9	29.8	8.8	54.5	0.6	6.1	1.1	6.3	13.5	68.1

Table 3-24. 2009 Base 4 On-the-Books Inventory – Daily Onroad Mobile CO Emissions for St. Louis Nonattainment Area Counties

Date	Missouri Nonattainment Counties CO (tpd)					MO NAA Total CO (tpd)	Illinois Nonattainment Counties CO (tpd)				IL NAA Total CO (tpd)	NAA Totals CO (tpd)
	Franklin	Jefferson	St Charles	St Louis	St Louis City		Jersey	Madison	Monroe	St Clair		
Sat, 6/15	29.5	37.9	50.3	211.6	58.3	387.6	5.4	48.1	9.0	48.2	110.7	498.3
Sun, 6/16	28.1	35.5	47.3	196.7	53.8	361.5	5.1	44.0	8.2	43.9	101.2	462.6
Mon, 6/17	49.1	61.5	82.1	337.9	92.7	623.3	5.8	78.9	14.9	78.9	178.4	801.7
Tue, 6/18	46.5	58.4	78.1	321.9	88.5	593.3	5.7	73.7	13.6	73.4	166.4	759.8
Wed, 6/19	46.0	58.0	77.2	318.5	87.6	587.2	5.6	72.0	13.4	71.6	162.6	749.8
Thus, 6/20	49.3	62.1	82.6	341.0	93.9	628.9	5.8	77.1	14.2	76.6	173.7	802.6
Fri, 6/21	46.8	59.0	78.7	325.1	89.5	599.0	5.9	74.2	13.7	73.9	167.6	766.7
Sat, 6/22	29.8	38.2	50.7	212.6	58.6	390.0	5.2	48.1	8.9	48.2	110.3	500.3
Sun, 6/23	27.9	35.3	47.0	195.5	53.6	359.3	4.9	44.5	8.3	44.5	102.3	461.6
Mon, 6/24	50.1	63.0	83.9	345.9	94.8	637.8	5.5	77.2	14.3	77.0	174.0	811.8
Tue, 7/02	46.7	58.9	78.2	324.2	89.1	597.1	5.6	74.5	13.7	74.2	168.0	765.1
Wed, 7/03	45.6	57.5	76.6	316.8	87.0	583.5	5.6	73.6	13.5	73.1	165.8	749.2
Thus, 7/04	24.1	30.9	41.2	172.8	47.6	316.7	5.0	39.3	7.3	39.4	91.0	407.7
Fri, 7/05	50.1	62.9	84.2	347.1	95.2	639.6	5.9	80.1	14.6	79.3	179.8	819.4
Sat, 7/06	30.0	38.5	51.4	215.0	59.2	394.2	5.3	49.4	9.1	49.6	113.4	507.6
Sun, 7/07	28.2	35.6	47.6	196.9	53.9	362.2	5.0	45.1	8.4	45.1	103.6	465.8
Mon, 7/08	49.8	62.2	83.1	342.1	93.8	631.1	5.7	79.1	14.7	78.8	178.2	809.3
Tue, 7/09	46.4	58.4	78.3	323.6	89.0	595.8	5.7	75.6	13.9	75.2	170.5	766.2
Wed, 7/10	46.4	58.5	77.8	322.8	88.7	594.1	5.5	71.5	13.3	71.9	162.2	756.4
Thus, 7/11	49.7	62.5	83.1	344.4	94.6	634.3	5.7	75.1	14.0	74.9	169.7	804.0
Fri, 7/12	47.7	60.2	79.9	331.2	91.0	609.9	6.0	73.1	13.6	72.7	165.4	775.3
Sat, 7/13	30.0	38.4	50.9	213.7	58.9	391.9	5.3	47.7	8.9	47.8	109.7	501.6
Sun, 7/14	28.3	35.9	47.7	198.2	54.2	364.2	5.1	44.5	8.3	44.7	102.7	466.9
Mon, 7/15	50.1	62.9	83.3	344.6	94.6	635.6	5.7	78.7	14.5	78.4	177.3	812.9
Tue, 7/16	46.9	59.2	78.9	326.2	89.9	601.1	5.7	74.1	13.7	74.0	167.4	768.5
Mon, 7/29	50.5	63.2	84.2	346.6	94.9	639.3	5.6	78.7	14.4	78.2	176.9	816.2
Tue, 7/30	46.4	58.7	78.0	322.8	88.8	594.7	5.5	73.7	13.6	73.4	166.2	760.9
Wed, 7/31	45.7	57.6	76.5	316.6	87.2	583.6	5.5	72.1	13.3	71.8	162.7	746.3
Thus, 8/01	49.1	61.8	82.2	339.5	93.4	626.0	5.9	77.5	14.2	77.1	174.7	800.7
Fri, 8/02	47.4	59.8	79.6	328.5	90.2	605.6	6.0	75.5	14.0	75.7	171.3	776.9
Sat, 8/03	30.1	38.7	51.6	216.6	59.6	396.5	5.3	49.2	9.1	49.3	112.9	509.5
Sun, 8/04	28.3	35.8	47.8	198.5	54.3	364.8	5.0	45.9	8.5	46.0	105.5	470.2
Mon, 8/05	49.9	62.6	83.6	343.4	94.0	633.4	5.7	79.7	14.7	79.3	179.4	812.8

3.4 QUALITY ASSURANCE AND QUALITY CONTROL

The development of the 2002 and 2009 emissions inventories included step-by-step quality assurance (QA) and quality control (QC). The SMOKE and EMS emissions modeling systems generate numerous summary reports that were reviewed to assure that no emissions were gained or lost in each step of the processing of the raw annual, county-level emissions into gridded, hourly, speciated emissions needed by the photochemical model.

Tables 3-25 through 3-32 illustrate this series of QA checks for selected states based on the 2002 Base 4 typical emissions for Wednesday, June 19. Table 3-25 demonstrates that the raw annual

point source emissions inventory is consistent with the annual emissions after the 36 km gridding matrix has been applied. Table 3-26 shows that, for a weekday in June, the point source emissions after the application of the temporal matrix are the same as the emissions after the application of both the temporal and 36 km gridding matrices. Similar results are shown for area sources (Tables 3-27 and 3-28), offroad mobile sources (Tables 3-29 and 3-30), and onroad mobile sources (Tables 3-31 and 3-32). All "raw" emissions in these tables were taken from SMOKE output reports following the SMKINVEN step. The gridded, annual emissions are from reports following the SMKINVEN and GRDMAT steps. Temporalized emissions are from reports generated after SMKINVEN and TEMPORAL, and the temporalized and gridded emissions follow SMKINVEN, GRDMAT, and TEMPORAL. Because the onroad mobile emissions were generated by running the MOBILE6 model within the SMOKE framework, the "raw" inventory for this source type consists of the annual VMT inputs.

VOC speciation cannot be quality assured by summing the mass from SMOKE reports. The speciation step groups emissions of various compounds with different molecular weights into a single CB4 species with an average molecular weight. Once combined into the CB4 species, it is very difficult to track the mass correctly (email communications received from Marc Houyoux, EPA, and Abby Hoats and Greg Yarwood, ENVIRON, February 28, 2007). As an example, for area sources, summing the temporalized, gridded (36 km), and speciated mass emissions for ALD2, ETH, FORM, ISOP, OLE, PAR, TOL, and XYL results in a Missouri statewide total of 266.5 tons/day for a weekday in June. However, as shown in Table 3-28, the total temporalized and gridded VOC emissions for Missouri for a weekday in June is 289.7 tons/day. The difference between the summed speciated mass and total VOC mass varies between about 6-12% depending on the state and SCC. Therefore, a set of tables demonstrating mass conservancy through the speciation step is not included. As quality assurance for the SPCMAT step, as with all SMOKE processing steps, the log files were reviewed carefully and any warning or error messages were resolved.

Table 3-25. 2002 Base 4 Typical Inventory – Comparison of Raw Annual and Gridded (36 km) Annual Point Source Emissions

State	Raw NOx (tpy)	Gridded NOx (tpy)	Raw VOC (tpy)	Gridded VOC (tpy)	Raw CO (tpy)	Gridded CO (tpy)
Non-EGU Point Sources						
Arkansas	27,706	27,706	32,097	32,097	51,509	51,509
Illinois	97,012	97,012	73,485	73,486	82,141	82,141
Indiana	80,432	80,432	55,933	55,933	364,580	364,580
Kentucky	41,485	41,485	45,035	45,036	111,940	111,940
Missouri	41,231	41,231	33,646	33,646	109,090	109,090
Ohio	65,897	65,897	28,621	28,622	237,970	237,970
Tennessee	73,303	73,303	88,055	88,055	119,320	119,320
EGU Point Sources						
Arkansas	39,200	39,200	468	468	3,849	3,849
Illinois*	177,581	NDA	1,570	NDA	14,323	NDA
Indiana*	287,424	NDA	2,016	NDA	15,475	NDA
Kentucky	195,720	195,720	1,283	1,283	10,611	10,611
Missouri	140,350	140,350	1,449	1,449	10,026	10,026
Ohio*	375,504	NDA	1,743	NDA	14,393	NDA
Tennessee	155,890	155,890	840	840	6,547	6,547

NDA = Not Determined for Annual Emissions

* EMS-2003 processing did not use annual estimates as a starting point, but rather hourly-specific estimates based upon 2000-2003 CEM data for a weekday, a Saturday, and a Sunday in each month. Therefore, gridded annual emission estimates are not provided.

Table 3-26. 2002 Base 4 Typical Inventory – Comparison of Temporalized (June Weekday) and Temporalized (June Weekday) and Gridded (36 km) Point Source Emissions

State	Temporalized NOx (tpd)	Temporalized & Gridded NOx (tpd)	Temporalized VOC (tpd)	Temporalized & Gridded VOC (tpd)	Temporalized CO (tpd)	Temporalized & Gridded CO (tpd)
Non-EGU Point Sources						
Arkansas	76.0	76.0	87.7	87.7	141.4	141.4
Illinois	358.3	358.3	314.2	314.2	326.7	326.7
Indiana	223.8	223.8	153.4	153.4	997.0	997.0
Kentucky	113.9	113.9	117.0	117.0	309.8	309.8
Missouri	115.1	115.1	103.9	103.9	304.3	304.3
Ohio	180.6	180.6	78.9	78.9	646.5	646.5
Tennessee	204.9	204.9	245.5	245.5	327.7	327.7
EGU Point Sources						
Arkansas	120.0	120.0	1.4	1.4	11.8	11.8
Illinois*		905.0		12.0		149.7
Indiana*		859.5		6.1		47.0
Kentucky	553.6	553.6	3.6	3.6	30.1	30.1
Missouri	421.6	421.6	4.3	4.3	30.1	30.1
Ohio*		1103.4		5.3		43.9
Tennessee	440.9	440.9	2.4	2.4	18.6	18.6

* The EMS-2003 emissions processing system performs temporal allocation subsequent to gridding (spatial allocation); consequently, "temporalized" output is redundant with "temporalized & gridded" output and any entries for the former would be identical to the latter and not provide any insight with respect to mass conservancy during the processing.

Table 3-27. 2002 Base 4 Typical Inventory – Comparison of Raw Annual and Gridded (36 km) Annual Area Source Emissions

State	Raw NOx (tpy)	Gridded NOx (tpy)	Raw VOC (tpy)	Gridded VOC (tpy)	Raw CO (tpy)	Gridded CO (tpy)
Arkansas	25,392	25,392	71,370	71,370	145,860	145,860
Illinois	22,274	22,274	248,700	248,700	12,271	12,271
Indiana	29,647	29,647	133,230	133,230	56,738	56,738
Kentucky	40,607	40,607	98,963	98,963	106,700	106,700
Missouri	34,749	34,749	136,330	136,330	269,010	269,000
Ohio	37,139	37,139	192,330	192,330	91,600	91,600
Tennessee	19,846	19,846	166,200	166,200	157,690	157,690

Table 3-28. 2002 Base 4 Typical Inventory – Comparison of Temporalized (June Weekday) and Temporalized (June Weekday) and Gridded (36 km) Area Source Emissions

State	Temporalized NOx (tpd)	Temporalized & Gridded NOx (tpd)	Temporalized VOC (tpd)	Temporalized & Gridded VOC (tpd)	Temporalized CO (tpd)	Temporalized & Gridded CO (tpd)
Arkansas	62.6	62.6	177.3	177.3	327.4	327.4
Illinois	61.0	61.0	681.4	681.4	33.6	33.6
Indiana	57.3	57.3	338.1	338.1	63.9	63.9
Kentucky	107.1	107.1	238.4	238.4	133.9	133.9
Missouri	70.5	70.5	289.7	289.7	236.6	236.6
Ohio	51.3	51.3	518.2	518.2	46.2	46.2
Tennessee	36.2	36.2	407.6	407.6	192.9	192.9

Table 3-29. 2002 Base 4 Typical Inventory – Comparison of Raw Annual and Gridded (36 km) Annual Offroad Mobile Source Emissions

State	Raw NOx (tpy)	Gridded NOx (tpy)	Raw VOC (tpy)	Gridded VOC (tpy)	Raw CO (tpy)	Gridded CO (tpy)
Arkansas	62,471	62,471	49,246	49,243	272,629	272,609
Illinois	209,545	209,545	93,887	93,887	982,653	982,653
Indiana	106,146	106,146	54,342	54,342	544,783	544,783
Kentucky	101,195	101,192	34,090	34,090	289,889	289,869
Missouri	95,049	95,046	58,390	58,387	510,585	510,545
Ohio	152,456	152,456	95,474	95,474	998,938	998,938
Tennessee	95,911	95,903	48,998	48,996	451,403	451,373

Table 3-30. 2002 Base 4 Typical Inventory – Comparison of Temporalized (June Weekday) and Temporalized (June Weekday) and Gridded (36 km) Offroad Mobile Source Emissions

State	Temporalized NOx (tpd)	Temporalized & Gridded NOx (tpd)	Temporalized VOC (tpd)	Temporalized & Gridded VOC (tpd)	Temporalized CO (tpd)	Temporalized & Gridded CO (tpd)
Arkansas	196.9	196.9	152.3	152.3	916.8	916.7
Illinois	589.5	589.5	261.7	261.7	2,773.8	2,773.8
Indiana	299.0	299.0	151.1	151.1	1,530.5	1,530.5
Kentucky	303.2	303.2	112.9	112.9	1,043.6	1,043.5
Missouri	314.0	314.0	191.9	191.9	1,832.7	1,832.5
Ohio	425.5	425.5	264.7	264.7	2,798.9	2,798.9
Tennessee	296.7	296.7	161.4	161.4	1,607.7	1,607.6

Table 3-31. 2002 Base 4 Typical Inventory – Comparison of Raw Annual and Gridded (36 km) Annual VMT Inputs for Onroad Mobile Sources

State	Raw Annual VMT	Gridded Annual VMT
Arkansas	29,179,000,000	29,179,000,000
Illinois	106,969,195,000	106,969,195,000
Indiana	72,866,000,000	72,865,000,000
Kentucky	51,020,000,000	51,020,000,000
Missouri	64,329,440,000	64,328,805,000
Ohio	108,450,000,000	108,450,000,000
Tennessee	68,316,000,000	68,316,000,000

Table 3-32. Comparison of Temporalized (June Weekday) and Temporalized (June Weekday) and Gridded (36 km) Onroad Mobile Source Emissions

State	Temporalized NOx (tpd)	Temporalized & Gridded NOx (tpd)	Temporalized VOC (tpd)	Temporalized & Gridded VOC (tpd)	Temporalized CO (tpd)	Temporalized & Gridded CO (tpd)
Arkansas	488.9	488.9	120.2	120.2	1,682.7	1,682.7
Illinois	782.0	782.0	454.4	454.4	4,735.7	4,735.7
Indiana	585.1	585.1	409.6	409.6	4,090.8	4,090.8
Kentucky	425.8	425.8	255.8	255.8	2,627.3	2,627.3
Missouri	628.1	628.1	323.1	323.1	4,387.6	4,387.5
Ohio	865.0	865.0	573.0	573.0	5,871.3	5,871.1
Tennessee	572.1	572.1	431.7	431.7	4,207.5	4,207.5

Once the model-ready emissions files were generated for each major source category, the PAVE visualization program was used to animate the low-level emissions in order to view the spatial and temporal patterns of the emissions and identify any anomalies. Although such PAVE animations cannot be included in this report, Figures C-1 through C-6 and C-7 through C-12 in Appendix C provide example static spatial maps of NOx and VOC emissions, respectively, for a typical weekday, Saturday and Sunday in the June episode at different times throughout each day. These plots give an indication of the spatial and temporal distribution of emissions in the Base 4 model validation inventory and are also an illustration of the types of graphics used in the QA/QC process.

4.0 MODEL PERFORMANCE EVALUATION

In this section we present a comparison of the St. Louis 2002 base case modeling against monitored ozone concentrations in order to evaluate the fitness of the air quality modeling database for use in the modeled attainment test. A summary of findings from the model performance evaluation is provided at the end of this section.

4.1 MODEL PERFORMANCE EVALUATION APPROACH

EPA has published draft final 8-hour ozone modeling guidelines (EPA, 2006) that are used as a basis, in part, for judging the adequacy of the St. Louis base case simulation. The EPA 8-hour ozone performance evaluation procedures represent an update and refinement of those in previous modeling guidance documents (EPA, 1991; 1999; 2005). EPA recommends two types of evaluation of model performance. The first type is called an operational evaluation and focuses on how well the model is able to reproduce observed ozone concentrations near the surface and aloft. The second type of evaluation is the diagnostic evaluation and attempts to characterize the model's sensitivity to changes in emissions. The operational evaluation will be presented in this section, and the diagnostic evaluation appears as part of the Weight of Evidence Determination, and is discussed in Section 6.

There are two main components in EPA's draft 8-hour ozone guidance operational ozone model performance: (1) Overview of Model Performance Using Computer Graphics; and (2) Ozone Metrics.

Overview of Model Performance Using Computer Graphics

EPA's 2006 draft 8-hour ozone guidance lists four types of graphic displays that are used to obtain an overview of model performance:

- Tile plots of observations and predictions: These are presented for both daily 1-hour and 8-hour maxima. Tile plots are used to understand the spatial differences and displacements of the predicted and observed ozone concentrations and to complement the ozone performance metrics. For example, a modeled ozone plume that is displaced slightly from the location indicated by the ozone monitoring network may produce very poor ozone metrics but may still be a reliable tool for control strategy evaluation. If the correct sources and processes are being simulated and produce accurate peak ozone that is merely displaced from its true location, the modeled plume should respond appropriately to control measures. Tile plots can be used to assess model performance upwind and downwind of urban areas, and are helpful in interpreting performance issues arising from transport as well as local photochemical production of ozone.

- Scatter plots and quantile-quantile (Q-Q) plots: Scatter plots of predicted and observed ozone within the non-attainment area provide a measure of how well the model replicates the observed ozone concentrations at or in the vicinity of the monitor. Scatter plots are generated using hourly modeled and observed ozone, as well as modeled and observed 1-hour and 8-hour daily maximum ozone. Scatter and Q-Q plots provide a measure of how well the model reproduces the frequency distribution of the observed ozone concentrations.

- Time series plots: Time series plots of predicted and observed hourly ozone concentrations for each monitoring site in the non-attainment area, as well as key sites outside the non-attainment area. The time series provide a stringent test of how well the model replicates the observed hourly ozone at the same time and location as the observed value. Problems with timing and amplitude of modeled ozone peaks are readily apparent in a time series plot.

- Animations: Animations of 1-hour ozone were generated for all modeling episodes of the purpose of model performance evaluation and diagnosis. These animations are important tools for investigation of the timing and location of ozone maxima as well as transport patterns and were used to examine the St. Louis ozone modeling outputs, but cannot be presented as part of this document.

Ozone Metrics

EPA's 2006 draft 8-hour ozone guidance identifies several ozone metrics to be applied to the modeled hourly ozone and 8-hourly maximum ozone. The metrics suggested by EPA and applied in this study are the unpaired peak accuracy (UPPA), paired peak accuracy (PPA), mean normalized bias (MNB), and mean normalized gross error (MNE). The UPPA describes how well the model predicts the peak observed value at the same time as the peak observed value, but not necessarily at the same location. A more rigorous test is the PPA, which measures how well the model predicts the peak at the same time and place as the observed peak. The MNB indicates whether the ozone is under- or over-predicted on average, as compared with observations. Note

that this does not determine whether or not the model correctly predicts the ozone spatial distribution correctly. Finally, the MNGE measures the absolute value of the difference between observed and predicted ozone, normalized by the observed value.

These statistical measures were calculated for all monitor times and locations in the St. Louis Non-Attainment Area, and are presented as a daily average over all monitors. The ozone threshold for comparison with observations for these statistics is 60 ppb (EPA, 2006).

4.2 MODEL PERFORMANCE METRICS AND GOALS

The current EPA guidance on evaluating models is that "there is no single definitive test for evaluating model performance. Further, even within a single performance test, it is not appropriate to assign 'bright line' criteria that distinguish between adequate and inadequate performance. In this regard, EPA recommends that a 'weight of evidence' approach be used to determine whether a particular modeling application is valid for assessing the future attainment status of an area. EPA recommends that States/Tribes undertake a variety of performance tests and weight them qualitatively to assess model performance. From an operational standpoint, EPA recommends that States/Tribes compare their evaluation results against similar modeling exercises to ensure that the model performance approximates the quality of other applications" (EPA 2006).

In the spirit of this guidance, we compare the results of the performance evaluation discussed below with recent similar studies as part of the Weight of Evidence Determination presented in Section 6. We carry out our evaluation of the model's 1-hour and 8-hour ozone performance according to the EPA 1-hour and 8-hour Guidance Documents (EPA 1991 and EPA 1999, respectively). We will compare the ozone metrics described above with the performance benchmarks described in these two documents (see Table 4-1). We treat these benchmarks not as a bright line test, but as a general indication of performance comparable to previous applications used to compile the benchmarks.

Table 4-1. EPA Performance Benchmarks (EPA, 1991)

Ozone Metric	EPA Performance Benchmark
Unpaired Peak Accuracy (UPPA)	±20%
Mean Normalized Bias (MNB)	±15%
Mean Normalized Error (MNGE)	35%

We present daily averaged 1-hour and 8-hour ozone metrics for each episode day in bar chart form. The EPA performance benchmarks are shown on these bar charts for reference. EPA benchmarks of ±20% are also shown on the scatter plots.

4.3 OZONE MODEL PERFORMANCE STATISTICS

In this section, we discuss the performance of the CAMx photochemical grid model over the St. Louis Non-Attainment area during the three summer 2002 ozone episodes. The model was run on a 36/12/4 km grid, and results from the 4-km grid are shown here. For this base year model run, the 2002 Base 4 model validation emissions were used. For each episode, we present bar charts showing ozone metrics, scatter plots, and spatial plots of surface layer ozone. The 1-hour performance metric bar charts are shown in Figure 4-1, and the 8-hour performance metric bar charts are in Figure 4-2. Note that all three episodes are shown on these bar charts with a large

divider separating the episodes. Data for paired peak accuracy, normalized bias, and normalized error are not shown for days where all observed daily maximum ozone concentrations fell below the EPA 60 ppb threshold (1-hour or 8-hour averages). When the value of the UPPA, PPA, and MNB performance statistics exceeded ±30%, their value was truncated to 30% for ease of display, and they protrude slightly above the upper- or lower-most gray bar of the graph. One-hour performance scatter plots may be found in Appendix D. It should be noted that the performance statistics have been updated to reflect the Central Daylight Time instead of the Greenwich Mean Time used in the air quality modeling exercise. This slight change allows for a day-to-day comparison of the monitored concentrations versus modeled predictions without any artificial error induced by the five hour time difference between CDT and GMT.

4.3.1 Performance Evaluation for Episode 1: June 10-24, 2002

4.3.1.1 Episode 1 Ozone Performance Metrics

The 1-hour model performance statistics for Episode 1 are shown in Figure 4-1 and for the last 7 days of the June 2002 episode in Table 4-2.

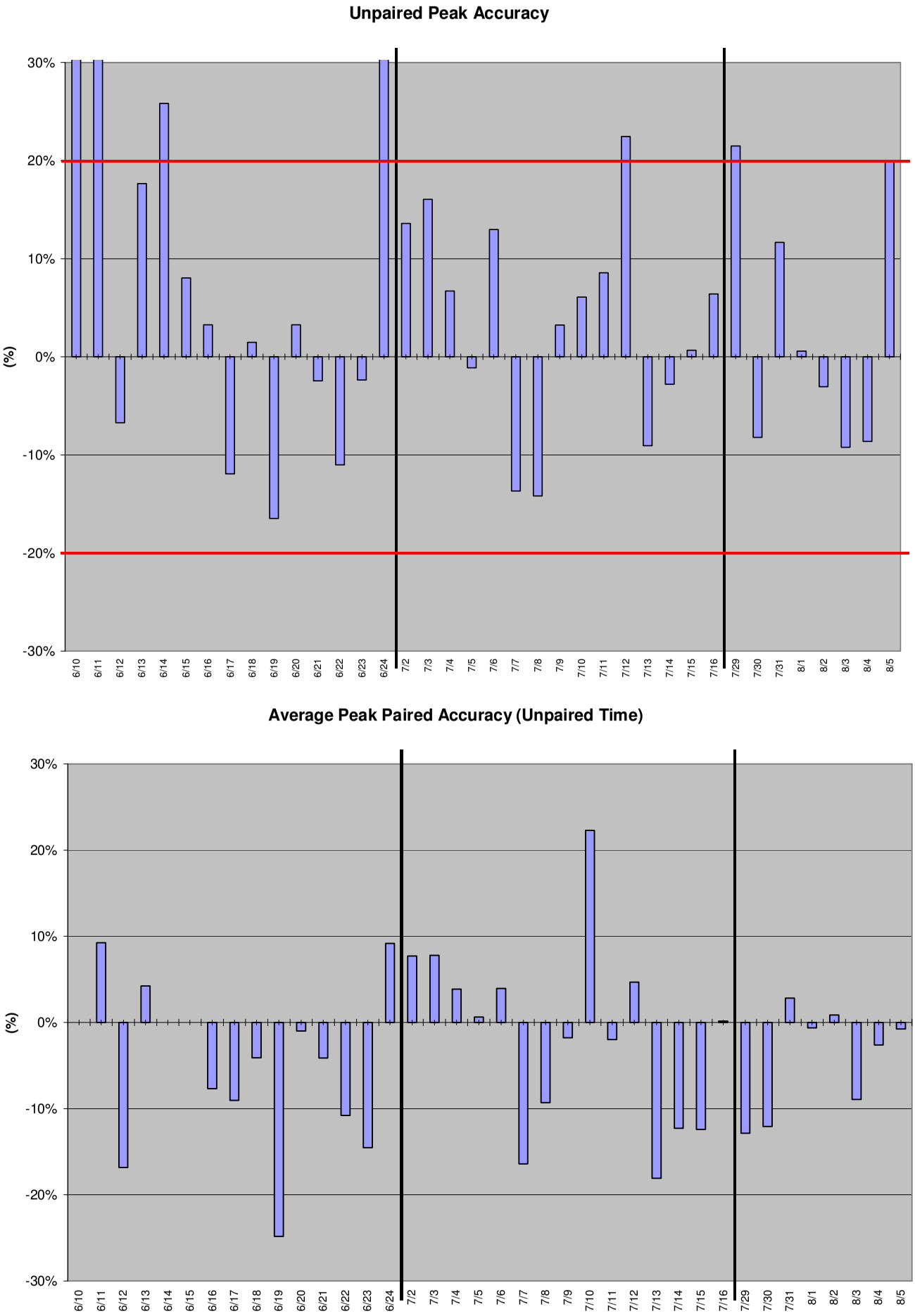
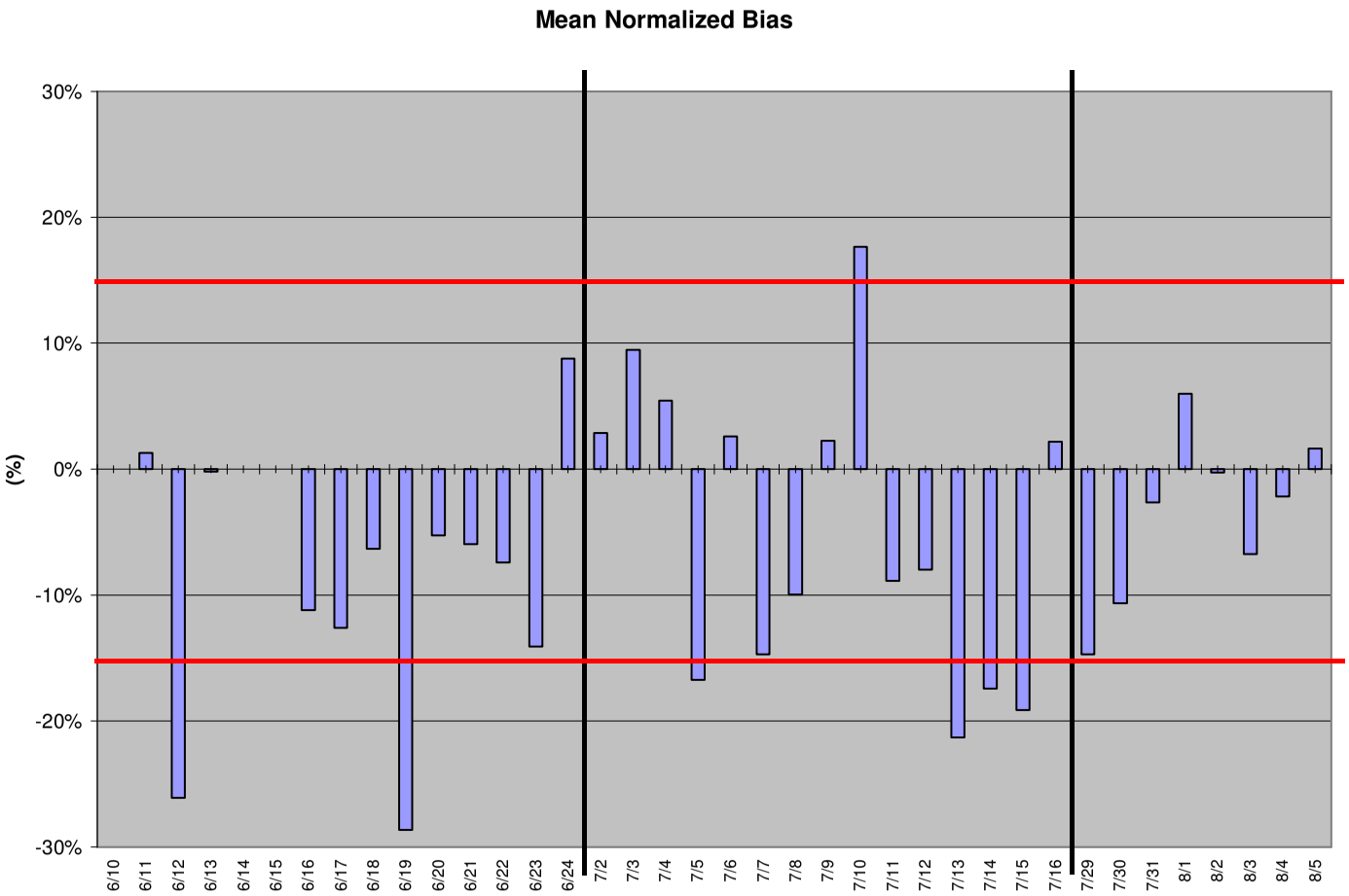


Figure 4-1A. 1-hour ozone model performance statistics for the three St. Louis episodes. 2002 Baseline Emissions scenario.



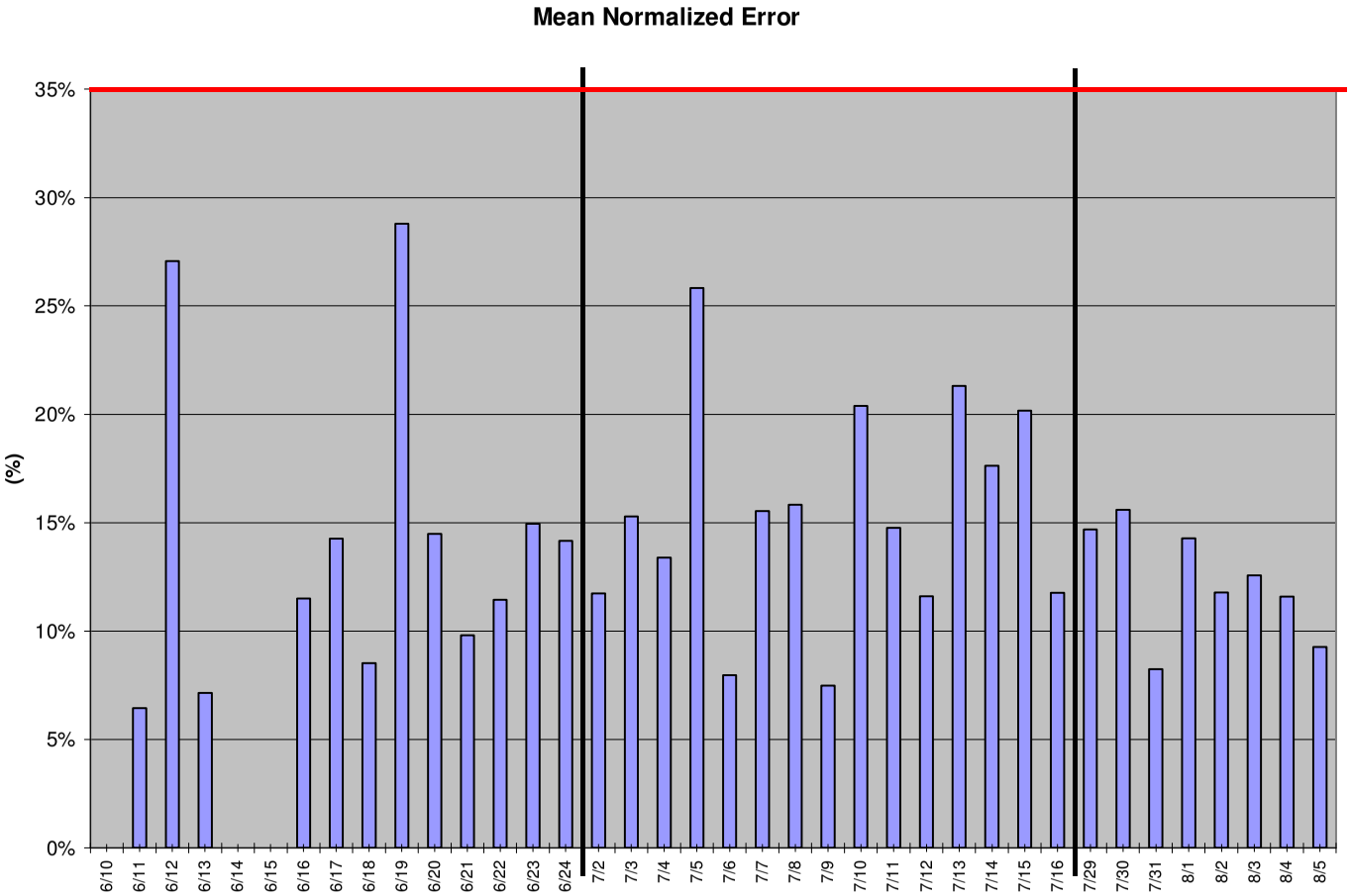


Figure 4-1B. 1-hour ozone model performance statistics for the three St. Louis episodes. 2002 Baseline Emissions scenario.

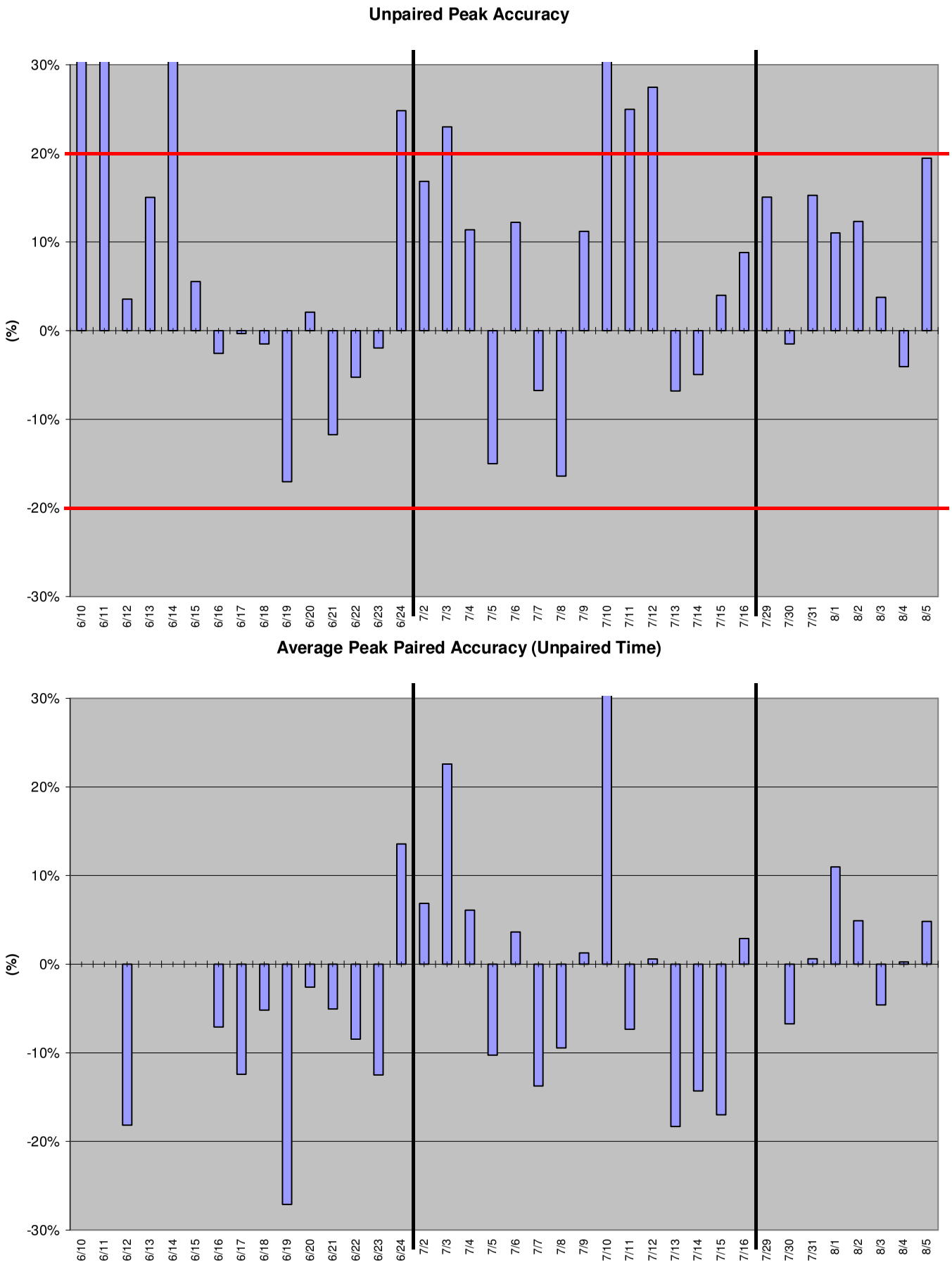
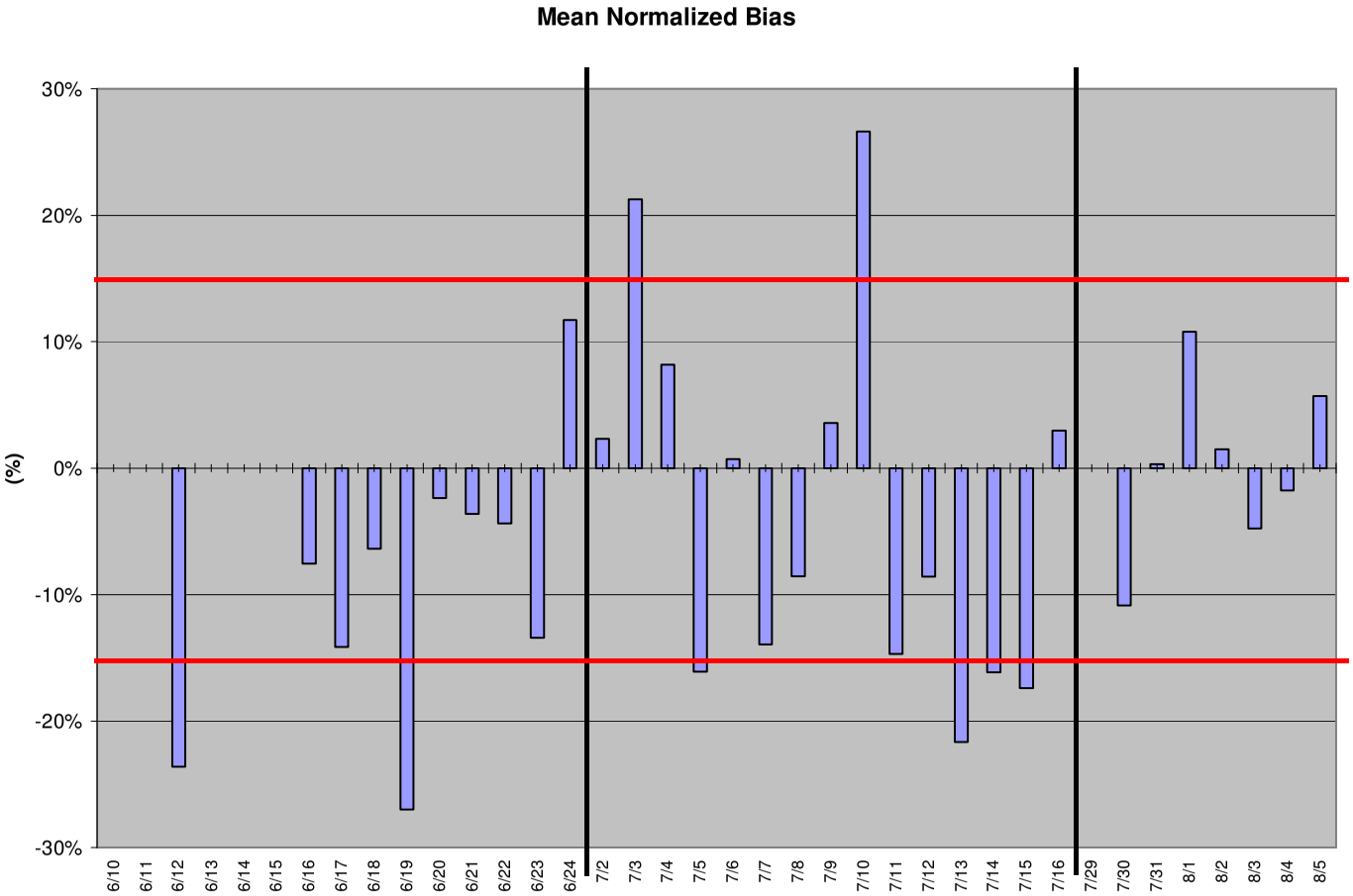


Figure 4-2A. 8-hour ozone model performance statistics for the three St. Louis episodes. 2002 Baseline Emissions scenario. 2002 Baseline Emissions scenario.



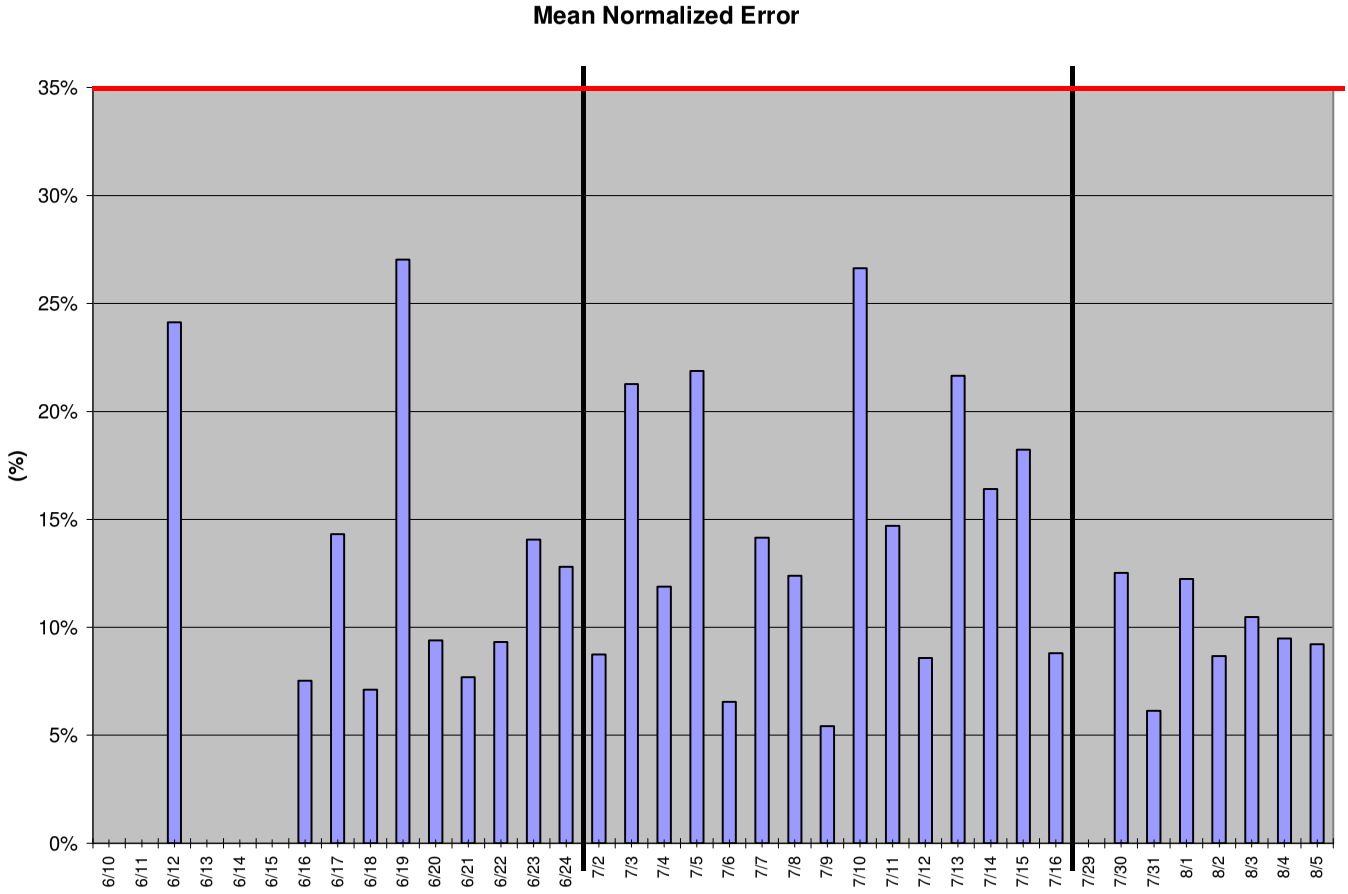


Figure 4-2B. 8-hour ozone model performance statistics for the three St. Louis episodes. 2002 Baseline Emissions scenario.

Table 4-2. Performance Metrics for Episode 1 (1-hour average).

Metric	June 12	June 17	June 18	June 19	June 20	June 21	June 22	June 23	June 24
UPPA	-6.72%	-11.93%	1.48%	-16.48%	3.27%	-2.46%	-11.03%	-2.38%	**30.45%**
APPA	-16.84%	-9.04%	-4.09%	-24.81%	-0.99%	-4.13%	-10.77%	-14.52%	9.17%
MNB	**-26.09%**	-12.59%	-6.32%	**-28.66%**	-5.27%	-5.96%	-7.41%	-14.07%	8.78%
MNE	27.07%	14.27%	8.53%	28.79%	14.49%	9.81%	11.45%	14.96%	14.17%

The first episode was characterized by relatively low ozone during the first 8 days of the episode. During the period June 10-17, there were three days that did not have any 1-hour concentrations above the 60 ppb threshold (June 10, 14, and 15). In addition, there were three other days with less than 15 valid comparison pairs (June 11, 13, and 16). The highest observed ozone came during June 20-23. The UPPA lies within the EPA benchmark on 8 of the 9 episode days when statistics were calculated, and outside the benchmark on 1 of the days. There is no clear positive or negative bias in the UPPA. The average peak paired accuracy (APPA), a more rigorous test than the UPPA, shows evidence that CAMx is, at least, slightly underpredicting the monitored peak ozone concentrations. The APPA is negative on all but one episode day (June 24). Further evidence of a systematic underprediction is seen in the normalized bias. The MNB is also negative for all episode days except June 24, and is outside the benchmark on 2 of 9 days. During the high ozone period, June 20-24, model performance is within the EPA benchmarks for nearly all ozone metrics. This is critical because these days are used in the attainment demonstration for several monitors. The normalized error is within the benchmark for all episode days.

4.3.1.2 Episode 1 Scatter Plots

We present the 1-hour and 8-hour ozone scatter plots of observed and predicted ozone pairs in Appendix D. In this section, we focus on the 8-hour scatter plots because the 8-hour ozone performance is more directly related to the attainment demonstration. The scatter plot illustrates the correlation between observed and modeled ozone over the three summer 2002 episodes for all monitors. Each point on the plot corresponds to an observed and measured value pair at a specific monitor and time. The dashed lines indicate the EPA performance benchmark. Scatter plot data are also presented on the same figure in quantile-quantile (Q-Q) form. In these figures, good performance would be characterized by: (1) most of the scatter plot points lying close to the 1:1 line and preferably within the ±20% lines and (2) a Q-Q distribution very close to the 1:1 line.

EPA's (1999) guidance contains 8-hour ozone model performance goals to predict the observed daily maximum 8-hour ozone concentrations *near the ozone monitor* to within ±20% (EPA, 1999). Near the monitor is defined as the array of grid cells centered on the grid cell containing the monitor as used in EPA's 8-hour ozone attainment test (e.g., 7 by 7 array of cells for a 4 km grid). We have defined three approaches for selecting the predicted 8-hour ozone concentration "near the monitor" for the scatter plot performance test:

> Spatially Paired estimated daily maximum 8-hour ozone at the monitor is compared with the observed value. This is the most stringent definition of "near the monitor" and the ±20% performance goal likely does not apply. But it is a useful and particularly stringent performance metric.

Maximum predicted 8-hour ozone concentrations near the monitor (i.e., in the array of cells). This definition is the same as used in EPA's attainment test. However, care must be taken when interpreting the ±20% performance goal; if the modeled 8-hour ozone has an overprediction bias greater than +20% then this may not indicate a poorly performing model. There may be ozone concentration gradients that result in higher ozone away from the monitoring network so a perfect model may not achieve the performance goal of <20% difference from the observed value.

Closest predicted 8-hour ozone where the estimated daily maximum 8-hour ozone near the monitors is selected that matches the observed value the best. This performance metric is directly comparable to the ±20% performance goal.

Figures D-51 through D-53 are the scatter plots for observed and predicted 8-hour daily maximum ozone defined in the three ways discussed above. While the scatter plots differ in their details, they show a consistent picture of CAMx performance during Episode 1. When the observed daily maximum 8-hour ozone is greater than 80 ppb, the model tends to underpredict rather than overpredict ozone. At observed values greater than 85 ppb, only one data point indicates an ozone overprediction. The rest of the observed/modeled pairs fall below the 1:1 line (Figures D-116 and D-118). At observed values lower than about 60 ppb, the model tends to overestimate the daily maximum ozone. The majority of the points fall within the ±20% lines, however, indicating reasonable performance. Note that performance improves as the observed values rise above about 95 ppb, and lie almost entirely within the benchmark. The overall picture that emerges from the scatter plots is that model performance improves with increasing ozone concentration, and that CAMx tends to underestimate the variability in the observed ozone concentrations. The modeled peaks are underestimated and the minima are overestimated.

4.3.1.3 Episode 1 Spatial Plots and Conceptual Model Comparison (June 19-23)

Sections 1 and 2 of Appendix D display spatial plots of predicted daily maximum 1-hour and 8-hour ozone concentrations in the St. Louis area and vicinity with superimposed observations for Episodes 1-3. For brevity and relevance to the attainment demonstration we will focus on the spatial plots of 8-hour ozone. Figure 2-3 displays a map of the ozone monitors in the St. Louis ozone NAA. Note that in the spatial ozone maps, as well as the model performance statistics discussed above, we include several ozone monitors located outside of the St. Louis ozone NAA. These monitors are sometimes impacted by the St. Louis urban plume, and allow us to estimate the regional background ozone outside the St. Louis plume. Below, we discuss the spatial ozone maps of daily maximum 8-hour ozone for each day of the episode, with an emphasis on model performance within the St. Louis NAA.

June 10-11, 2002 (Julian days 2002161-2002162):

These are clean days for the St. Louis area, and constitute the ramp-up to the high ozone period of Episode 1. All observed daily maximum 8-hour ozone values are below 60 ppb.

June 12, 2002 (2002163): The highest observed 8-hour ozone concentrations on June 12th occur east of St. Louis at the Edwardsville (78 ppb) and Maryville (80 ppb) ozone monitors in Madison County, Illinois, with the remainder of the St. Louis ozone monitoring network measuring 8-hour ozone concentrations < 70 ppb. The maximum 1-hour ozone concentrations were measured at Maryville (99 ppb) along with Ferguson and Edwardsville (87 ppb). The model predicts that the

St. Louis urban ozone plume is also advected east and reproduces the 80 ppb region-wide observed 8-hour ozone maximum at Maryville reasonably well. However, the model estimates that ozone continues to increase east of Maryville with a maximum 8-hour ozone concentration of 82.6 ppb occurring in the southeast corner of Madison County. This location corresponds to the 1-hour peak predicted concentration. The model illustrates a tendency to overestimate plume travel during this episode. Since the Maryville monitor is the easternmost of the St. Louis ozone monitors, the model prediction of ozone plume travel further east of Maryville can not be evaluated.

June 13, 2002 (2002164): Both the observations and modeled 8-hour ozone concentrations characterize June 13, 2002 as one of the cleanest ozone days of the three St. Louis ozone episodes. The observed daily maximum 8-hour ozone concentrations in the St. Louis NAA range from 46 to 55 ppb, and the modeled values are also in the 50-63 ppb range, indicating good agreement.

June 14, 2002 (2002165): The observed daily maximum ozone concentrations on June 14th indicate that it the cleanest day modeled with monitored values in the St. Louis NAA ranging from 34 to 44 ppb and modeled values in the 35-45 ppb range. Again, the observations and modeled ozone agree well on this clean day.

June 15, 2002 (2002166): In the St. Louis NAA, the modeled (45-55 ppb) and observed (45-55 ppb) daily maximum 8-hour ozone concentrations at the monitoring locations on June 15th are still low. However, the model suggests a slightly higher ozone concentrations occurring southeast of St. Louis with an 8-hour ozone maximum of 59 ppb. The maximum is located outside the network, and cannot be verified by the observations. Performance is still quite good for 1-hour and 8-hour ozone on June 15th.

June 16, 2002 (2002167): Ozone continues to be low in the St. Louis NAA on June 16th. The observed daily maximum ozone suggests a small ozone gradient from north (~50 ppb) to south (62 ppb monitored and 58 ppb predicted at Bonne Terre) in the observations that are also reflected in the modeled ozone field.

June 17, 2004 (2002168): Both the observed (69 ppb peak) and modeled (69 ppb peak) daily maximum ozone concentrations increased relative to the previous day on June 17th, with the observed and modeled 8-hour ozone peaks almost exactly co-located. Overall, the maximum 1-hour and 8-hour maxima are slightly underpredicted throughout the area. The overnight hours exhibit a large extent of very low ozone concentrations (0 or near 0) in the downtown area and suburban areas both in the modeling exercise and in the monitored data. The monitored values start increasing 1-2 hours before the modeled predictions contributing to the slight overall underprediction.

June 18, 2002 (2002169): Overall maximum 8-hour ozone concentrations increase again and the overall modeled 8-hour maximum was 80 ppb north of the metropolitan area while the monitored value was 79 ppb at Jerseyville. There was a slight systematic underprediction of the 1-hour and 8-hour maximum concentrations throughout the monitoring network with a single large overprediction at the South Broadway monitor (8-hour maximum - 36 ppb monitored vs. 61 ppb modeled).

June 19, 2002 (2002170): There is a significant increase in the observed daily maximum 8-hour ozone concentrations on June 19th with the 8-hour ozone NAAQS exceeded at Jerseyville (91 ppb), Orchard Farm (87 ppb), West Alton (90 ppb), and Alton (88 ppb) ozone monitors. This represents all the distant suburban monitors north of the St. Louis area. The maximum ozone 8-hour ozone prediction from the St. Louis area was in the low 70 ppb range well north of St. Louis. However, the model continues to estimate low ozone in St. Louis on this day as seen in previous days. The model appears to have a westerly bias for the plume and exhibits a large suppression signature in the urban and downwind suburban centers well into the late morning hours that carries over into the afternoon and evening hours. The ozone suppression within St. Louis itself reduces the modeled 8-hour ozone to the 50-65 ppb level when 70-85 ppb is observed. As is apparent from the ozone performance metrics, the model is a day late in predicting the rise in ozone during the June episode resulting in large under-predictions on day 170, but the model "catches up" to the high observed values on day 171.

The conceptual model for this day reflects light and variable surface winds around St. Louis along with a surface high over the Ohio River Valley/Great Lakes. As discussed above, the model has too much ozone suppression in the morning hours and does not produce ozone in the near suburban area north of the downtown. The higher predicted values occur downwind (north and northwest of the metropolitan area) outside the monitoring network. The model also missed the local scale Houston, IL exceedance. This day is not a good performing day in the analyses.

June 20, 2002 (2002171): The modeled St. Louis urban ozone plume is clearly evident on June 20th with modeled 8-hour ozone concentrations exceeding 80 ppb occurring to the north-northwest of downtown. The highest observed 100 ppb 8-hour ozone concentration at the Jerseyville monitor is slightly underestimated by the model (95ppb), and the 92 ppb observed peak at Orchard Farm is overestimated (99 ppb). The overall maximum 8-hour predicted concentration was 102 ppb just east of the Jerseyville monitor. The maximum 1-hour concentration was predicted very accurately (both observed and monitored values were 119 ppb). Although the observations and the model prediction agree on the existence of an ozone plume extending northwest of the city, the orientation of the modeled ozone plume may be slightly displaced to the west relative to the observed plume. The MM5 model wind direction predictions on this day indicated a small easterly bias that corresponds to the orientation issue seen here. Generally, this day represents the best model prediction of peak ozone concentrations during this episode. The overall performance at all sites is quite good with a slight ozone overprediction in the southern portion of the network. The model successfully simulates the regional ozone background.

The conceptual model identifies south and southeasterly wind directions with calm winds in the morning hours. The photochemical model illustrates the directional transport appropriately and predicts the highest ozone values slightly too late in the afternoon along with the directional problem noted above. The model does appear to simulate the magnitude of the ozone plume effectively and provides good overall ozone performance on this day.

June 21, 2002 (2002172): The model reproduces the observed north-south orientation of the St. Louis urban plume on June 21st, but underestimates the magnitude of the observed ozone. As on June 20, a bias in the wind direction supplied by MM5 displaced the plume too far to the west. Note that agreement between the observed and modeled plumes would improve if the modeled plume were translated slightly to the east. The modeled peak 8-hour ozone concentration is 97 ppb and occurs near the Orchard Farm monitor where 97 ppb was observed. However, the high

observed ozone at the Jerseyville (110 ppb) and West Alton (101 ppb) monitors are underestimated (95 and 87 ppb). The overall prediction on this day is the best with respect to bias and error for the June episode and reflects a slight overprediction in the downtown area to offset the slight underprediction at the northerly monitoring stations.

Again, the conceptual model indicates calm winds in the morning with a slow southerly push as the day progresses. The high monitored concentrations begin at the right time in the model (11:00 AM). The modeled plume is somewhat removed (too far downwind) from the actual plume likely due to NOx suppression and/or excessive wind speed predictions. However, the model appears to simulate the highest ozone concentrations with accuracy especially given the plume shift generated by the wind bias from MM5.

June 22, 2002 (2002173): The modeled 8-hour ozone peak of 106 ppb occurs just downwind of the observed 8-hour ozone peak of 112 ppb at Orchard Farm. The observed 8-hour ozone concentrations exceeded 100 ppb at six monitors on this day, and the model predicted values in the range 89 ppb to 94 ppb for all of these monitors. Regional background ozone appears to be underestimated slightly, as well. In general, the model consistently underpredicts ozone formation just slightly on June 22, but is geographically accurate (the model is high where the monitored values are high and lower where the monitored values are lower).

This day was noted as a high regional event in the conceptual model with transport from southern Illinois and Kentucky. The model does an excellent job of identifying the pollutant transport from the areas noted and does predict higher concentrations regionally (upwind) on this day. This day monitored substantially higher concentrations than the previous days and the model predicts that same trend. The photochemical model does an outstanding job directionally and with respect to overall maximum predicted concentrations along with identifying the pollutant transport phenomenon into St. Louis.

June 23, 2002 (2002174): Both observations and model predictions show an ozone plume extending northwest from St. Louis. The highest observed daily maximum 8-hour ozone concentration of 101 ppb at Orchard Farm is underestimated by the model (88 ppb). However just east of Orchard Farm is the modeled region-wide maximum 8-hour ozone value of 99 ppb. In the southern portion of the monitoring network, the 1-hour ozone prediction is substantially low and is likely due to the model's inability to reproduce the higher regional background ozone on this day.

As stated previously, the model does not handle the continued high regional ozone as well on this day with respect to the previous day. High monitored values at the southern sites in the network and a separate 1-hour peak at the northern sites are not simulated in the photochemical analyses (potentially due to regional underprediction and the overstatement of ozone suppression in the urban center). Nonetheless, the model does an adequate job directional and predicts the 1-hour and 8-hour peak concentration magnitudes quite well.

June 24, 2002 (2002175): Both the observations and predictions indicate lower 8-hour ozone concentrations on June 24th than on the preceding days. The highest observed value is 81 ppb that occurs at the Jerseyville monitor. The model agrees reasonably with the monitored value at the Jerseyville monitor (78 ppb), but overestimates ozone (94 ppb) at the Orchard Farm monitor (observed 79 ppb). The model predicts a region of elevated ozone concentrations to the near west of the St. Louis NAA, but this feature cannot be resolved by the monitoring network outside

of the Orchard Farm overprediction. Nonetheless, the model overpredicts ozone concentrations. The photochemical model does not reflect the "wash-out" from rain showers in the St. Louis area during the afternoon on this day likely causing the model overprediction.

In general, the model does an adequate job of simulating areas with high monitored concentrations during this episode. However, the model predicts too much ozone suppression in the downtown and suburban areas (NOx concentrations too high) that results in the modeled plume traveling too far downwind before higher concentrations are predicted.

4.3.1.4 Precursor Model Performance Evaluation for Episode 1

The model performance evaluation for CO, NO, and NO2 is presented below in Tables 4-3A-4-3C. The metrics are very similar to the ozone metrics reported and include unpaired peak accuracy, paired peak accuracy, mean normalized bias, and mean normalized error. One issue with using these statistical measures is the choice of threshold to calculate the last three metrics. Since the concentrations for NO and NO2 are often zero (0) or near zero ppb, the choice for these pollutants was 0.1 ppb to ensure the evaluation was conducted for the entire range of concentrations. The bias and error statistics are calculated by dividing the difference in predicted vs. observed concentration by the observed concentration. When the observed value is very small any difference in predicted concentration vs. observed concentration will result in a very high positive bias result. Presented here are two different analyses, the first is a run that includes the OB70 kv methodology with no Kvpatch adjustment and the second is the final basecase run using the CMAQ kv scheme with the Kvpatch adjustment. Time series plots for all three pollutants at a subset of monitors are included in Appendix D.

Table 4-3A. NO Model Performance Evaluation for June 10-24, 2002.

Day	Max Obs	UPPA-OB	PPA-OB	MNB-OB	MNE-OB	UPPA-CMAQ	PPA-CMAQ	MNB-CMAQ	MNE-CMAQ
02160	62	-73.34%	4.69%	24.59%	99.41%	-71.85%	1.31%	-11.52%	82.34%
02161	42	-49.86%	43.43%	34.18%	106.37%	-40.74%	34.91%	-12.29%	73.65%
02162	64	-45.58%	3.69%	58.19%	130.00%	-16.75%	16.74%	28.55%	111.41%
02163	66	170.91%	82.07%	204.81%	264.30%	44.38%	-31.83%	29.92%	121.82%
02164	19	519.21%	132.43%	102.91%	170.63%	130.63%	27.42%	-21.49%	91.29%
02165	19	-33.89%	84.23%	-24.81%	62.94%	-21.63%	-36.40%	-65.40%	66.62%
02166	61	36.10%	56.41%	102.66%	177.59%	-20.08%	-8.51%	16.33%	105.60%
02167	143	72.02%	174.11%	449.16%	487.90%	9.12%	21.32%	42.11%	117.64%
02168	114	-9.14%	185.43%	155.79%	221.86%	-43.23%	118.48%	7.96%	102.37%
02169	35	129.63%	659.09%	304.17%	361.96%	155.54%	478.53%	222.22%	283.62%
02170	96	-77.38%	-34.02%	7.95%	86.36%	-82.17%	-48.27%	-41.50%	69.98%
02171	133	-47.23%	34.08%	16.45%	99.07%	-73.83%	2.53%	-30.93%	77.82%
02172	100	37.68%	0.77%	24.09%	95.96%	-52.88%	-65.36%	-62.59%	78.58%
02173	30	146.03%	219.18%	123.34%	201.88%	3.17%	11.08%	-5.28%	101.57%
02174	94	48.35%	158.58%	164.22%	208.99%	-43.26%	-1.28%	12.67%	89.54%

Table 4-3B. NO2 Model Performance Evaluation for June 10-24, 2002.

Day	Max Obs	UPPA-OB	PPA-OB	MNB-OB	MNE-OB	UPPA-CMAQ	PPA-CMAQ	MNB-CMAQ	MNE-CMAQ
02160	36	15.10%	8.23%	30.45%	46.59%	17.09%	4.88%	12.93%	41.75%
02161	38	17.45%	-11.06%	32.18%	54.15%	20.77%	-11.05%	9.44%	38.00%
02162	49	118.07%	57.77%	75.94%	89.30%	103.50%	49.30%	61.82%	79.48%
02163	49	35.52%	33.66%	101.87%	109.62%	32.53%	-1.74%	44.57%	63.32%
02164	32	126.53%	82.47%	42.71%	66.17%	106.94%	24.51%	8.09%	60.01%
02165	38	35.58%	62.23%	23.73%	43.45%	37.81%	37.07%	-5.01%	42.47%
02166	50	-65.26%	24.11%	36.44%	53.27%	-8.31%	4.26%	2.38%	39.13%
02167	124	-40.45%	12.14%	64.53%	78.01%	-50.88%	-3.87%	22.27%	45.40%
02168	48	22.24%	7.44%	34.97%	57.00%	15.99%	-1.16%	3.40%	41.71%
02169	61	5.04%	50.52%	90.55%	108.70%	1.62%	36.18%	58.89%	79.19%
02170	45	49.36%	5.85%	30.73%	55.03%	47.78%	-13.86%	0.70%	38.77%
02171	78	-3.77%	12.64%	45.97%	58.70%	-10.51%	-6.95%	-1.27%	31.98%
02172	76	17.16%	43.05%	40.09%	62.11%	7.41%	-13.00%	-4.79%	40.54%
02173	61	30.71%	31.01%	46.25%	66.95%	-38.71%	-19.01%	-1.12%	35.27%
02174	49	46.99%	63.61%	76.58%	86.94%	45.24%	24.40%	37.13%	52.14%

Table 4-3C. CO Model Performance Evaluation for June 10-24, 2002.

Day	Max Obs	UPPA-OB	PPA-OB	MNB-OB	MNE-OB	UPPA-CMAQ	PPA-CMAQ	MNB-CMAQ	MNE-CMAQ
02160	1000	-40.79%	-31.60%	-17.20%	63.31%	-35.00%	-41.26%	-29.60%	63.59%
02161	1000	-36.11%	-24.30%	0.44%	69.93%	-32.43%	-42.67%	-15.48%	66.09%
02162	1600	1.19%	-1.66%	46.83%	86.38%	7.41%	11.30%	32.36%	78.47%
02163	1500	15.55%	11.05%	26.83%	70.76%	3.80%	-11.63%	-10.29%	63.41%
02164	590	97.94%	87.33%	27.32%	52.70%	20.19%	22.60%	-7.33%	42.03%
02165	610	-21.67%	0.22%	27.64%	45.59%	-37.60%	1.30%	-0.20%	41.99%
02166	1160	8.82%	-43.78%	-7.66%	35.00%	-18.77%	-51.76%	-23.53%	38.07%
02167	1430	51.38%	18.51%	41.64%	71.06%	11.55%	-4.98%	1.66%	49.28%
02168	860	16.03%	17.96%	27.34%	62.14%	4.12%	6.83%	-0.35%	45.72%
02169	830	52.91%	82.57%	45.22%	78.65%	55.77%	67.07%	25.08%	64.11%
02170	980	-15.21%	4.68%	4.37%	50.80%	-16.46%	5.65%	-14.79%	51.99%
02171	2680	-64.86%	-25.90%	-5.51%	43.15%	-64.04%	-31.17%	-26.96%	47.00%
02172	3850	-62.47%	-30.90%	-8.57%	48.19%	-76.87%	-53.17%	-34.01%	52.96%
02173	1200	47.35%	3.01%	4.15%	47.96%	-11.61%	-42.63%	-23.40%	51.52%
02174	800	95.48%	20.68%	28.30%	53.71%	48.77%	-7.07%	-0.82%	36.62%

Overall, the performance is not exceptional for either of the two scenarios for any of the pollutants. However, the final basecase performs better (closer to observations) than the OB70 – no Kvpatch scenario. The OB70 scenario predicts higher concentrations especially for the NO and NO2 species lending weight to the discussion in the ozone performance section about overprediction of NO and NO2 in the model contributing to overall underprediction. The performance for ozone in the OB70 scenario was further underpredicted on virtually every day during this episode. Even with the Kvpatch adjustment and the use of the CMAQ kv scheme, the model still has a tendency to overpredict the NO and NO2 concentrations in the urban center on a number of days in the June episode.

4.3.2 Performance Evaluation for Episode 2: July 2-16, 2002

4.3.2.1 Episode 1 Ozone Performance Metrics

The 1-hour model performance statistics for Episode 2 are shown in Figure 4-1 and in Table 4-4. During Episode 2, measured ozone concentrations remained high throughout the episode; no days were omitted from the analysis because of observed ozone < 60 ppb as in Episode 1. There are three days (July 10 - 12) that had 10 or less valid pairs over 60 ppb. The UPPA exceeded the benchmark on 1 of 15 days for the 1-hour average and 4 of 15 days for the 8-hour average. During the first 8 days of Episode 2, there is no consistent pattern of ozone overprediction or underprediction. Generally, the model performs very favorably when compared to the model's tendency to underpredict ozone peaks in Episode 1. After elimination of the three lower ozone days, the first part of the episode showed no clear bias (APPA and MNB) toward positive or negative values using both the 1-hour and 8-hour statistics; this is a marked contrast to the underprediction seen in Episode 1. Three of the last four days of the episode, the APPA and the MNB are generally negative, indicating that the model underpredicted 1-hour and 8-hour ozone. Overall, 7 out of 15 days had a negative MNB for both 1-hour and 8-hour ozone in Episode 2, and the MNB exceeded the EPA benchmark on 6 of 15 days. The normalized error was within the benchmark for the entire episode for both 1-hour and 8-hour averages.

Table 4-4. Performance Metrics for Episode 2 (1-hour average).

Metric	July 2	July 3	July 4	July 5	July 6	July 7	July 8	July 9	July 10
UPPA	13.60%	16.05%	6.70%	-1.11%	12.98%	-13.67%	-14.20%	3.24%	6.10%
APPA	7.71%	7.78%	3.86%	0.61%	3.95%	-16.40%	-9.32%	-1.78%	22.28%
MNB	2.87%	9.46%	5.44%	**-16.74%**	2.61%	-14.70%	-9.95%	2.26%	**17.66%**
MNE	11.74%	15.29%	13.40%	25.82%	7.97%	15.53%	15.83%	7.48%	20.39%

Metric	July 11	July 12	July 13	July 14	July 15	July 16
UPPA	8.75%	**22.45%**	-9.07%	-2.80%	0.67%	6.41%
APPA	-1.98%	4.67%	-18.09%	-12.29%	-12.39%	0.15%
MNB	-8.87%	-7.98%	**-21.31%**	**-17.43%**	**-19.12%**	2.18%
MNE	14.77%	11.61%	21.31%	17.62%	20.17%	11.76%

4.3.2.2 Episode 2 Scatter Plots

The scatter plots for Episode 2 (Figures D-54 through D-56) show the same basic features seen in the Episode 1 scatter plots, with the model tending to overpredict when ozone is low and underpredict when ozone is high. The r^2 values are lower in Episode 2 than in Episode 1 for all three plots; this reflects the greater degree of scatter around the 1:1 line. In Episode 2, the problem with overestimation of low ozone values is more severe than in Episode 1. The Q-Q line lies further from the 1:1 line at observed concentrations < 60 ppb in Episode 2 than in Episode 1. At observed ozone concentrations greater than 85 ppb, the model's tendency to underestimate ozone is less pronounced in Episode 2; but the accuracy of the predictions is not increased, and this is reflected in the increased value of r^2.

4.3.2.3 Episode 2 Spatial Plots and Conceptual Model Comparison

July 2, 2002 (2002185): On July 2, the model does a good job of replicating the pattern of reduced ozone in the urban core, but predicts an ozone plume extending from the urban core north-northwestward that does not appear in the observations. The model predicts a maximum 8-hour ozone value of 104 ppb north-northwest of the St. Louis area. The observed 8-hour maximum is located to the southwest at Orchard Farm, with a value of 89 ppb. The model prediction for the Orchard Farm monitor was 96 ppb. The model is slightly overstating ozone formation and the ozone plume was misplaced to the west due to a predicted bias in the wind direction. Ozone concentrations in the downtown portion of the ozone network are slightly overestimated, and it is possible that regional background ozone entering from the east may be overstated, based on the easternmost and southernmost monitors overpredicting 8-hour concentrations by 6-10 ppb.

The surface high pressure center over southern Illinois in the conceptual model was predicted too far north by MM5 and resulted in the winds having a slight easterly bias on this day. Scattered cloud cover around the urban area likely contributed to the model's overprediction mentioned above. The model tracks a large NOx plume from south-central Illinois on this day that contributes to high ozone concentrations coming into the area noted above.

July 3, 2002 (2002185): The situation on July 3 is similar to July2, with the model simulating observed ozone well in the St. Louis urban core, and overstating the intensity of the ozone plume extending downwind of the city. The overprediction is systematic throughout the area and is worse in the downtown area for the 1-hour and 8-hour concentrations. Upwind ozone concentrations outside the St. Louis NAA were well-simulated.

The photochemical model performs exceptionally well with respect to the stagnation noted in the conceptual model. The extent of the plume is well contained within the suburban area and the location of the predicted maxima are directionally accurate (with the lowest concentrations predicted in the eastern portions of the monitoring network). This appears to be a solid representation of stagnation events around the St. Louis area by the photochemical model.

July 4, 2002 (2002185): The overall performance on this day is quite good with respect to overall peak performance and spatial prediction of the ozone plume. The model simulates higher concentrations in the urban center than on the previous day that corresponds to the actual monitored concentrations. The peak 8-hour observation occurs at the Ladue monitor (103 ppb) with the modeled prediction at (115 ppb) with the peak 1-hour observation and prediction (111 vs. 119 ppb) matching very closely as well. The 1-hour and 8-hour ozone predictions for all the downtown sites are well simulated. Nonetheless, the Queeny Park monitor has a large overprediction for maximum 8-hour ozone (83 ppb obs vs. 107 ppb pred).

The model predicts relatively well in the central portion of the network where monitored values are highest and predicts adequately the upwind concentrations monitored at the Bonne Terre monitor (to the south). In general, the model slightly overpredicts the ozone formation on this day, but simulates the stagnation event accurately to a large extent.

July 5, 2002 (2002186): There is a systematic underpredicton of 1-hour and 8-hour ozone concentration on July 5th. The spatial distribution of the underprediction illustrates reasonable

performance in the northern portion of the network that is far worse in the downtown and near suburban areas. The principal cause of the underestimation is a drastic decrease in predicted ozone concentrations in the afternoon hours while the observations remain elevated. The modeled peak of 93 ppb is lower than the two nearby observed peak 8-hour ozone concentrations (110 ppb at Sunset Hills and 99 ppb at Queeny Park) the initial plume development is generally simulated well by the model. Although the model does a good job of reproducing the spatial pattern of maximum observed ozone near St. Louis City and immediately downwind of it, the non-peak ozone concentrations are dramatically underpredicted due to the issue described above.

The conceptual model indicates flow from the north and northeast again on this day. The model does a good job of simulating the peak ozone concentrations and the push to the west and south over the course of the day. High concentration at the southern monitors are reflected very well in the photochemical analyses with respect to magnitude and location.

July 6, 2002 (2002187): Both the observed and modeled 8-hour ozone concentrations are lower on July 6th than on previous days with observed daily maximum values ranging from 73 to 84. The model estimates higher ozone (93 ppb) to the southwest of St. Louis, however there are no monitors that far to the southwest of St. Louis to confirm or deny its presence. Observed ozone to the southwest of downtown St. Louis are also elevated relative to those in the urban core, suggesting the modeled urban plume has the correct spatial alignment. The model predicts very accurately across the network and provides some of the best performance for any of the three episodes.

The conceptual on this day reflects a frontal passage from the north and the model predicts dramatically lower concentrations across the region on this day with some lingering high values in the western portion of the nonattainment area. The model simulates the lower values in the eastern portion of the domain transitioning to higher values in the western portion very well for both the 1-hour and 8-hour averaging times.

July 7, 2002 (2002188): The observed ozone on July 7th indicates winds out of the northeast with the highest daily maximum 8-hour ozone values occurring at Sunset Hills (93 ppb), Ladue (88 ppb), Queeny Park (85 ppb) and Margaretta (85 ppb). In general, the modeled St. Louis ozone plume is consistent with this pattern extending southwestward away from downtown. The model underpredicts slightly for all the sites and especially underpredicts the upwind sites to the north and many of the downtown sites. The maximum 8-hour prediction is 87 ppb slightly to the south and west of the monitoring network. Again, the model overstates the suppression of ozone near the city center. Maximum observed 8-hour concentrations for the upwind monitors are 71-77 ppb, while the model predictions are in the 60-70 ppb range.

The conceptual model for this day indicates a wind shift from early morning southerly with northeasterly in the late morning and early afternoon. MM5 does not represent the surface flow from the south very well, but does accurately represent the northeasterly push later in the day. Therefore, the direction of the plume in the photochemical model is accurate, but as stated happened too far downwind into southwestern St. Louis County and Franklin County causing underprediction at the Sunset Hills, Ladue, and Margaretta monitoring sites. The model does reflect some transport from the Ohio River Valley, but not to the extent seen in the monitored values.

July 8, 2002 (2002189): July 8th was the highest 8-hour ozone day of the three ozone episodes

with a peak observed value of 119 ppb measured at the Maryville monitoring site. The modeled 8-hour ozone peak on this day was 100 ppb, and occurred near the Wood River monitor. At the Maryville monitor, the model estimates a peak 8-hour ozone value of 90 ppb. The model underpredicts the maximum concentrations at every monitor. The other maximum measured 8-hour ozone values in excess of 100 ppb on this day are located in the downtown area or just northeast of the area. Again, ozone formation in the model appears to occur too slowly and is impacted by a substantial ozone suppression dynamic in the downtown area, resulting in an underestimation bias at monitors within and close to downtown St. Louis. In general, the model prediction is too slow to form elevated ozone concentrations.

The conceptual model for this day suggests light surface winds in the morning with a southerly push moving to southwesterly/westerly. The model provides a fairly accurate representation of the spatial orientation of the plume, but still seems to be overpredicting the ozone suppression in the urban center around the Margaretta and E. St. Louis monitors. This likely causes the model to be "late" when predicting high 1-hour concentration by an hour or two. Many of the sites have the appropriate magnitude for the 1-hour predicted maximum but occur too late and do not have enough hours of high concentration to average an 8-hour concentration close to the observed values.

July 9, 2002 (2002190): On July 9th, the modeled urban plume stretches far downwind to the northeast indicating stronger and more organized flow than on previous days. The only observed 8-hour ozone exceedance on this day is at the Maryville monitor where a 91 ppb value is measured. The modeled value at the Maryville monitor is 88 ppb, which matches the observed value well. The remaining maximum concentrations are predicted very closely and the model predicts the increase in concentrations from west to east across the network quite accurately.

The conceptual model highlights the westerly flow in the afternoon hours and the model represents that flow quite well with the plume advancing off to the east quickly. The model does not appear to reflect the time of the frontal passage flow the north appropriately or the location of the front itself. The model does predict the lower concentrations in the western portion of the network with respect to the higher concentrations in the eastern portion of the network.

July 10 2002 (2002191): July 10th is a clean out day in St. Louis with the maximum observed value at any monitor of 50 ppb in the St. Louis NAA and a regional maximum of 66 ppb. The model estimated most daily maximum ozone concentrations on this day to be in the 50 to 80 ppb range, with values exceeding 80 ppb due to the presence of an estimated elevated ozone cloud to the south-southwest of St. Louis. Although the ozone maximum of this estimated elevated ozone cloud lies further southwest than the St. Louis monitoring network, its presence is not reflected in the observations. As in Episode 1, the model delays the decrease in ozone concentrations relative to observations after a period of high ozone.

The model does accurately predict the high 1-hour predicted concentrations at the Bonne Terre monitor identified in the conceptual model (two hours late) on this day. The much lower values than the previous day also reflect the model's ability to distinguish between very high ozone days and days with much lower concentrations.

July 11, 2002 (2002192): July 11th is a clean ozone day in the St. Louis area as seen in both observations and model predictions.

July 12, 2002 (2002193): July 12th is also a low ozone day in St. Louis with observed and predicted 8-hour ozone concentrations less than 70 ppb.

July 13, 2002 (2002194): On July 13th ozone in St. Louis begins to rise with observed exceedances to the south-southwest of downtown at the Sunset Hills (90 ppb), Arnold (89 ppb), Ladue (86 ppb) and South Broadway (85 ppb) monitoring sites. The model also predicts an elevated ozone cloud to the southwest of St. Louis with an 8-hour ozone peak of 83 ppb, but it occurs too far downwind and does not simulate the elevated concentrations seen at the Queeny Park, Sunset Hills, and Arnold monitors. At the monitors, the model severely underestimates the observed 8-hour ozone peaks.

The conceptual model for this day reflects northeasterly winds with relatively high incoming ozone concentrations from the northeast. The meteorological prediction seems to cause a lag in high incoming concentrations, the model predicts very low ozone concentrations from the north on this day entering the St. Louis area. Overall, the model underpredicts this day for the entire area.

July 14, 2002 (2002195): Observed and modeled 8-hour ozone concentrations continue to rise on July 14th and both the model and observations agree that the highest ozone concentrations occur to the southwest of St. Louis. The modeled region-wide 8-hour ozone peak (93 ppb) agrees reasonably well (-5%) with the observed peak (98 ppb) at the Sunset Hills monitor, it occurs too far downwind (to the southwest) and at the Sunset Hills monitor the modeled 8-hour ozone value is 17 ppb lower (81 ppb). Although the model is characterized by an under-prediction tendency on this day, the spatial orientation of the urban ozone plume is quite good, albeit with an underestimation bias.

The conceptual model indicates light winds in the morning and again a northeasterly push in the late morning/early afternoon. Again, the magnitude and direction of the peak ozone predictions for this day are adequate. Upwind concentrations are underpredicted higher on this day and were likely a cause of the downwind maximum concentration underprediction. Nonetheless, the upward overall concentration gradient from the previous day is a indicator of acceptable model prediction.

July 15, 2002 (2002196): Observed exceedances of the 8-hour ozone standard are widespread across the St. Louis monitoring network on July 15th, suggesting stagnant conditions. The model predicts a region of high ozone lying southwest of the city, with maximum value 118 ppb, which is an overestimate of the observed maximum of 114 ppb. As seen in other days, the model overstates the magnitude and extent of the local suppression of ozone centered on the downtown St. Louis area, resulting in an underestimation bias of the observed 8-hour ozone concentrations at the six sites in excess of 100 ppb by 10-25%. The performance on this day is very similar to July 5th with good initial 1-hour peak representation, but a drastic decrease in model predictions at monitors in the urban center and slightly downwind in the next few hours while the monitors continue to observe elevated concentrations.

The conceptual model identified this as a stagnation event with a high pressure center very near the St. Louis area. The model predicts the stagnation event to a large extent, but still pushes the plume too far to the south and west with respect to the monitored concentrations. Ozone formation is still suppressed too much on this day in the downtown area, but the overall magnitude of the peak is accurate along with the overall stagnation pattern of the event.

July 16, 2002 (2002197): The maximum observed 8-hour ozone concentration on July 16th was 98 ppb and occurred at the West Alton monitor north of St. Louis. The modeled maximum 8-hour ozone value was 107 ppb and occurred west of West Alton near the Orchard Farm monitor; The model predicts extremely well in and around central St. Louis and ozone formation in the modeled ozone plume occurs close to observed timing. In the same vicinity as the observed peak, the modeled ozone formation catches up with the 98 ppb 8-hour peak observed at the West Alton monitor due north of St. Louis reproduced quite well (98 ppb, <1%).

The conceptual model for July 16th suggests this is a southerly push episode day with concentrations over the metropolitan area moving to the north suburbs and into the rural areas later in the day. The photochemical model predicts this movement to the north and northeast of the urban center and predicts the magnitude of the plume very well near the West Alton and Orchard Farm monitors. In addition, it simulates the upwind concentrations adequately to the south of St. Louis.

4.3.2.4 Precursor Model Performance Evaluation for Episode 2

The same metrics are presented for the July episode as were presented for the June episode regarding precursor performance in Tables 4-5A-4-5C. Unfortunately, the comparison between the two different scenarios carried out for the June episode is not available for the July episode. The OB70 scenario was run with an older set of meteorological data (Base 1 vs. Base 2) discussed previously. Therefore, the comparison is not valid since the underlying meteorological data was substantially different. Nonetheless, the final basecase performance statistics are presented here.

Table 4-5A. NO Model Performance Evaluation for July 2-16, 2002.

Day	Max Obs	UPPA-CMAQ	PPA-CMAQ	MNB-CMAQ	MNE-CMAQ
02183	117	12.68%	72.23%	-10.60%	79.98%
02184	50	119.30%	-11.31%	21.98%	107.93%
02185	51	21.80%	-50.92%	-29.79%	100.57%
02186	84	43.26%	-19.74%	209.63%	285.24%
02187	21	85.95%	150.73%	-16.50%	89.96%
02188	22	143.32%	57.20%	-1.48%	91.63%
02189	77	3.90%	65.84%	54.60%	141.74%
02190	25	55.80%	25.21%	24.13%	117.81%
02191	24	312.21%	185.21%	54.55%	145.35%
02192	12	229.67%	95.20%	29.97%	123.34%
02193	17	280.41%	205.35%	45.44%	122.35%
02194	11	82.64%	72.06%	-19.23%	88.40%
02195	10	124.00%	152.48%	18.58%	103.01%
02196	74	1.49%	0.14%	86.55%	154.08%
02197	80	21.61%	-0.50%	10.81%	109.39%

Table 4-5B. NO2 Model Performance Evaluation for July 2-16, 2002

Day	Max Obs	UPPA-CMAQ	PPA-CMAQ	MNB-CMAQ	MNE-CMAQ
02183	59	83.47%	26.94%	52.90%	78.91%
02184	57	63.56%	50.70%	27.84%	57.17%
02185	66	48.83%	16.66%	22.28%	50.29%
02186	59	72.22%	65.85%	84.67%	99.63%
02187	37	63.26%	29.37%	34.61%	63.42%
02188	63	1.74%	9.06%	1.17%	39.86%
02189	55	63.91%	-3.70%	26.09%	48.28%
02190	41	84.24%	-0.64%	18.44%	49.67%
02191	48	53.08%	36.39%	23.61%	47.05%
02192	37	44.68%	99.30%	44.91%	64.17%
02193	44	42.04%	53.15%	34.61%	59.65%
02194	38	72.41%	16.79%	-11.20%	35.51%
02195	41	51.06%	-0.23%	8.95%	40.32%
02196	57	116.52%	73.00%	61.03%	81.21%
02197	60	31.09%	10.66%	7.81%	38.97%

Table 4-5C. CO Model Performance Evaluation for July 2-16, 2002.

Day	Max Obs	UPPA-CMAQ	PPA-CMAQ	MNB-CMAQ	MNE-CMAQ
02183	1960	1.64%	-12.88%	-14.12%	43.92%
02184	900	79.67%	35.03%	6.39%	36.86%
02185	2100	-38.74%	-36.09%	-23.73%	29.65%
02186	2600	12.49%	38.03%	0.83%	56.89%
02187	800	117.70%	-30.52%	-2.25%	48.51%
02188	1000	-4.14%	-38.75%	-27.19%	44.33%
02189	900	72.30%	0.02%	28.89%	62.09%
02190	870	46.48%	51.93%	34.63%	81.86%
02191	1100	26.39%	18.08%	15.37%	55.75%
02192	790	33.74%	-5.49%	8.12%	54.12%
02193	830	33.75%	6.90%	-23.82%	33.02%
02194	800	-0.22%	-22.46%	-31.18%	36.88%
02195	1000	-5.31%	-33.10%	-29.52%	34.67%
02196	1000	136.00%	76.22%	8.08%	42.22%
02197	1090	93.56%	9.88%	-15.74%	24.23%

Overall, the performance for the July episode is slightly worse than the June episode. A pattern of overprediction still exists for much of the episode for NO and NO2. This is especially true for the sites in the downtown area.

4.3.3 Performance Evaluation for Episode 3: July 29 – August 5, 2002

4.3.3.1 Episode 3 Ozone Performance Metrics

The 8-hour model performance statistics are shown in Figure 4-1 and in Table 4-6.
The model gave its best overall performance during the third episode. The UPPA exceeded the

benchmark on only 1 of 8 days. This day (July 29) had low observed ozone concentrations and was overpredicted by 21% just over the 20% threshold. The APPA showed a reduction in magnitude as well as a slight tendency toward underprediction of the peak. In Episode 3, the normalized bias improved as well. During Episode 3, the MNB was within the benchmark on all days, did not show a consistent under- or overprediction, and demonstrates great accuracy with respect to the monitored values produced by the model. The normalized error was within the benchmark for the entire episode and was generally smaller in magnitude than during the first two episodes.

Table 4-6. Performance Metrics for Episode 3 (1-hour)

Metric	July 29	July 30	July 31	Aug 1	Aug 2	Aug 3	Aug 4	Aug 5
UPPA	**21.50%**	-8.22%	11.65%	0.57%	-3.04%	-9.22%	-8.62%	19.86%
APPA	-12.85%	-12.07%	2.81%	-0.61%	0.86%	-8.94%	-2.61%	-0.75%
MNB	-14.69%	-10.65%	-2.64%	6.00%	-0.27%	-6.75%	-2.16%	1.63%
MNE	14.69%	15.60%	8.24%	14.28%	11.79%	12.57%	11.60%	9.27%

4.3.3.2 Episode 3 Scatter Plots

The scatter plots for Episode 3 (Figures D-57 through D-59) reflect the improved performance relative to Episode 2. In Figure D-57, in which observed and predicted pairs are matched at the monitor location, the Q-Q line lies entirely within the ±20% line, in contrast to the corresponding plots for Episodes 1 and 2 (Figures D-51 and D-54), in which the Q-Q line is outside the benchmark for low values of observed ozone. Note, however, that Episodes 1 and 2 have points with very low (< 40 ppb) observed ozone values than does Episode 3. In Episode 3, the model's tendency to underestimate ozone at values > 85 ppb has also been ameliorated. For all three types of scatter plots, there are fewer observed/modeled pairs lying below the -20% benchmark in Episode 3 than for the other two episodes.

4.3.3.3 Episode 3 Spatial Plots and Conceptual Model Comparison

<u>July 29, 2002 (2002210)</u>: July 29 was a clean day in the St. Louis NAA with all observed ozone levels ~60 ppb.

<u>July 30, 2002 (2002211):</u> On July 30, the observations and the model show a plume extending west-southwestward away from downtown St. Louis. The highest 8-hour observed value is 90 ppb at the Queeny Park monitor; the model predicts a value of 78 ppb at the Queeny monitor. The model predicts a regional maximum value of 89 ppb just downwind of the Queeny monitor. The monitoring network does not extend far enough to the west to evaluate the accuracy of concentrations in the model plume. The model undepredicts the maximum 1-hour and 8-hour ozone concentrations upwind of the area on this day at Alton, Wood River, and West Alton most notably. Nearer to the St. Louis urban core, the model predicts concentrations adequately at the Sunset Hills, Arnold, and Ladue monitors suggesting the underprediction might be the result of the underestimation of incoming ozone to the area.

The conceptual model identifies the urban plume moving to the southwest over the Queeny Park monitor. Ozone formation closer to the urban center was prevalent on this day with high 1-hour concentrations at Ladue and Sunset Hills. The model adequately simulates these near-core ozone peaks and does predict the downwind 1-hour and 8-hour concentrations adequately.

July 31, 2002 (2002212): Both the observed and predicted daily maximum 8-hour ozone concentrations across the St. Louis monitoring network are relatively low (typically 50 to 70 ppb) and agree well with each other on July 31. The model estimates a cloud of elevated ozone in excess of 80 ppb to the west and west-northwest of St. Louis with a peak 8-hour ozone value of 90 ppb. As this modeled elevated ozone cloud lies west of the St. Louis ozone monitoring network, its presence can not be confirmed or denied. However, the highest observed 8-hour ozone concentrations on this day of 70-78 ppb occur at the westernmost monitoring sites (Orchard Farm, Jersey County and Queeny Park) at the edge of the modeled elevated ozone cloud; the model agrees with the observed values at these three sites very closely. Thus, the modeling results are consistent with the measurements, and the measurements do suggest that an elevated cloud of ozone may have existed to the west of St. Louis. In addition, the model captures the ozone gradient from west to east remarkably well on this day.

Higher surface wind speeds were present on this day than on previous days. The downwind plume predicted by the model to the north and west of the monitoring network is directionally appropriate, but can not be verified at this time.

August 1, 2002 (2002213): Observed ozone exceedances of 92 ppb, 89 ppb and 86 ppb occurred at the three sites to the north-northeast of St. Louis, Wood River, West Alton and Alton. The modeled 8-hour ozone peak of 102 ppb occurs near the observed maxima. At the Wood River monitor, the model agrees with the observed value predicting a concentration of 97 ppb. The modeled spatial alignment and magnitude of the ozone plume is quite good on this day, and is reflected in the model performance statistics discussed above. The 1-hour maximum spatial orientation of the plume is outstanding on this day and reflects a high precision with the meteorological predictions.

The photochemical model prediction on this day may be the best of any day in the three episodes with respect to direction of plume travel and timing of ozone development over the suburban area. The model does an outstanding job of representing the low incoming concentrations to the St. Louis area and the downwind concentrations in the core ozone plume.

August 2, 2002 (2002214): Both the modeled and observed ozone on August 2nd suggest a 180 degree wind reversal from the previous day with the observed highest ozone occurring to the south and southwest of downtown St. Louis on August 2. The lone observed 8-hour ozone exceedance on this day (86 ppb at Arnold) is underestimated at the monitoring site by –5% (82 ppb). However, just west of the Arnold site is the maximum 8-hour predicted concentration for the day of 96 ppb. Because the modeled ozone cloud to the southwest of St. Louis lies beyond the St. Louis monitoring network, its presence cannot be confirmed or denied by the observations. However, the model is reproducing the observed ozone quite well at the monitoring sites, and this is reflected in good model performance statistics for this day. Again, the extent and direction of the ozone plume is well-predicted by the model.

The conceptual model details a frontal passage over the St. Louis area (north to south) on August 2nd. The photochemical model reflects this event and the corresponding wind shift with accuracy. The modeled predictions correlate nicely with the timing of the frontal passage and the magnitude of the 1-hour and 8-hour concentration to the south of the metropolitan area.

August 3, 2002 (2002215): Again, both the observed and modeled ozone indicate a wind flow

change from the previous day with the highest modeled and observed 8-hour ozone concentrations occurring north of St. Louis on August 3rd. However, the observed highest values occur just north of the city center at the West Alton (99 ppb) and Alton (93 ppb) sites, whereas the modeled maximum 8-hour ozone concentrations occur to the north-northwest of the urban core. The modeled 8-hour ozone peak of 103 ppb occurs near the Orchard Farm monitor where an 8-hour ozone exceedance as observed (89 ppb). At the West Alton site, the model reproduced the observed region-wide maximum ozone concentrations (99 ppb) to within –11% (88 ppb). However, the edge of the model plume of high ozone lies near the Alton site so that the observed 8-hour ozone concentration at this site (93 ppb) is underestimated by –17% (77 ppb). Note that the displacement of the plume slightly to the west is due to a slight easterly wind direction bias in MM5. The two ozone exceedances in the southern portion of the St. Louis ozone monitoring network (Arnold and Sunset Hills) are underestimated by approximately –22% and -11%, respectively. Even with a slight spatial alignment problem and the underestimation of exceedances to the south of downtown, model performance on this day is reasonably good.

The front passes back over the St. Louis area on this day and the surface winds shift back to the south and the highest ozone concentrations occur north of the urban center. Carry-over from the previous day is likely contributing to higher ozone concentrations on August 3rd. Overall prediction of the elevated ozone plume is good with the slight westerly bias noted above. In addition, the photochemical model predicts very accurately the downtown core sites of Margaretta and Clark on this day.

August 4, 2002 (2002216): Unlike many other of the high ozone days in the St. Louis area, the modeled local suppression of ozone over the St. Louis urban core and delayed ozone formation does not appear to be a problem on August 4th. Six ozone monitors in the St. Louis area recorded exceedances of the 8-hour ozone NAAQS on this day with three of them exceeding 90 ppb. The observed region-wide maximum 8-hour ozone value of 98 ppb at the Margaretta monitor is reproduced by the model to within -12% at the same location (86 ppb). The modeled 8-hour maximum is just to the north of the downtown area and was predicted to be 94 ppb. The overall performance throughout the network is quite good on this day and this good model performance was also reflected in the performance statistics discussed above.

The photochemical model does an exemplary job of predicting plume movement (or lack thereof) in the urban center and prevailing out over the eastern portion of the domain. It also does a good job of simulating the lower incoming concentrations to the area on this day.

August 5, 2002 (2002217): No 8-hour ozone exceedances were observed on this day. However, the model predicted elevated ozone concentrations to the east-southeast of St. Louis with a region-wide maximum of 97 ppb. This plume does not appear in the observations. The Arnold monitor measured the 8-hour maximum concentration on this day of 81 ppb and the model accurately reflects this value with a prediction of 84 ppb. In addition, the ozone gradient from south to north is reflected well in the model predictions.

All graphical displays for the model performance evaluation are included in Appendix D.

4.3.1.4 Precursor Model Performance Evaluation for Episode 1

The model performance evaluation for NO and NO2 is presented below in Tables 4-7A-4-7B. The metrics presented are the same as the previous episodes. CO performance was not reported

due to the fact that the final basecause modeling did not include CO as an output species. In the same manner as the June episode, two different analyses are presented for comparison purposes, the first is a run that includes the OB70 kv methodology with no Kvpatch adjustment and the second is the final basecase run using the CMAQ kv scheme with the Kvpatch adjustment. Time series plots for NO and NO2 at a subset of monitors are included in Appendix D.

Table 4-7A. NO Model Performance Evaluation for July 29-August 5, 2002.

Day	Max Obs	UPPA-OB	PPA-OB	MNB-OB	MNE-OB	UPPA-CMAQ	PPA-CMAQ	MNB-CMAQ	MNE-CMAQ
02210	12	40.08%	184.52%	49.44%	134.05%	39.75%	100.77%	-26.49%	82.29%
02211	48	85.27%	-34.81%	68.08%	140.21%	1.75%	-40.41%	12.42%	102.93%
02212	37	324.19%	242.34%	182.85%	214.85%	110.78%	111.50%	-11.01%	78.32%
02213	38	119.76%	100.30%	95.24%	160.98%	40.53%	39.03%	-9.87%	87.36%
02214	33	411.61%	149.42%	153.63%	211.26%	184.00%	23.59%	10.52%	97.97%
02215	12	139.92%	-34.77%	-35.57%	67.53%	54.67%	-49.22%	-62.74%	68.20%
02216	25	373.76%	498.78%	143.36%	215.02%	-0.28%	111.44%	-30.83%	100.60%
02217	33	364.55%	176.55%	141.95%	174.49%	79.55%	123.34%	8.18%	85.11%

Table 4-7B. NO2 Model Performance Evaluation for July 29-August 5, 2002.

Day	Max Obs	UPPA-OB	PPA-OB	MNB-OB	MNE-OB	UPPA-CMAQ	PPA-CMAQ	MNB-CMAQ	MNE-CMAQ
02210	33	76.17%	33.41%	84.21%	95.21%	78.28%	4.48%	38.53%	59.85%
02211	48	38.51%	34.77%	63.43%	75.14%	36.48%	20.82%	26.55%	49.26%
02212	47	64.41%	80.91%	113.25%	117.55%	48.40%	33.62%	53.59%	65.06%
02213	49	46.46%	50.62%	77.11%	87.65%	55.79%	35.50%	36.89%	58.24%
02214	34	76.09%	55.52%	92.86%	102.48%	62.15%	31.08%	58.25%	76.03%
02215	49	41.41%	45.40%	45.15%	63.05%	38.15%	30.43%	11.51%	41.72%
02216	42	136.39%	80.86%	93.85%	106.98%	112.28%	16.65%	31.32%	55.14%
02217	45	66.83%	120.82%	48.79%	61.12%	69.83%	56.19%	14.73%	42.06%

Overall, the performance is not outstanding for either of the two scenarios for either of the pollutants. However, the final basecase performs substantially better than the OB70 – no Kvpatch scenario especially later in the episode. The OB70 scenario predicts higher concentrations especially for the NO and NO2 species lending weight to the discussion in the ozone performance section about overprediction of NO and NO2 in the model contributing to overall underprediction. In particular, the difference in NO performance is quite noticeable. With the Kvpatch adjustment and the use of the CMAQ kv scheme, the model does not have a strong tendency for overprediction of NO, but still has a tendency to overpredict NO2 concentrations in the urban center on a number of days in this episode.

4.4 EVALUATION AT KEY MONITORS FOR ATTAINMENT DEMONSTRATION DAYS

In this section, we focus on model performance at monitors that play a key role in the attainment demonstration. These are the monitors with the highest design values, defined here to be monitors with future year (2009) design values ≥ 80 ppb. The three monitors in the St. Louis Non-Attainment Area that meet this criterion are: Orchard Farm (81.3 ppb), Sunset Hills (80.8

ppb), and West Alton (80.3 ppb). We focus on model performance at the each monitor during times when the modeled 8-hour ozone daily maximum near the monitor was greater than or equal to 85 ppb, as these are the days used in the design value analysis for the attainment demonstration. We used the spatial plots of 8-hour ozone to gain an overall picture of model performance on each high ozone day. In addition, we compare the hourly observed and modeled time series at the three monitors. We examine the 1-hour ozone performance at the monitor, as this is a more stringent test of model performance than is the 8-hour ozone performance, requiring the model to reproduce the observed variability with higher temporal resolution. Flaws in performance that may be obscured in an 8-hour average will be shown in clearer relief if evaluated hourly. The observations are shown on the time series figures as blue points, and the modeled time series is denoted by a solid black line. The maximum and minimum range of modeled predictions near the monitor (i.e., 4 cells) is shown as gray shading.

Orchard Farm Monitor

The Orchard Farm monitor is located northwest of the urban core of St. Louis, in St. Charles County (Figure 2-2). During Episode 1, the days on which the modeled average 8-hour daily maximum ozone concentration at Orchard Farm exceeded the 85 ppb threshold were June 20-24. On June 20-23, the Orchard Farm monitor lay in the path of an ozone plume extending northwest from downtown St. Louis (Figures D-11 through D-14), and on June 24, lay on the periphery of the plume (Figure D-15). The 1-hour predicted and observed ozone time series for Episode 1 are shown in Figure D-39. The model does a reasonably good job of reproducing the observed 1-hour ozone variability during the June 20-24 period, but has difficulty simulating the amplitude of the daily ozone maxima. Peak ozone is under-predicted on June 22 (100 ppb predicted vs. 125 ppb observed, -20%) and June 23 (94 ppb predicted vs. 110 ppb observed, -14%), and over-predicted on June 20 (113 ppb predicted vs. 101 ppb, 12%) , June 21 (107 ppb predicted vs. 104 ppb observed, 3%) and June 24 (100 ppb predicted vs. 89 ppb, 12%). There is no clear bias toward under- or over-estimation of peak ozone, and the timing of the peak ozone is reasonably well simulated and is 1-3 hours early on all days except on June 23, when the observed time series shows a second, later peak that the model does not capture. The model also reproduces the observed daily minima with reasonable fidelity. On June 19, the observations show the onset of the June 19-24 high ozone event; however, the model does not generate high ozone levels until June 20. June 19 is not used as part of the attainment demonstration, however, so the model's poor performance on June 19 does not bias the results of the attainment test. Orchard Farm is located outside downtown St. Louis, and during June 20-23, was in the area impacted by the St. Louis urban ozone plume (Spatial plots, Figures D-11 through D-14). Performance was reasonably good at this monitor for this episode, with errors that could be explained by bias in the wind field. On June 20-24, the Orchard Farm monitor lay in a region of strong gradients of modeled ozone (Figures D-11 through D-15), so that any bias in the input wind field would have a large impact on model performance. Good performance at this monitor is at least partly due to the fact that by the time the air mass has traveled from downtown St. Louis to Orchard Farm, the model has had time to ramp up ozone production; since CAMx has trouble with delayed ozone formation, monitors located nearer the city center saw more underestimation of peak ozone concentrations during this high ozone event.

The Episode 2 days used in the attainment demonstration were July 2-5, and July 16. The observed and modeled Orchard Farm time series for Episode 2 are shown in Figure D-40. On July 2 and July 3, the St. Louis ozone plume extended northward (Figures D16-D17). The

Orchard Farm monitor lies in a region of strong gradients of modeled ozone on both of these days, and lies near the modeled ozone maximum on July 3. The model overestimates the amplitude of the peak on July 2 (106 ppb predicted vs. 100 ppb observed, 6%) and July 3 (94 ppb predicted vs. 91 ppb observed, 4%). The timing of the ozone peak is slightly delayed on July 2 and July 3. On July 4, a stagnation event occurred and the plume moved into the western portion of St. Louis County, so that the Orchard Farm monitor was no longer in the region of highest ozone (Figure D-18). The extent of the elevated concentrations are very near the monitor on July 4th and the 1-hour temporal profile for the Orchard Farm monitor values match very closely with the model predictions until the early evening hours. On July 5, the wind shifted again so that the plume orientation was to the west of downtown. The model reproduces the peak ozone well on July 4 (93 ppb predicted vs. 91 ppb observed, 2%) and July 5 (99 ppb predicted vs. 91 ppb observed, 8%). The timing of the maximum ozone prediction on July 5 was 3 hours earlier than observed (12:00 PM CDT predicted vs. 3:00 PM CDT observed).

On July 16, the main ozone plume is directly over the Orchard Farm monitor (Figures D-30). Peak ozone is overestimated (116 ppb predicted vs. 108 ppb, 8%) and minimum ozone is overestimated in the morning hours. This is the last day of the episode and the modeling ends at 18:00 CDT, but the maximum ozone values are captured earlier in the day.

Figure D-89 shows the observed and modeled Orchard Farm 1-hour ozone concentration time series for episode 3. July 31 and August 3 are the two days for which the modeled 8-hour daily ozone maxima are greater than 85 and are the days used in the attainment demonstration. Model performance on July 31 is excellent. On this day, the Orchard Farm monitor was at the edge of the ozone plume (Figure D-33). The timing and amplitude (87 ppb predicted vs. 94 ppb observed, -7%) of the ozone peak are well-simulated, as are the minima on either side of the peak. On August 3, the predicted early morning minimum is not as low as in the observations, but the amplitude of the peak is reproduced very well, although there is an overestimation (116 ppb predicted vs. 114 ppb observed, 2%) of the peak value. Ozone formation in the model matches that of observed ozone very closely. The Orchard Farm monitor lies very near the maximum of the modeled plume, but the observations indicate that the model places the plume too far to the west.

To summarize the performance at Orchard Farm, the only monitor with a 2009 design value greater than 81 ppb, CAMx reproduces the observed 1-hour ozone concentrations with reasonably good fidelity on all days and exhibits excellent performance during Episode 3. This highlights the effect of using the 85 ppb threshold in the design value analysis. The confidence gained by this evaluation in the model predictions at this monitor is considerable.

<u>Sunset Hills Monitor</u>

The Sunset Hills monitor lies southwest of St. Louis City (Figure 2-2), and is closer to the city center than the Orchard Farm monitor. For Episode 1, June 22 and June 23 are the days used in the attainment demonstration. On June 22 and June 23, the Sunset Hills monitor lies southeast of the main ozone plume (Figures D-13 and D-14). The 1-hour time series (Figure D-39) shows that there is good correspondence between the observed and predicted values in the morning, when ozone is increasing, but as the time of peak ozone approaches, the model predictions are underestimated. On June 22 the model predicts a peak of 98 ppb while the observations show a peak of 106 ppb (-8% difference), and the modeled peak is delayed by five hours relative to the observations. However, the hours preceding and after the peak are very similar in concentrations

(all above 90 ppb) and the model simulates this very well. On June 23, the modeled peak (85 ppb) occurs two hours earlier than the observed peak (103 ppb observed, -20% difference).

Episode 2 days used in the attainment demonstration were July 3-6, July 8, and July 15-16. During Episode 2, there is a consistent tendency to underestimate the daily 1-hour ozone peak at Sunset Hills (Table 4-8 and Figure D-40).

Table 4-8. Modeled and Observed Peak 1-hour Ozone Concentrations at the Sunset Hills Monitor During Episode 2 Days Used in the Attainment Test

Date	Predicted O_3 (ppb)	Observed O_3 (ppb)	Difference
July 3	109	105	4%
July 4	104	112	-7%
July 5	90	128	-29%
July 6	94	91	3%
July 8	101	93	8%
July 15	115	130	-11%
July 16	90	95	6%

The model performed best on July 3, 4, 6, 8, and 16. On July 3 and 8, the ozone event was a stagnation event with high monitored values throughout the network. On July 4, 6, and 15, the Sunset Hills monitor was located in or near a plume of ozone extending outward from St. Louis. The peak timing and amplitude were reasonably well reproduced for all days except July 5. On July 5, the plume extended to the west of the city, and did not impact the Sunset Hills monitor, and performance at the monitor was considerably worse. The model predicts well with respect to the diurnal profile observed or July 16 even though the plume travel is to the west and north of the Sunset Hills monitor.

July 30, and August 2 and 5 are the Episode 3 days used in the attainment demonstration. Model performance on July 30 and August 5 was excellent with modeled peak ozone within 4% of the observed value on both days (Figure D-41). On August 2, the model underpredicts the peak ozone value (86 ppb predicted vs. 100 ppb observed, -14%). Overall, there is very good correspondence between the modeled and observed 1-hour times series during Episode 3 at Sunset Hills.

The Sunset Hills monitor performs only slightly worse than the Orchard Farm monitor on days used in the attainment demonstration calculation and exhibits a trend of following the diurnal monitored profile very closely on a large number of days.

West Alton Monitor

The West Alton monitor is located north of St. Louis City, in St. Charles County (Figure 2-2). Observed hourly ozone concentrations were less than 85 ppb during the first 10 days of Episode 1. We focus on model performance during the June 20-24 period, when the modeled 8-hour daily maximum ozone at the monitor was >85 ppb. The model underpredicts the 1-hour ozone maximum on each day during this period (Table 4-9 and Figure D-41), but simulated the timing of the peaks reasonably well. As discussed previously on two of the days, the model illustrates a westerly bias in plume travel and misses the peak values occurring at the West Alton monitor. Due to this phenomena, the predicted peaks are 2-4 hours earlier than the actual monitored peak concentrations.

Table 4-9. Modeled and Observed Peak 1-hour Ozone Concentrations at the West Alton Monitor During Episode 1 Days Used in the Attainment Test

Date	Predicted O_3 (ppb)	Observed O_3 (ppb)	Difference
June 20	92	105	-12%
June 21	94	110	-15%
June 22	92	119	-22%
June 23	82	101	-19%
June 24	85	93	-9%

During Episode 2, July 2-5, 8-9, 15-16 are the days used in the attainment demonstration. The model illustrates no patter on the first four days of peak over/underpredicion. As with the other sites, the performance late in the episode is underestimated (Table 4-10). The underprediction is most pronounced on July 15-16. On July 8, the modeled peak is 7 hours delayed relative to the observed peak; on July 9, the peak is delayed by 5 hours.

Table 4-10. Modeled and Observed Peak 1-hour Ozone Concentrations at the West Alton Monitor During Episode 2 Days Used in the Attainment Test

Date	Predicted O_3 (ppb)	Observed O_3 (ppb)	Difference
July 2	82	87	-5%
July 3	111	105	6%
July 4	100	93	8%
July 5	87	98	-11%
July 8	102	112	-9%
July 9	77	83	-7%
July 15	86	98	-13%
July 16	104	116	-10%

August 1, 3 and 4 are the days used in the attainment demonstration for Episode 3. On the first two days at this monitor, the model has a slight underprediction bias. On August 1, the bias is –9% (114 ppb obs vs. 105 ppb pred). On August 3 the model underestimates the peak amplitude (98 ppb predicted vs. 130 ppb observed, -25%). However, the model overestimates the peak concentration on August 4 (103 ppb predicted vs. 98 ppb observed, 5%). In general, the prediction at the West Alton monitor is somewhat degraded when compared to the other two monitors in this evaluation, but still performs adequately to be used in the attainment demonstration test.

4.5 CONCLUSIONS

The model performance evaluation is summarized below:

- Model performance issues identified in initial basecase of the St. Louis modeling (exaggerated ozone suppression over downtown St. Louis, delayed ozone formation leading to a general under-prediction bias) have been ameliorated to a large extent in the final modeling, but are still present.
- The depth of the ozone hole in downtown St. Louis is sometimes overstated by the model using the CMAQ minimum Kv setting and the KvPatch adjustments.
- Delayed ozone formation causes underprediction of ozone at monitors near the periphery

of the urban core on several days.

- Some of the model performance issues may be attributed to bias in the MM5 wind field. Small errors in the location of strong ozone gradients associated with the St. Louis urban plume can lead to large discrepancies between observed and modeled ozone.
- The model tends to overestimate surface layer ozone when observed ozone concentrations are low (i.e. less than 60 ppb), and to underpredict when observed ozone concentrations are high (> 85 ppb).
- The model performs better on days with high ozone than on days with relative low ozone levels; this means that the model tended to exhibit its best performance on the days used in the modeled attainment test.
- Model performance is mixed during Episodes 1 and 2, with the model failing to meet the UPPA benchmark on 25% of episode days, and the normalized benchmark on 30% of episode days.
- Model performance is excellent during Episode 3, and is within the EPA performance benchmarks for all days for normalized bias and normalized error.
- The model had difficulty simulating the onset and dissipation of high ozone events (e.g. June 19), often delaying the increase or decay in ozone concentrations by a full day relative to observed values.
- The more extensive monitoring system in regions further downwind of downtown St. Louis will aid future modeling efforts (e.g. Pacific in western St. Louis County).

From the analysis in Section 4, we may draw several conclusions regarding model performance:

- The use of the 85 ppb ozone threshold excludes from the design value projection analysis the time period July 11-15, during which the MNB was near or did actually exceed the benchmark. The threshold therefore, has the effect of including only the days where the performance was generally within the benchmark.
- Because the model performance is best on high ozone days, which are the days used in the attainment test, the 2002 episodic modeling is suitable for use in the attainment demonstration.
- Performance at the three critical monitors with observed design values > 80 ppb was acceptable on the high ozone days used in the attainment demonstration.

As with any long episodic (38 days) simulation, the St. Louis 2002 Base Case simulation performs better on some days than others. On most episode days, the model achieves most of EPA's model performance evaluation goals for 8-hour and 1-hour ozone concentrations. The 1-hour and 8-hour ozone hourly performance statistics do suggest an underestimation tendency that is related in part to the simulation of the St. Louis urban core ozone hole and the model's tendency to delay ozone formation in the St. Louis urban plume relative to observations. However, in general, the St. Louis base case model simulation exhibited sufficient skill in meeting most performance goals that it may be used to project future-year ozone air quality and 8-hour ozone attainment, recognizing the inherent uncertainties in atmospheric modeling process.

5.0 ATTAINMENT DEMONSTRATION MODELING ANALYSES

In this section, we discuss the procedures used for the future-year modeling and the projections of future-year 8-hour ozone design values for the 2009 OTB emission scenario.

5.1 FUTURE-YEAR MODELING INPUTS

Development of the 2009 future-year base case emission inputs is described in Section 3. The same June, July, and August 2002 meteorological conditions were used in the future-year 2009 modeling as were used in the base case modeling. Thus, effects of climate change, land use variations and other phenomena that may affect meteorological conditions in the future are not accounted for. The same initial and boundary conditions were used for the 2002 base case and 2009 future-year modeling.

There was an additional basecase modeling run used to "adjust" the 2002 model performance evaluation emission inventory dataset to one that could be projected to 2009 and used in the attainment demonstration. This scenario was called the "typical" scenario and utilized a non-hourly CEM inventory for large electric generating units (EGUs) in order for the future year projections to not have the hourly bias from the CEM inventory to the non-CEM projected 2009 inventory. This means that the 2002 modeling runs used for the Relative Reduction Factor (RRF) calculation discussed below included the typical scenario and not the model performance evaluation scenario.

5.2 PROJECTION OF 2009 8-HOUR OZONE DESIGN VALUES

The EPA draft guidance for 8-hour ozone modeling contains specific procedures for using modeling results in a relative fashion to scale the observed 8-hour ozone design values to project future-year 8-hour ozone design values for comparisons with the NAAQS (EPA, 2006). These procedures were used to estimate 2009 8-hour ozone design values under the 2009 OTB emission scenario. If the future design value for a monitor is less than or equal to 84.9 ppb, the modeled attainment test is passed. If the future design value is greater than or equal to 85.0 ppb, the modeled attainment test is not passed. If the future design value lies between 82 and 87 ppb, a weight of evidence (WOE) determination is required (EPA 2006) in order to provide corroborative information that attainment is achieved.

The procedures for projecting future-year 8-hour ozone design values starts with a current-year observed 8-hour ozone design values for each monitor. The modeling results are then used to scale the observed 8-hour ozone design values to the future-year. This is done through the calculation of model-estimated RRFs that are the ratio of the model-estimated 8-hour ozone concentrations from the future-year to current-year emission scenarios. The RRF is used to scale the current year observed design value (DVC) to estimate the projected future-year 8-hour ozone design value (DVF):

$$DVF = DVC \times RRF$$

The RRF is defined as the ratio of the average of the maximum 8-hour ozone concentrations *near each monitor* for the future-year emissions scenario to the average for the current year base case emissions scenario. The EPA default definition "near the monitor" refers to an array of 7 x 7 grid cells centered on the monitor for the 4 km grid cell resolution used in the St. Louis application (EPA, 2006).

EPA's draft 8-hour ozone modeling guidance includes the following language for selecting the current-year observed 8-hour ozone design values that are used in the modeled attainment demonstration test:

> *"For the modeled attainment tests we recommend using the average of the three design value periods which include the baseline inventory year…The average of the three design value periods best represents the baseline concentration, while taking into account the variability of meteorology and emissions (over a five year period)."* (EPA, 2006).

For the 2002 baseline inventory year used in the St. Louis ozone modeling, the time periods used to calculate the 5-year baseline design value are 2000-2002, 2001-2003, and 2002-2004. This has the effect of weighting the design value toward the middle of the time period, which is the baseline inventory year 2002. For each monitor, the ratio of the 2009 to the 2002 model estimated average daily maximum 8-hour ozone "near" the monitor was calculated. Only days for which the modeled 2002 daily maximum 8-hour ozone was greater than or equal to the threshold value of 85 ppb were used in the design value analysis.

EPA recommends that at least of 10 modeling days be included in the calculation of the RRF and future year design values with an absolute 5 day minimum. The criterion for using an episode day in calculating the episode average design value for that monitor is that the modeled daily maximum 8-hour ozone near the monitor exceeds a minimum threshold value. EPA recommends use of an 85 ppb threshold in the design value calculations, but if insufficient number of days are available to calculate the RRFs then this threshold can be reduced by 1 ppb until sufficient modeling days are obtained or until a 70 ppb floor is obtained. We began the analysis with a threshold of 85 ppb. In Section 6, we describe a similar design value analysis in which a minimum threshold of 70 ppb was used. Figure 5-1 shows the results of the 2009 design value projection for the St. Louis 4-km domain using the 85 ppb threshold. The current year 5-year baseline design values are shown in yellow and the future year (2009) projected design values calculated with a threshold of 85 ppb are shown in orange. The values of 82 ppb and 85 ppb are shown as lines in Figure 5-1; the 85 ppb represents the 8-hour ozone NAAQS and if projected design values fall between 82 ppb and 87 ppb EPA guidance recommends that a weight of evidence determination be made. NOTE: The St. Louis attainment demonstration did not reflect any future design values over 82 ppb.

For 8 sites in the St. Louis NAA, the current year 5-year baseline design value exceeds the 8-hour ozone NAAQS. The projected design values for 2009 show that no monitor is estimated to exceed 85 ppb, so that all monitors are projected to attain the 8-hour ozone NAAQS. One monitor (Orchard Farm) has a future year design value greater than 82 ppb and less than 85 ppb. This indicates that a weight of evidence determination is reasonable (see Section 6). Figure 5-2 shows the number of days of data used in the design value projection for each monitor. There are two sites with fewer than 10 days of available data using the 85 ppb threshold. The Bonne Terre monitor has 6 days of data and the Arnold monitor has 8 days that meet this criterion; however, these sites' current year (and past year's) design values are less than 85 ppb so they already attain the 8-hour ozone NAAQS. The design value analysis shows that on-the-books (OTB) controls are estimated to be sufficient for the St. Louis area to pass the modeled attainment demonstration test.

In Section 4 we noted that the ozone model performance for some days from the three 2002 episodes modeled failed to achieve EPA's ozone model performance goals with the model tending to underestimate the observed ozone concentrations. We note here that the use of the 85 ppb threshold automatically drops the poor performing days from attainment test. Figure 5-3 shows the normalized bias for the Orchard Farm monitor for all three 2002 episodes. Days used

in the design value projection are circled in red; these are high ozone days during which the daily maximum 8-hour ozone exceeded 85 ppb. CAMx performed better on high ozone days than on low ozone days (See Section 4), and the normalized bias is smaller on those days, falling within EPA performance benchmarks for all days used in the design value projection.

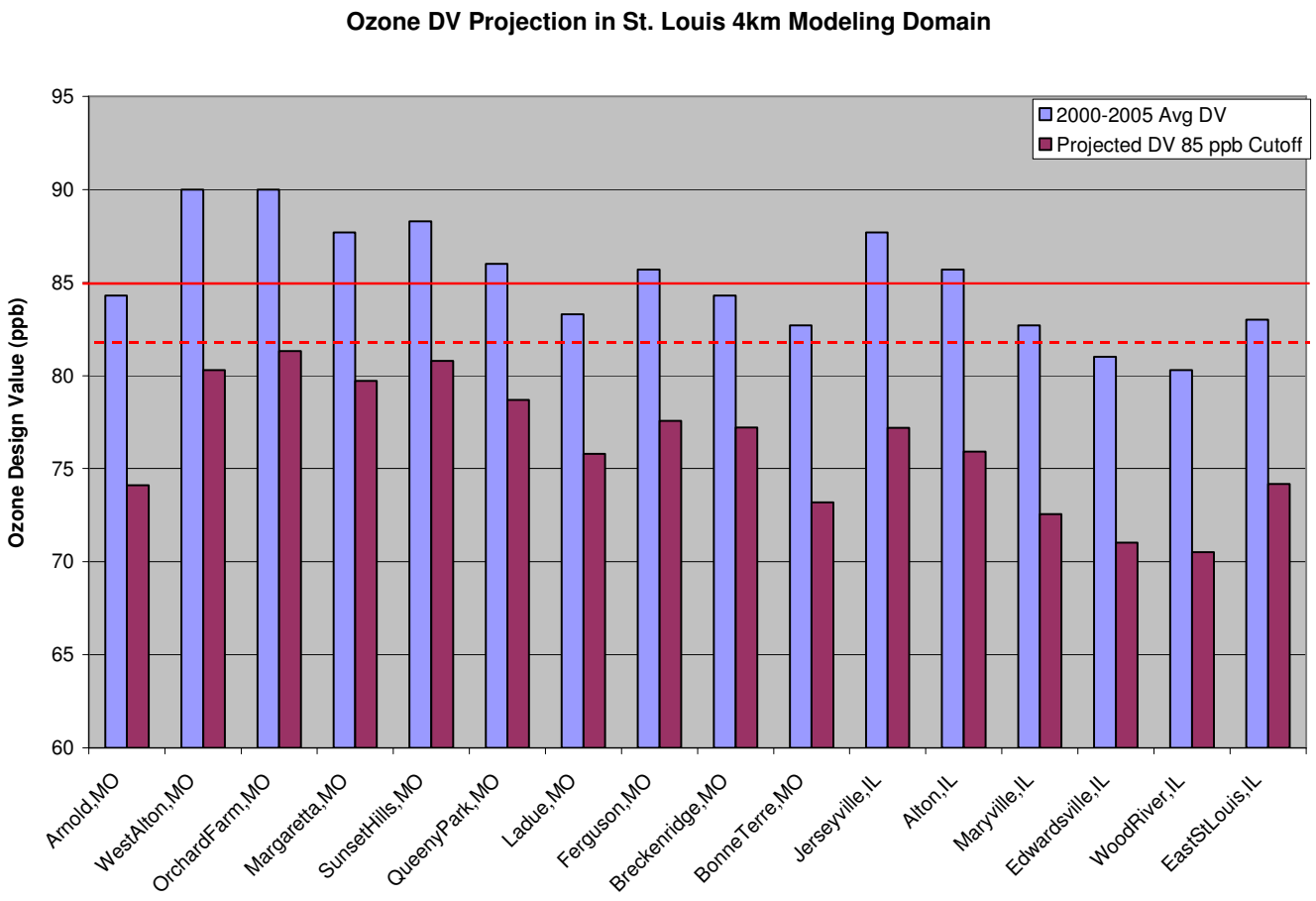


Figure 5-1. Design value projection for the future year 2009 (OTB Controls Scenario) for the St. Louis 4-km domain monitors.

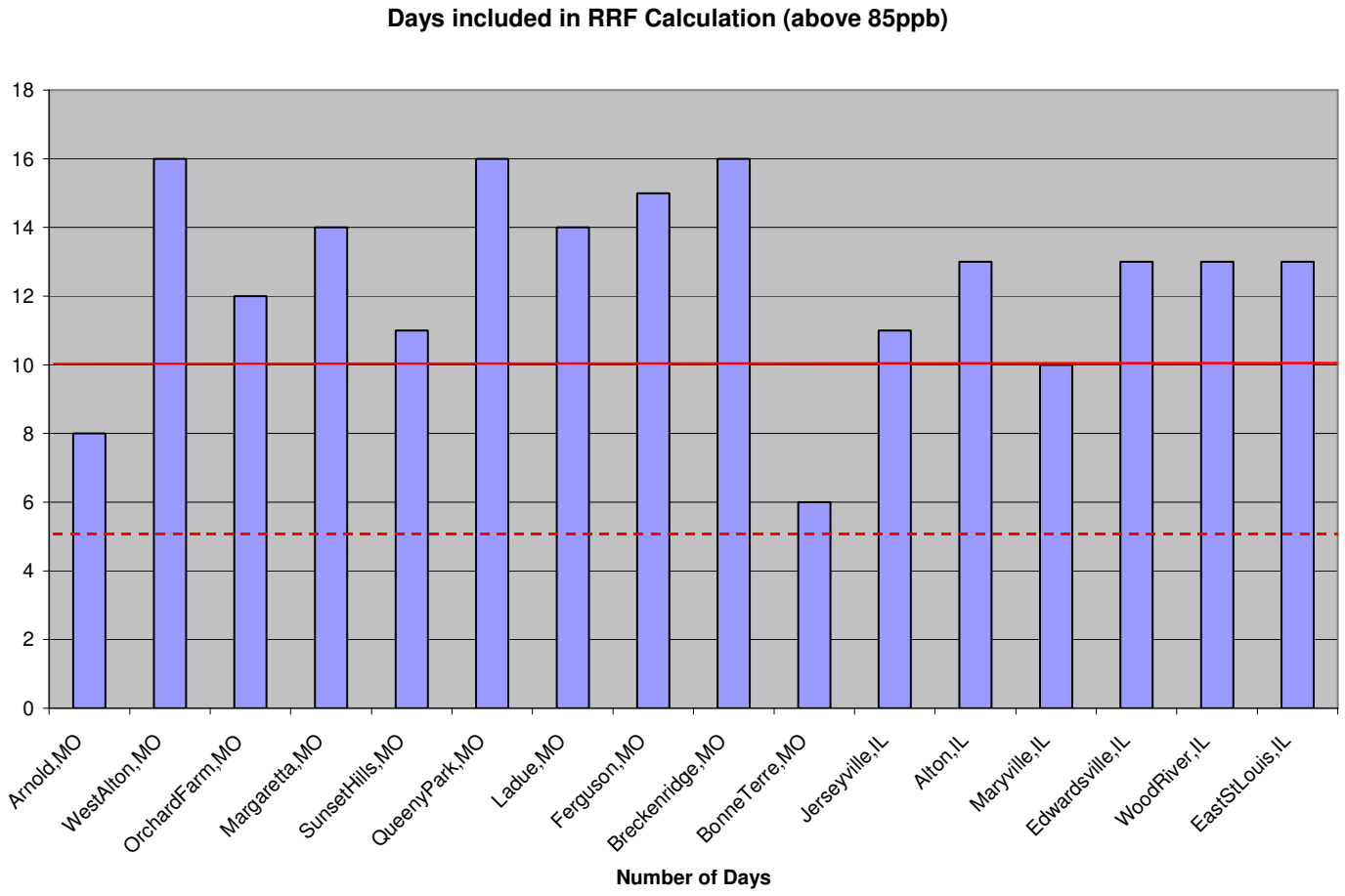


Figure 5-2. Number of days used in determining the projected future year (2009) design value for each monitor in the St. Louis 4-km domain.

Figure 5-3. Normalized bias performance statistics for days used in the modeled attainment test for the Orchard Farm Monitor.

5.3 SCREENING ATTAINMENT DEMONSTRATION TEST FOR UNMONITORED AREAS

Section 5.2 presented the modeled attainment demonstration results at monitors in the St. Louis NAA. EPA's draft guidance (EPA 2006) also requires an 8-hour ozone attainment demonstration to perform an "unmonitored area analysis" whose purpose is to use a combination of model output and ambient data to identify areas that might exceed the NAAQS if monitors were located there. The unmonitored area analysis should identify areas where future design values are predicted to be greater than the NAAQS". The draft guidance recommends interpolating base year observed data and then adjusting the interpolated field using base year gridded model output gradients; then gridded model RRFs are to be applied to the gradient adjusted base year field, and locations that exceed the NAAQS in the future may be identified. The EPA is developing "Modeled Attainment Test Software" (MATS) to perform this task, but the software was not available at the time of the St. Louis modeling study. Consequently we performed an unmonitored area analysis in a manner that is consistent with the intent of the EPA algorithm described above.

First, we generated a spatial map of RRFs for the St. Louis NAA that essentially treats each grid cell as a monitor. The RRF is the ratio of the 2009/2002 modeled surface layer daily maximum 8-hour ozone value in each grid cell, and is calculated for each day of the three summer episodes. From these daily values, an average RRF over all three summer 2002 episodes was computed. These average RRFs are shown in Figure 5-4. The top panel of Figure 5-4 shows RRFs calculated with a threshold of 70 ppb; this means that in order for a grid cell's data to be included in the RRF calculation on a particular day, the daily maximum 8-hour ozone value had to exceed the 70 ppb threshold. If the peak 8-hour ozone value on that day did not exceed the threshold, that day was excluded from the 3-episode average for that grid cell. The lower panel of Figure 5-4 shows the RRFs calculated using a threshold of 85 ppb. Note that there are locations that are blank; in these grid cells, the daily maximum ozone never exceeded 85 ppb.

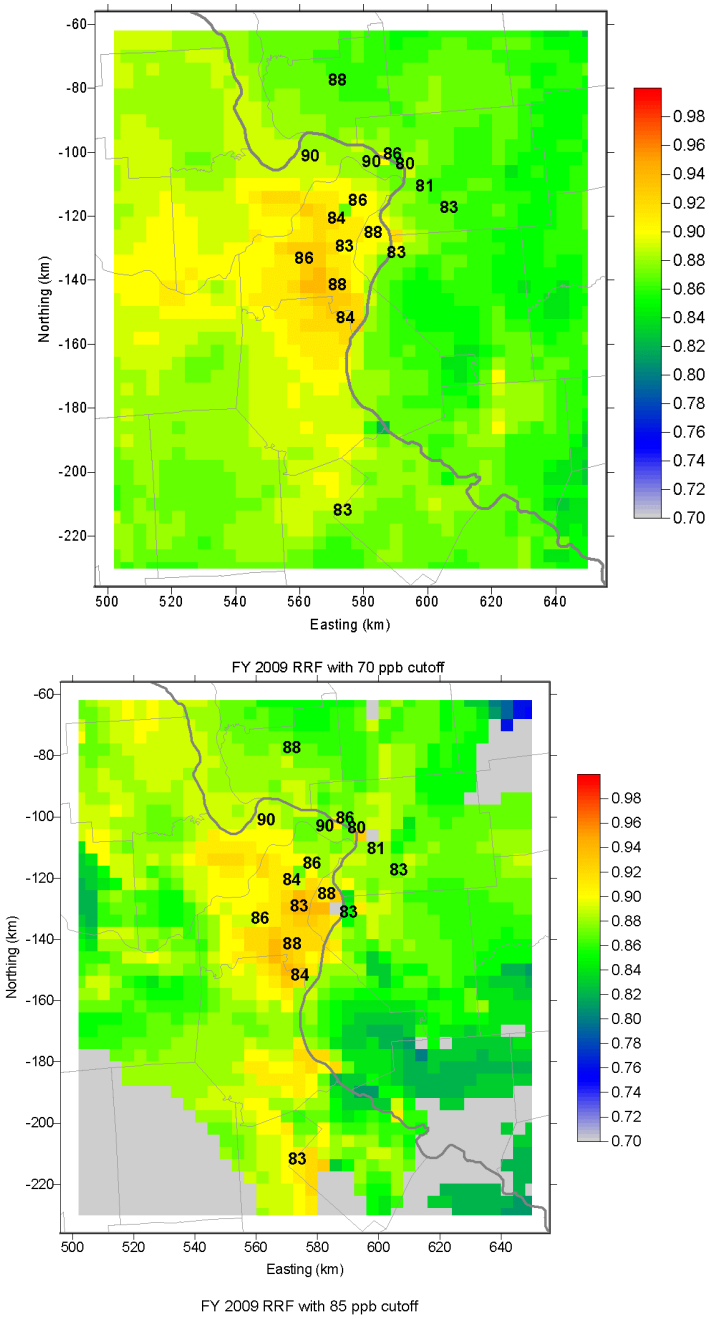


Figure 5-4. Episode 1-3 average 2009/2002 modeled relative reduction factors for the St. Louis NAA. Black numbers within domain indicate 2002 monitor design values. Upper (lower) panel shows RRFs calculated with a daily maximum 8-hour ozone threshold of 70 ppb (85 ppb).

Overlaid with the modeled RRFs in Figure 5-4 are the 2002 observed 5-year baseline design values at the St. Louis NAA monitors. By multiplying the RRF times the 2002 observed design values, we can estimate future year design values at each grid cell in the St. Louis NAA. Table 5-1 shows the maximum observed design value consistent with 2009 attainment for each RRF cut point shown on the color scales in Figure 5-4. Figure 5-4 shows that the RRF field is less than 1 everywhere within the St. Louis NAA for both the 70 ppb and 85 ppb thresholds. The RRF field shows a pronounced east-west gradient, with lower RRFs to the east of downtown St. Louis, and higher RRFs to its west. Lower values of the RRFs indicate that the model has a stronger response to emissions reductions in a given region. The low RRFs indicate that it is highly unlikely that there would be an unmonitored area in the eastern half of the 4 km domain that would be out of attainment in 2009.

The model is relatively stiff in its response to future emissions reductions in St. Louis County. In both the 70 ppb and 85 ppb cutoff cases, there are areas in St. Louis County for which the RRFs are greater than 0.94. An unmonitored area in this region with a current year design value greater than 90.3 would be expected to be out of attainment in 2009. The maximum observed 2002 design value in the area of RRFs near 0.92 to 0.94 is 88 at the Sunset Hills monitor; therefore, Figure 5-4 shows that no monitored area within the St. Louis NAA is expected to be out of attainment in 2009.

Table 5-1. Maximum Observed Design Value Consistent with 2009 Attainment Shown for Each RRF Cutpoint Shown on the Scales in Figure 5-4

Cut Point	Maximum Design Value
1.00	84.9
0.97	87.5
0.94	90.3
0.91	93.3
0.88	96.5
0.85	99.9
0.82	103.5

The two monitors with the highest 2002 design values are Orchard Farm and West Alton, both with design values of 90 ppb. For both thresholds, the Orchard Farm monitor has a future year design value nearly 82 ppb. Because the Orchard Farm monitor lies near the 0.91 contour, we note that assuming a RRF of 0.94 (i.e., assuming that Orchard Farm falls on the other side of the contour, and further assuming the maximum value of the RRF), the Orchard Farm monitor still has a future year design value that is less than 85 ppb. Both panels of Figure 5-4 show that the West Alton monitor has a future year design value < 82 ppb.

5.4 SUMMARY OF MODELED ATTAINMENT DEMONSTRATION

During 2002, 8 monitors in the St. Louis NAA had a design value that exceeded the 8-hour ozone NAAQS. The projected design values for the future year 2009 show that no monitor in the St. Louis NAA exceeds 84.9 ppb, so that all monitors attain the 8-hour standard. This attainment demonstration suggests that OTB controls will be sufficient to bring the St. Louis NAA into attainment of the NAAQS by 2009. However, one monitor (Orchard Farm) in the St. Louis NAA has a future year design value very nearly 82 ppb. In an effort to provide further confidence that

attainment is likely, a weight of evidence determination was performed (Section 6).

6.0 WEIGHT OF EVIDENCE ANALYSIS

When observed 2000-2004 8-hour ozone design values are used, the projected 8-hour ozone design values in the St. Louis NAA for the 2009 On-The-Books emission scenario are all below 85 ppb, thereby satisfying the modeled attainment demonstrating test. However, the projected 2009 design value for one St. Louis NAA monitor (Orchard Farm) was very nearly 82 ppb, so a weight of evidence determination is provided. EPA Guidance states that if there is a future design value between 82-87 ppb at one or more sites/grid cells, then "a weight of evidence demonstration should be conducted to determine if aggregate supplemental analyses support the modeled attainment test" (EPA 2006). In fact, EPA suggests that a supporting weight of evidence (WOE) always be conducted to corroborate the modeled attainment demonstration test. In a weight of evidence determination, results from several types of air quality analyses are considered and the results reviewed for consistency with the conclusion of the modeled attainment test regarding the likelihood that the proposed control strategy will result in a NAA meeting the NAAQS. The credibility of each type of analysis used in the WOE determination must be assessed and finally, a conclusion reached regarding the likelihood of attainment. Several types of supplementary analyses are suggested by EPA:

- Additional modeling
- Trends in ambient air quality and emissions
- Observational models and diagnostic analyses

6.1 OVERVIEW OF WOE ANALYSIS

The St. Louis WOE is centered on the modeled attainment demonstration using CAMx described in Sections 4 and 5. Supplemental analyses used in the St. Louis WOE determination are:

Additional Modeling:

- Additional modeling metrics
- Corroborative modeling analysis using CMAQ
- CAMx modeled attainment test using alternative cutoff
- Independent corroborative modeling analyses
- Comparisons of 2009/2002 emissions reductions with other studies
- 8-hour ozone design value projections using the maximum current DVs.
- Ozone source apportionment modeling using CAMx

Trends in Ambient Air Quality and Emissions:

- Trends in Air Quality Analysis
- Trends in emissions

Observational Models and Diagnostic Analyses

- None

6.2 MODELED ATTAINMENT DEMONSTRATION USING CAMX

EPA requires a fully-evaluated, high quality modeling analysis that projects future design values that are close to the NAAQS. In Sections 1 through 5 of this TSD, we have described the modeled attainment demonstration using CAMx. The model performance evaluation presented in Section 4 suggests that the model simulates near-surface ozone concentrations with good fidelity on the high-ozone days used in the attainment demonstration. The design value analysis (Section 5) suggests that On the Books Control Strategies are sufficient to bring the St. Louis NAA into attainment by 2009.

6.3 ADDITIONAL MODELING METRICS

EPA suggests several modeling metrics that may be examined in the weight of evidence (WOE) determination to provide assurance that passing or nearly passing the recommended attainment and screening tests indicates attainment (EPA, 2006, pg. 90). The additional modeling metrics measure how much estimated elevated 8-hour ozone concentrations are reduced from the current year base case by the future-year control strategy. Three of the recommended metrics are as follows:

> Percent change in # Grid-Hours > 85 ppb: Compute the relative change in the number of grid cell-hours during the modeling episode in which the estimated 8-hour ozone concentrations are greater than 85 ppb.
>
> Percent change in # Grid-Cells > 85 ppb: Compute the number of grid-cells in which the daily maximum 8-hour ozone concentrations is greater than 85 ppb.
>
> Relative Difference (RD): The Relative Difference (RD) in 8-Hour ozone concentrations greater than 85 ppb is the ratio of the average of estimated excess 8-hour ozone above 85 ppb of the future-year simulation to the base-year base case.

The first two metrics above are metrics for 8-hour ozone exposure. The # Grid-Hours with 8-hour ozone $\geq$ 85 ppb is the number of grid cell-hours that the model estimated 8-hour ozone concentrations exceeds the health-based standard. The # Grid-cells 8-hour ozone > 85 ppb represents the real extent of modeled exceedances. The Relative Difference metric has the form of a dosage calculation that is weighted by how much the 8-hour ozone concentration is above 85 ppb.

As part of the WOE, EPA guidance states that "large" reductions in these metrics are consistent with the conclusion that application of the control strategies used in the future year case would result in attainment of the 85 ppb standard (EPA, 2006). EPA does not provide a definition for "large" reductions, but suggests that substantial reductions in these metrics provide support for a determination that attainment is likely.

Table 6-1 shows a reduction of 79% in the number of grid hours with 8-hour daily maximum ozone > 85 ppb across all three episodes. Table 6-2 shows a 73% reduction in the number of grid cell hours with 8-hour daily maximum ozone > 85 ppb across all three episodes. Table 6-3 shows a reduction of 83% in the relative difference of ozone > 85 ppb across all three episodes. Also, the best performing episode (July-August) reflects greater than a 90% reduction for both grid hours and relative difference. These are substantial reductions, and lend weight to the

conclusion reached based on the modeled attainment test, that the St. Louis NAA will achieve attainment in 2009 using OTB control strategies.

Table 6-1. Number of Grid Hours with 8-hour Daily Maximum Ozone > 85 ppb

Episode	2002 Base	2009 OTB	Difference
1	5,287	415	-92%
2	5,679	2,078	-63%
3	1,112	98	-91%
Total	12,078	2,591	-79%

Table 6-2. Number of Grid Cells with 8-hour Daily Maximum Ozone > 85 ppb

Episode	2002 Base	2009 OTB	Difference
1	1,004	153	-85%
2	1,219	486	-60%
3	282	49	-83%
Total	2,505	688	-73%

Table 6-3. Relative difference (RD) in 8-hour ozone concentrations > 85 ppb

Episode	2002 Base	2009 OTB	Difference
1	30,401	927	-97%
2	38,794	11,508	-70%
3	5,537	151	-97%
Total	74,732	12,586	-83%

6.4 ATTAINMENT TEST WITH ALTERNATIVE CUT-OFFS

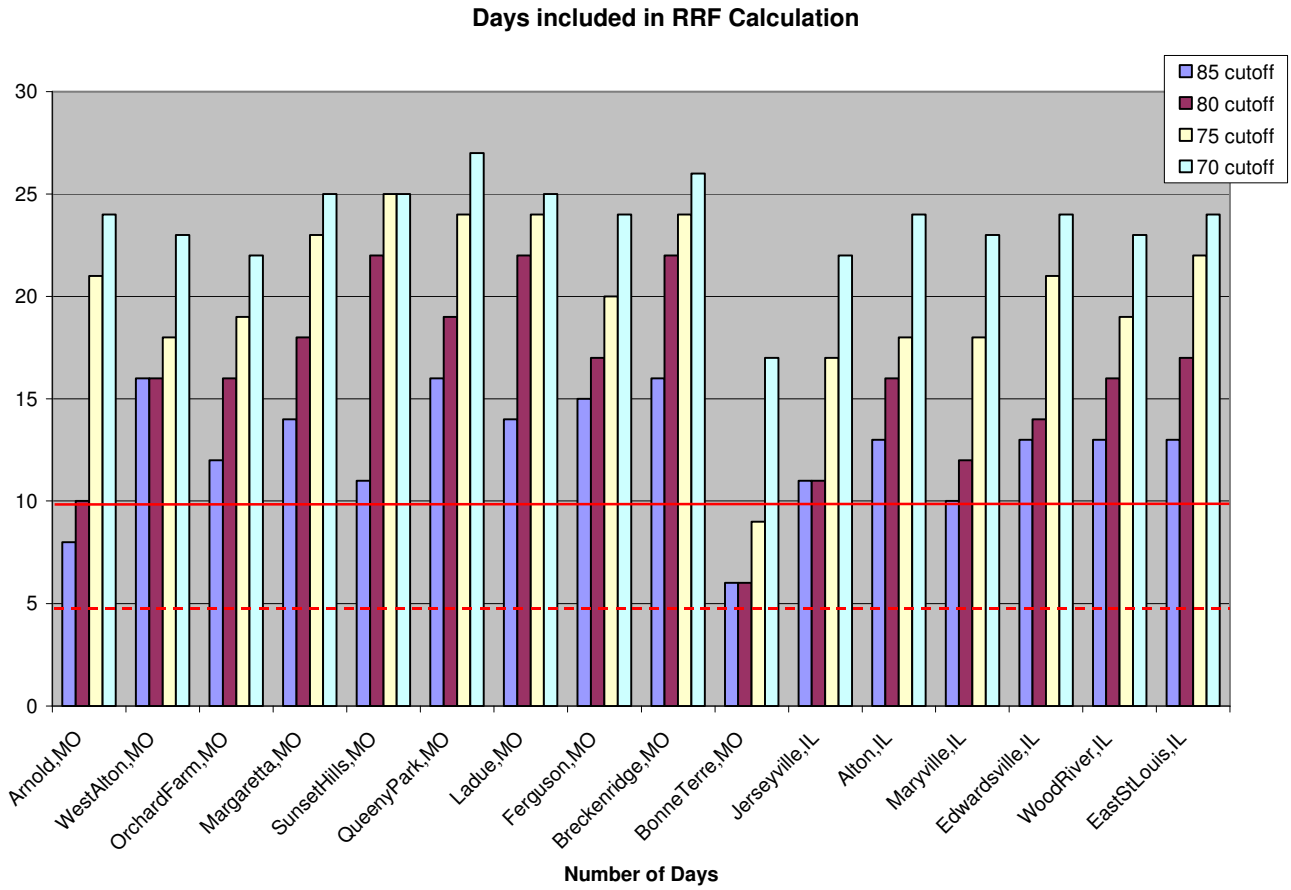
As part of the weight of evidence demonstration, a second attainment test was performed in which the 85 ppb threshold for inclusion of modeled days was replaced by a 70 ppb threshold. This 70 ppb threshold attainment test was performed in a manner identical to the test described in Section 5.2 except for the value of the threshold. The ratio of the 2009 to 2002 model estimated average daily maximum 8-hour ozone near each monitor was calculated using only monitors having modeled days in which 2002 daily max 8-hour ozone was greater than or equal to 70 ppb.

Figure 6-1 shows the number of days used in the 85 ppb threshold attainment test described in Section 5.2, and in the 80, 75, and 70 ppb threshold attainment test. Using the 85 ppb threshold, there are 2 sites with fewer than 10 days during which the daily maximum 8-hour ozone exceeded the threshold; the Bonne Terre, MO and Arnold monitors have 6 and 8 days of data meeting this criterion. With the relaxation of the threshold from 85 ppb to the lower thresholds, all monitors used in the attainment test now have sufficient days available for inclusion in the design value analysis. In particular, the Bonne Terre, MO monitor now has 17 modeled days with sufficiently high ozone that they can be included in the design value analysis.

Figure 6-2 shows the results of the 70 ppb -85 ppb threshold design value analyses. For 8 of the 16 monitoring sites, the current year 5-year baseline design values exceed the 8-hour ozone NAAQS. The projected design values for 2009 for all the threshold cases show that no monitor

exceeded 85 ppb, so that all monitors attain the 8-hour ozone standard. All the threshold cases show very similar results, with design values differing by less than 5%. The results of the other threshold design value analysis reinforce the conclusion drawn in Section 4.3 that on-the-books (OTB) controls are sufficient for the St. Louis area to pass the modeled attainment demonstration test.

Figure 6-1. Number of days used in the 8-Hour ozone future year design values projections



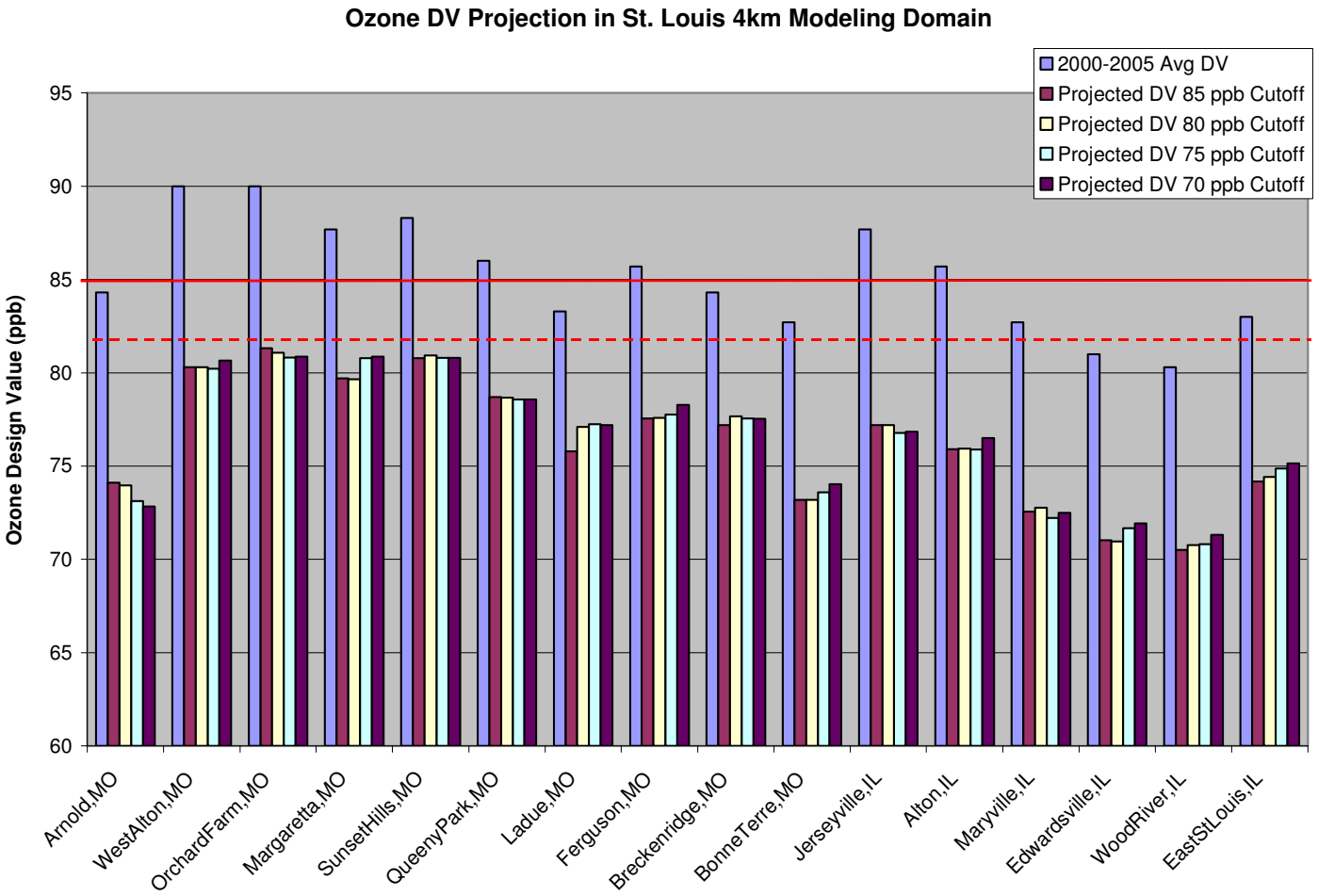


Figure 6-2. 2009 future year design value projections for monitors in the 4-km St. Louis domain

In addition to the different thresholds for the calculation of the future year design value, the maximum of each design value for the three time periods (2000-2002, 2001-2003, and 2002-2004) was calculated separately. Figure 6-3 shows the results of this analysis. Again, the future year design values are below the NAAQS.

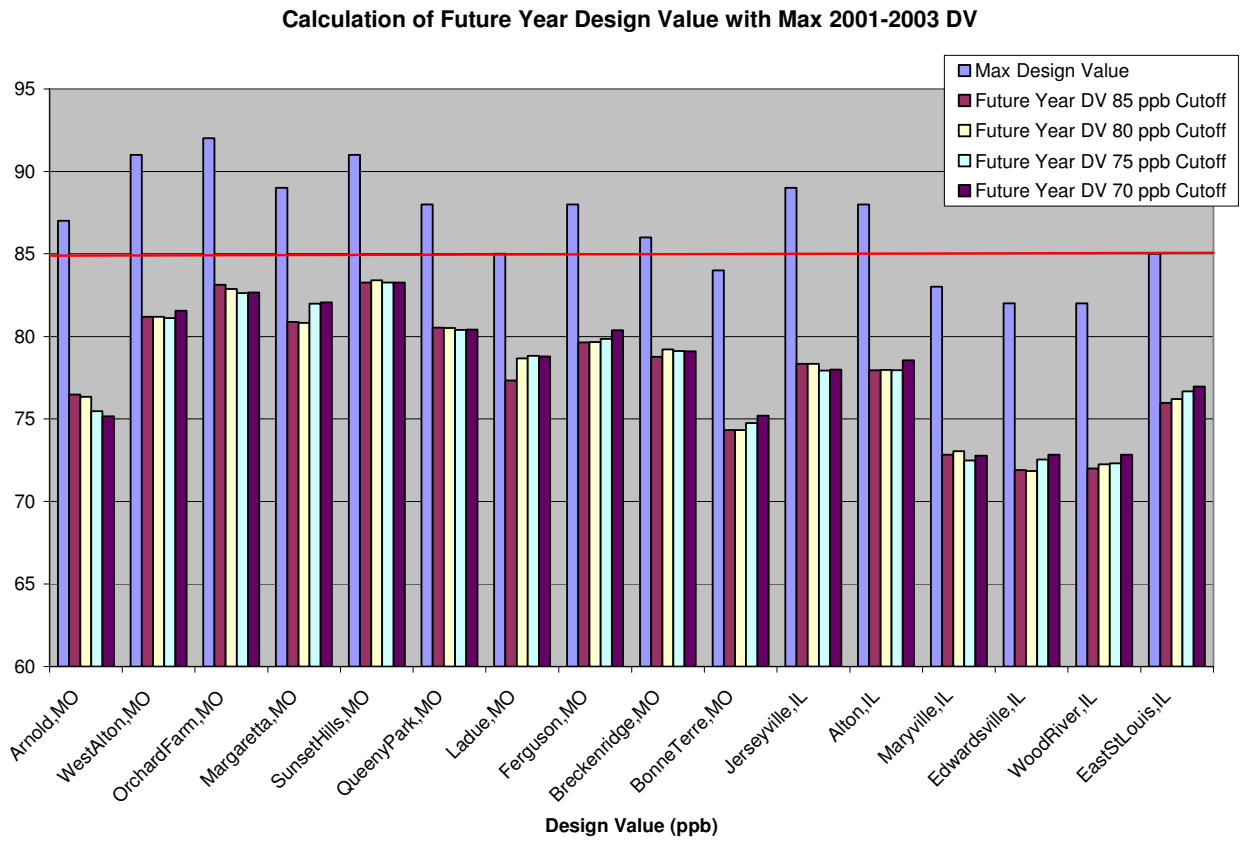


Figure 6-3. Future year design values based on the maximum design values for the 2000-2002, 2001-2003, 2002-2004 time periods calculated separately

6.5 INDEPENDENT CORROBORATIVE MODELING ANALYSIS

Other groups have independently modeled St. Louis for current and future-years and perform design value projections. In particular, modeling performed by EPA as part of the CAIR and by LADCO as part of the MRPO regional modeling have also made 2008 design value projections for St. Louis. Although these other modeling studies may not of necessarily follow all of the EPA SIP modeling recommendations and may not be "SIP quality," it is still useful to compare them with the St. Louis Study results to see whether they corroborate the 8-hour ozone attainment demonstration test.

6.5.1 EPA Interstate Air Quality Rule CAMx Modeling

EPA performed air quality modeling of the Eastern United States in support of the Interstate Air Quality Rule (EPA 2004). CAMx was run on a 36/12 km domain for a 2001 base year and 2010 and 2015 base scenarios for three summer episodes. The St. Louis NAA was located within the 12 km grid of this simulation. The future year base scenarios used only on-the-books controls, consistent with the St. Louis modeling presented in Sections 1 through 5 of this TSD. Because CAIR modeled the 2001 calendar year, then the starting point for the CAIR 2010 design value projections was the 5-year baseline design value for 1999-2003, rather than 2000-2004 used in the St. Louis study.

Table 6-4 summarizes the results of the CAIR modeling projected 8-hour ozone design values analysis for the St. Louis NAA monitors. All four monitors used in this analysis (Arnold, West

Alton, Sunset Hills, and Margaretta) have 2001 5-year baseline design values that exceed the NAAQS. The future year design values for 2010 and 2015 attain the NAAQS for all four monitors, and are, in fact, all less than 82 ppb. The results of the CAIR modeling are therefore consistent with the conclusion from the present study that the St. Louis NAA will achieve attainment of the 8-hour ozone NAAQS by 2010.

Table 6-4. Modeled Design Values from CAIR for St. Louis Area Monitors from the Technical Support Document for the Interstate Air Quality Rule Air Modeling Analyses (EPA 2004)

Monitor Number	Monitor	Ambient 2000-2002 DV	IAQR Modeled Design Values	
			2010 Base DV	2015 Base DV
290990012	Arnold	86	75	72
291831002	West Alton MO	90	81	78
291890004	Sunset Hills MO	89	81	78
295100086	Margaretta MO	88	80	77

6.5.2 Lake Michigan Air Directors Consortium CAMx Modeling

LADCO has conducted modeling of the summers of 2001-2003 using CAMx on a 36/12 km grid (Koerber 2006). The 12 km grid included the St. Louis NAA. LADCO used OTB control measures to project ozone design values for 2009. Figure 6-4 shows the observed 2002 and projected 2009 design values for the 12 km grid domain. For the 2009 future year, all grid cells in the St. Louis NAA have design values less than 85 ppb. One grid cell had a design value greater than 82 ppb and less than 85 ppb; this is the grid cell that contains St. Louis City. All other grid cells in the St. Louis NAA had design values less than 82 ppb. The St. Louis NAA is therefore shown to reach attainment of the NAAQS by 2009; this result is consistent with the results of the St. Louis attainment test described in Section 5.

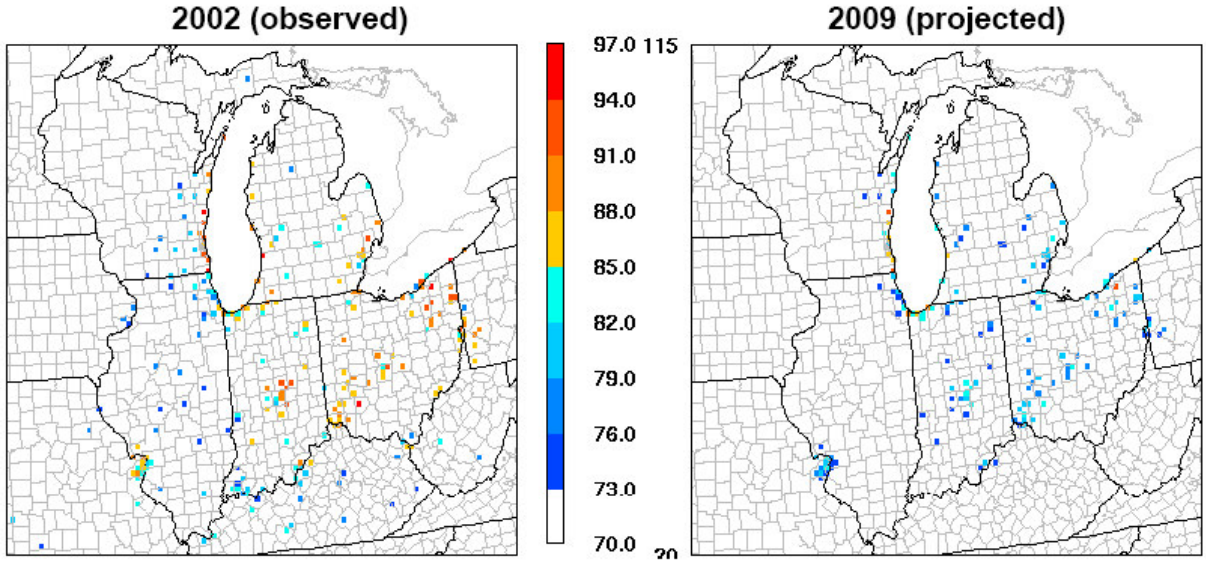


Figure 6-4. Projected 2009 8-hour ozone Design Values as presented by Mike Koerber, Lake Michigan Air Directors Consortium (LADCO) October 31, 2005 "Regional Air Quality Planning for the Upper Midwest: Attainment Strategy options".

6.6 COMPARISONS OF 2002/2009 EMISSION REDUCTIONS WITH OTHER STUDIES

In this section, we compare the 2002/2009 emission inventory reductions in the St. Louis 8-Hour Ozone and $PM_{2.5}$ Modeling Study emissions inventory with similar base/ future year reductions in inventories from similar studies. Table 6-5 is a summary of the 2002 and 2009 anthropogenic emission inventories for the St. Louis NAA. Significant reductions in emissions are expected between 2002 to 2009. For a typical summer weekday, CO emissions are reduced by 19%, NOx emissions by 27%, and VOC emissions by 19%. The largest reductions are in the on-road mobile source VOC (44%) and NOx (47%) categories. These onroad mobile source reductions between 2002 and 2009 drive the St. Louis attainment demonstration. We compare these emissions reductions to those seen in other recent SIP modeling studies to determine whether the St. Louis NAA emissions reductions are similar in magnitude as calculated in other studies.

Table 6-5. St. Louis 2002 and 2009 Total Anthropogenic Emissions for a Typical Summer Weekday (tons per day)

St. Louis	CO	NOx	VOC
2002 Weekday	2291	526	320
2009 Weekday	1845	383	260
% Change 2002 to 2009	-19%	-27%	-19%

ODEQ 8-Hour Ozone Early Action Compact SIP: ENVIRON performed the necessary meteorological, emissions and photochemical modeling needed to develop an 8-hour ozone Early Action Compact (EAC) State Implementation Plan (SIP) for Tulsa and Oklahoma City (Morris et al. 2005a). The MM5 meteorological, EPA emissions and CAMx photochemical models were used to simulate an August 1999 episode. Link-based VMT data for the Tulsa and Oklahoma City were used along with MOBILE6 to generate on-road mobile source emissions. GLOBEIS was used to generate biogenic emissions. 1999 Base Case and sensitivity simulations were performed along with 2007 Base Case, sensitivity and control strategy simulations. Total anthropogenic emissions for a typical summer weekday in Tulsa and Oklahoma City are given in Tables 6-6 and 6-7 for 2002, 2007, and 2012. Comparisons with the St. Louis 2002/2009 changes in anthropogenic emissions show that for VOCs, the 2002/2009 reduction in St. Louis (-19%) is larger than the 2002/2007 and 2002/2012 reductions seen in Tulsa, but falls between the Oklahoma City 2002/2007 (-6%) and 2002/2012 (-38%) reductions. For NOx, the 27% reduction seen in St. Louis is larger than the 2002/2012 change in either Tulsa (-17%) or Oklahoma City (-26%). For CO, the St. Louis 2002/2009 reduction of -19% falls between the Tulsa 2002/2007 (-13%) reduction and the Tulsa 2002/2012 reduction (-23%). The St. Louis CO reduction is larger than, but comparable to the Oklahoma City 2002/2012 CO reduction of -16%. In summary, the 2002/2009 emissions reductions are comparable to emissions reductions for 2002/2007 and 2002/2012 for Tulsa and Oklahoma City. The use of reformulated gasoline may explain why St. Louis is achieving greater mobile source emission reductions.

Table 6-6. Summary of Total Anthropogenic Emissions for a Typical Summer Weekday in the Tulsa Area for 2002, 2007 and 2012 (tons per day)

Tulsa	CO	NOx	VOC
2002 Weekday	712	227	114
2007 Weekday	622	208	105
2010 Weekday	551	189	100.5
% Change 2002 to 2007	-13%	-8%	-8%
% Change 2002 to 2012	-23%	-17%	-12%

Table 6-7. Summary of Total Anthropogenic Emissions for a Typical Summer Weekday in the Oklahoma City Area for 2002, 2007 and 2012 (tons per day)

Oklahoma City	CO	NOx	VOC
2002 Weekday	858	184	224
2007 Weekday	774	167	210
2010 Weekday	720	135.4	138
% Change 2007	-10%	-9%	-6%
% Change 2012	-16%	-26%	-38%

Early Action Compact Study in Denver Front Range Region: ENVIRON/Alpine performed an 8-hr ozone photochemical modeling attainment demonstration as part of the Denver-Front Range Early Action Compact (EAC) Study. A state-of-science air quality modeling system (EPSx/MM5/CMAx) was applied for several ozone episodes during the summer of 2002 over the central Colorado region (Morris et al., 2004d). A summary of the current and future year emission inventories is given in Table 6-8.

Table 6-8. 2002 and 2007 Base Case VOC and NOx Emissions on the Denver Metropolitan Area and Weld County Regions (typical summer weekday and county specific emissions in tons per day) from Morris et al., (2004d)

	VOC Emissions (tpd)			NOx Emissions (tpd)		
Category	2002	2007	(%)	2002	2007	(%)
Point	192	203	+5.8%	105	107	+1.9%
Area	95	104	+9.5%	26	28	+7.8%
Non-Road	75	54	-28.1%	88	83	-6.2%
On-Road	139	102	-26.2%	144	107	-25.6%
Total	501	463	-7.4%	363	325	-10.3%

Comparison with the St. Louis 2002/2009 changes in anthropogenic emissions show that for VOCs, the 2002/2009 reduction in St. Louis (-19%) is larger than the 2002/2007 reduction seen in Denver (-7.4%). We would expect the St. Louis reductions to be larger than the Denver reductions, given the longer time span. Note that the 2002/2007 Denver VOC reduction is comparable to the Tulsa (-8%) and Oklahoma (-6%) 2002/2007 VOC reductions. For NOx, the situation is similar. The 2002/2009 St. Louis NOx reduction (-27%) is larger than the Denver 2002/2007 NOx reduction (-10%), and the Denver reduction is comparable to the 2002/2007 Tulsa (-8%) and Oklahoma City (-9%) reductions. As is the case with the St. Louis future year emissions scenario, on-road mobile sources make the largest contribution to NOx emissions reductions in the Denver area. For VOCs, the largest reductions come from non-road and on-road mobile sources. The Denver area 2002/2007 emissions reductions, therefore, seem

consistent with both the Tulsa/Oklahoma City and St. Louis future year emissions reductions.

Dallas-Fort Worth Ozone Control Strategy Modeling: ENVIRON performed emissions air quality modeling of the Dallas-Forth Worth (DFW) area in order to evaluate the effect of a series of control strategies as part of the DFW 8-hour ozone SIP development. As part of this modeling effort base year (1999) and 2009 future year emission inventories were developed. Tables 6-9 and 6-10 summarize the change in anthropogenic NOx and VOCs in going from 1999 to 2009. Because the base case year is 1999 rather than 2002, it is difficult to compare the DFW and St. Louis NAA emissions reductions directly. However, we note that DFW, like St. Louis, undergoes a large 1999/2009 reduction in on-road mobile source emissions (denoted "mobile" in Tables 6-9 and 6-10), showing a 56% reduction in NOx and a 46% reduction in VOCs.

Table 6-9. 1999 and 2009 Anthropogenic NOx Emissions in the Dallas-Fort Worth Area (typical summer weekday emissions in tons per day) from Tai and Yarwood, (2006)

NOx	Mobile	Elev. Pts	Low Pts	Area	Off-Road	Anthro
1999	485	199	4	53	166	907
2009	212	76	10	67	123	489
% Change	-56%	-62%	167%	27%	-26%	-46%

Table 6-10. 1999 and 2009 Anthropogenic NOx Emissions in the Dallas-Fort Worth Area (typical summer weekday emissions in tons per day) from Tai and Yarwood, (2006)

VOC	Mobile	Elev. Pts	Low Pts	Area	Off-Road	Anthro
1999	189	16	22	191	70	488
2009	103	34	22	216	45	419
% Change	-46%	109%	-1%	13%	-37%	-14%

ASIP 8-Hour Ozone Modeling

ENVIRON and Alpine Geophysics are conducting emissions and air quality modeling support for the ASIP (Association for Southeastern Integrated Planning States) 8-hour ozone SIP (ENVIRON and Alpine, 2006). Table 6-11 shows the 2002/2009 on-road mobile source reductions for the state of Missouri from the ASIP Base G emissions inventory. The ASIP on-road emissions in Table 6-22 are reported by state, so we may expect the on-road mobile source reductions in the St. Louis NAA to be somewhat larger on a percentage basis than for the whole of Missouri due to the presence of additional controls. This is because of the inspection/maintenance and reformulated gas programs that are in effect in the St. Louis NAA, but not in the remainder of Missouri. The 2002/2009 reduction in the ASIP on-road mobile source VOC inventory is 29%, compared to a 44% reduction in the St. Louis modeling. For NOx, the ASIP 2002/2009 reduction is 39%, while the St. Louis modeling reduction is 47%. The NOx reductions are roughly comparable, while the VOC reduction is significantly larger for the St. Louis NAA; it is not clear how much of the discrepancy in the VOC reduction is due to the additional controls in the St. Louis NAA.

Table 6-11. 2002 and 2009 Onroad Mobile Source Emissions in the State of Missouri from the ASIP Base G Emission Inventory (tons per day) (ENVIRON and Alpine, 2006)

On-Road Mobile	VOC	NOx
2002	112542	190017
2009	79447	116246
% Change	-29%	-39%

In summary, the 2002/2009 emissions reductions in the St. Louis Ozone Modeling Study are roughly comparable in magnitude as well as type when compared to similar studies, with the largest reductions in NOx and VOCs coming from on-road mobile sources.

6.7 OZONE SOURCE APPORTIONMENT MODELING

In this section, we describe CAMx ozone source apportionment modeling for St. Louis. The CAMx ozone source apportionment tool (OSAT) provides a method for estimating contributions of multiple source areas, categories, and pollutant types to ozone formation in a single CAMx model run. OSAT uses multiple tracer species to track the fate of ozone precursor emissions (VOC and NOx) from multiple source groups (e.g., St. Louis on-road mobile sources) and the ozone formation caused by emissions from each source group. The tracers track the effects of chemical reaction, transport, diffusion, emissions and deposition. Ozone formed within the modeled domain is allocated to either NOx or VOC sources depending on whether ozone is formed under NOx-limited or VOC-limited conditions. OSAT estimates the fractions of ozone arriving at the receptor that were formed en-route under VOC- or NO_X-limited conditions. Tracers measuring ozone formation under VOC limited conditions are denoted by O3V, and tracers of ozone formation under NO_X limited conditions are denoted by O3N. O3V (O3N) is formed in proportion to local dO_3/dt weighted by the distribution of VOC (NOx) precursors.

CAMx boundary conditions and initial conditions are tracked as separate source groups. Since there is no way of determining whether the ozone in the boundary and initial conditions was formed under VOC or NO_X limited conditions, this ozone is divided equally between O3N and O3V tracers. However, subsequent ozone formation within CAMx from boundary and initial condition VOCs and NO_X is allocated to O3V and O3N tracers on the basis of whether ozone formation occurred under VOC or NO_X limited conditions

For the St. Louis Ozone modeling, ozone source apportionment was carried out for Episode 3 (July 29 – August 5, 2002) using 2002 Base 1 emissions. Episode 3 was chosen for the OSAT analysis because it was one of the episodes that the model performed best. The 36/12 km grid configuration was used for the OSAT run; the 4 km grid was not used in this simulation, as inclusion of the high resolution grid would have imposed an excessive computational burden. The 15 geographic source regions used are shown in Figure 6-5. The source regions are:

- St. Louis Nonattainment Area (Missouri Side)
- St. Louis Nonattainment Area (Illinois Side)
- Missouri (Remainder) & Illinois (Remainder)
- Indiana (IN); Kentucky (KY); Tennessee (TN)
- Nebraska (NB); Iowa (IA); East; West
- Arkansas (AR); Texas (TX); Oklahoma (OK)

Three source categories were used in the OSAT analysis: (1) Biogenic sources; (2) Point source emissions; (3) low-level anthropogenic emissions. The contribution of each of the three source categories was calculated for each source region, and the contribution of the initial and boundary conditions was determined as well. Therefore, a total of 47 source groups (15 x 3 + 2) were tracked during the OSAT analysis. Once the CAMx OSAT simulation for Episode 3 was complete, ozone contributions were extracted for the St. Louis ozone NAA. Daily and episode average ozone contributions to St. Louis NAA ozone were calculated for times when the daily maximum 8-hour ozone concentrations exceeded 85 ppb. Ozone formed was allocated to NOx or VOC sources depending on whether ozone formation in the grid cell where the ozone was NOx-limited or VOC-limited.

Figure 6-6 shows the episode average contribution to the St. Louis NAA ozone when the value of the 8-hour daily maximum ozone was greater than 85 ppb. Contributions are shown by source category for each source region. Similar plots for the daily average OSAT results are shown in Figures 6-7 through 6-15, and their results are consistent with the episode average shown in Figure 6-6. In the discussion that follows, we focus on the episode average results. The regions making the largest contributions to St. Louis NAA ozone are those in its immediate vicinity. The St. Louis region lying within Missouri makes the largest contribution, followed by the Illinois St. Louis region, the remainder of Missouri, and the remainder of Illinois. Nearby states (KY, TN, AR, TX, OK) contribute 1-3 ppb or less to St. Louis ozone during Episode 3. Note that the use of the relatively coarse 36/12 km grid configuration tends to downplay the effects of local sources; despite this, the St. Louis area still makes the largest contribution to its own ozone concentrations on high ozone days. This episode represents a semi-stagnation event and does not fully capture the predominant transport regimes (Ohio River Valley, southeast, southwest) into the St. Louis area. This indicates that multi-state transport into St. Louis was not represented to the extent normally seen during transport episodes evaluated in the attainment demonstration.

The total average ozone over the St. Louis NAA for the episode was 96 ppb when considering only days when the daily 8-hour maximum was greater than 85 ppb. Averaged over the episode and across all source regions, low-level anthropogenic sources (i.e. mobile sources, area sources, etc.) were the largest contributor, making up 45 ppb (47%) of the total contribution. Biogenic emissions made the second largest contribution (23 ppb, 24%), followed by elevated point source emissions (12 ppb, 13%) and initial conditions (12 ppb, 12%). We note that OSAT allocates approximately 9 ppb ozone to biogenic sources in Missouri. Boundary conditions were the smallest contributor, with 4 ppb (4%). The large contribution of the initial conditions is an artifact introduced by commencing the OSAT simulation without a spin-up period. The contribution of the initial conditions decreases as the episode days pass (Figures 6-8 through 6-15), and the overstatement of the contribution of the initial conditions should not bias the results unduly.

Figure 6-7 is a breakdown of the episode average contribution for each source region showing how much of its ozone contribution was formed under NOx-limited and VOC-limited conditions. For the St. Louis source regions (both Missouri and Illinois), the preponderance of ozone is formed under NOx-limited (81 %) rather than VOC-limited (19 %) conditions. For nearly all of the rest of the source regions, most of the ozone is formed under NOx-limited conditions. The exception is the remainder of Missouri, for which biogenics (i.e. biogenic VOCs) constitute more than half of its total contribution to St. Louis ozone. The boundary and initial conditions are evenly partitioned between NOx-limited and VOC-limited formation, reflecting the assumption of equal division between O3N and O3V tracers discussed above.

The results of the St. Louis Episode 3 OSAT analysis may be summarized as follows:

- Based on OSAT, ~60% of ozone in St. Louis NAA is "anthropogenic" in origin.
- Local emissions in the St. Louis NAA are the largest contributor (~51%) to its own ozone on high ozone days.
- This ozone is primarily (80%) from low-level anthropogenic sources.
- Ozone is primarily (81%) formed under NOx-limited conditions.
- The next most important sources are other emissions in the remainder (i.e. regions outside St. Louis) of Illinois and Missouri (25%).

We now compare the results of the St. Louis ozone modeling OSAT analysis with the results of a similar study performed during the course of the Five States Stakeholder Modeling (Alpine and ENVIRON, 2006). The Five States Stakeholder Group performed additional modeling to complement the modeling performed by the MRPO/LADCO. They used the CAMx OSAT tool and calculated source region contributions to the St. Louis area during June-August 2002. The modeling was done on a 36/12 km grid using CAMx V4.30. 2009 On-The-Books Base Case Emissions were used. The 26 source regions used in this analysis are shown in Figure 6-16. The following six source categories were used: biogenic, electrical generating unit (EGU), non-EGU Point, on-road mobile, non-road mobile, and area sources. The Five States Stakeholder OSAT analysis results are summarized in Figure 6-17.

As in the present study, St. Louis is the largest contributor to its own 8-hour ozone concentrations. The St. Louis area contribution was typically 25-45 ppb, averaging out to approximately 40 ppb. On-road mobile sources constituted the largest St. Louis source category, contributing more than 50% of the total ozone. EGUs were the second largest contributor to St. Louis area ozone followed by area, non-EGU point sources, and non-road sources. The remainder of southern Illinois and the remainder of Missouri source regions are the next largest contributors after St. Louis. The results of the Five States Stakeholder OSAT analysis suggest that local controls in Missouri and Illinois would be most cost-effective, and are consistent with the results of the present study. In addition, the results clearly indicate that NOx is a primary contributor to elevated ozone concentrations in the St. Louis area and the NOx controls evaluated in the attainment demonstration are necessary and beneficial to attainment of the 8-hour ozone standard.

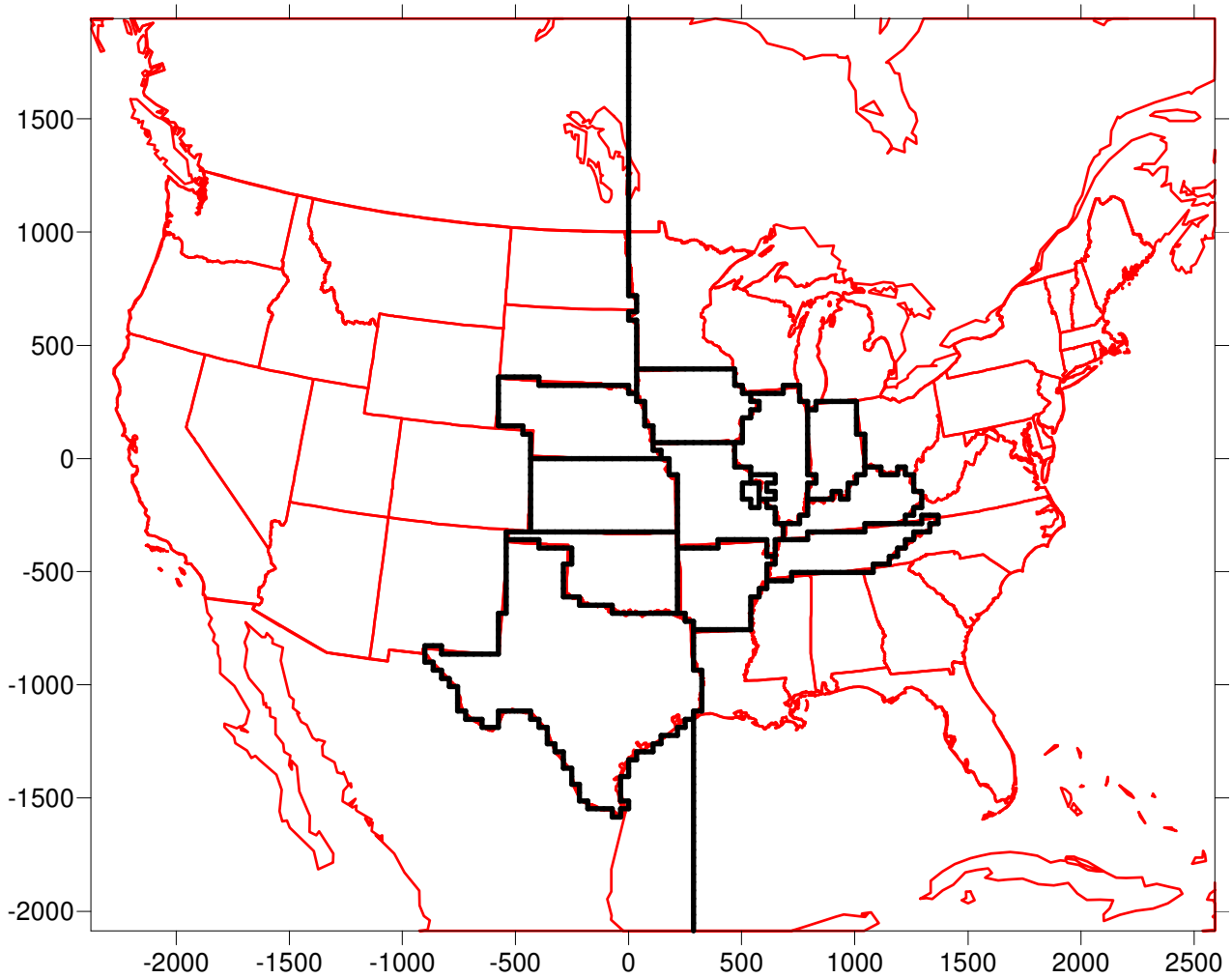


Figure 6-5. Source regions for ozone source apportionment in the St. Louis Modeling Study.

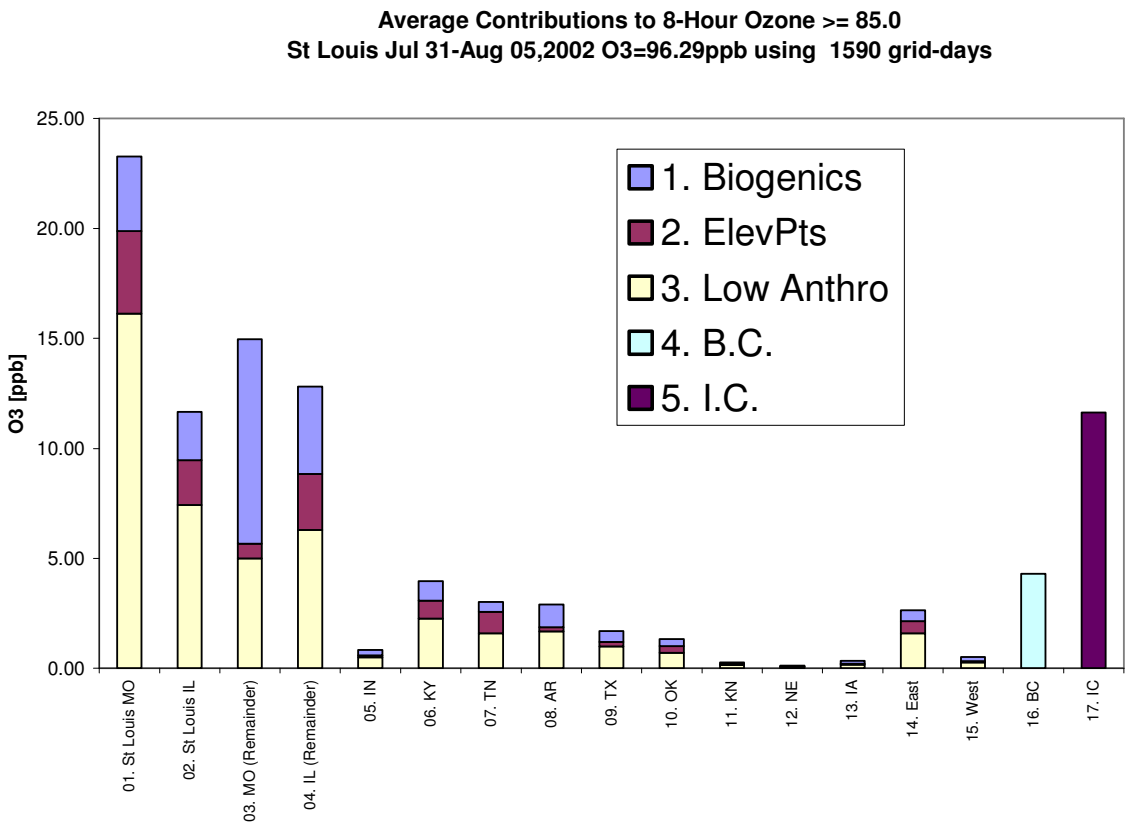


Figure 6-6. Average contribution from each source region to St. Louis 8-hour ozone ≥ 85 ppb for Episode 3.

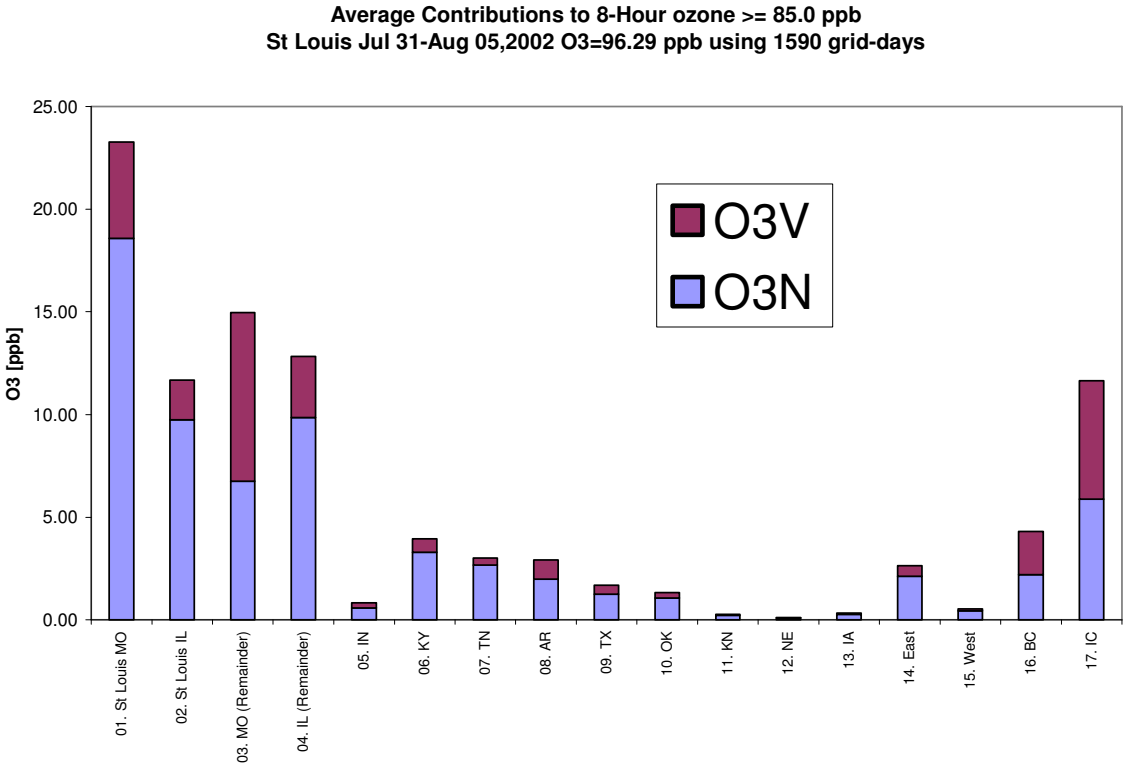


Figure 6-7: Average contribution from each source region to St. Louis 8-hour ozone ≥ 85 ppb for Episode 3. Dark red portion of bar represents contribution ozone formed under VOC-limited conditions, and light blue portion of bar represents the contribution from ozone formed under NOx-limited conditions.

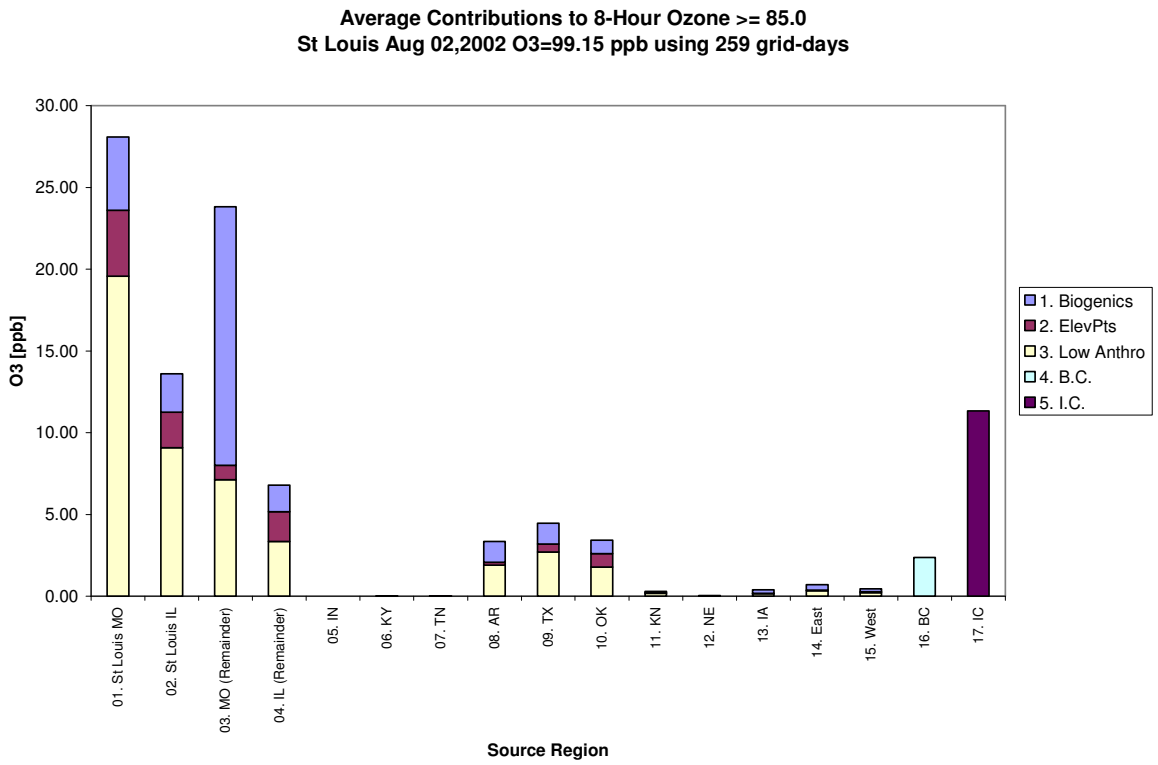


Figure 6-8. Average contribution from each source region to St. Louis 8-hour ozone ≥ 85 ppb for August 2.

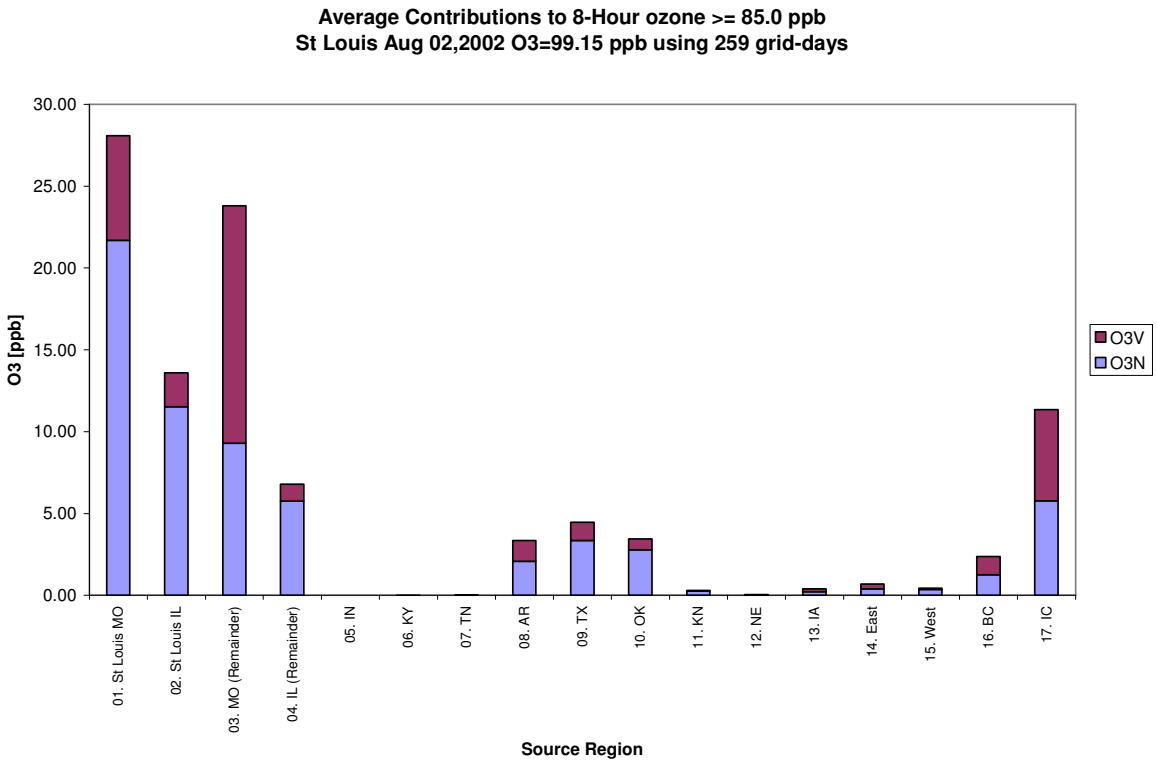


Figure 6-9. Average contribution from each source region to St. Louis 8-hour ozone ≥ 85 ppb for August 2. Dark red portion of bar represents contribution ozone formed under VOC limited conditions, and light blue portion of bar represents the contribution from ozone formed under NOx-limited conditions.

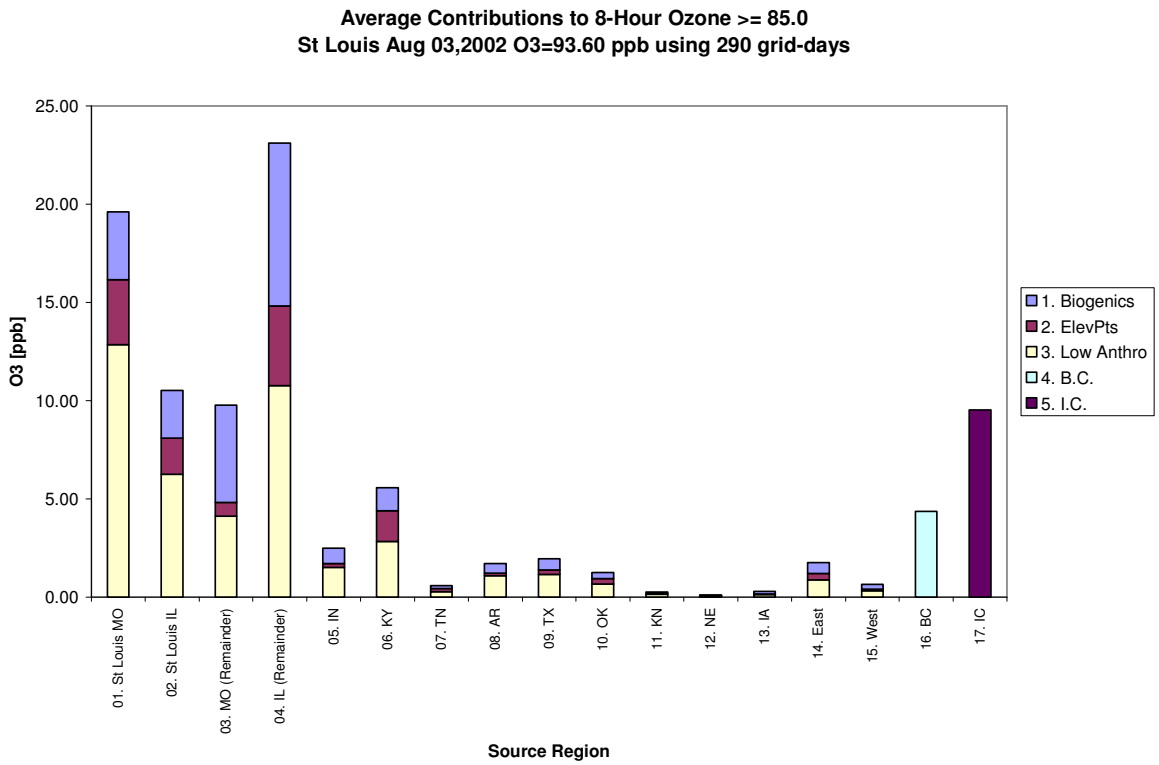


Figure 6-10. Average contribution from each source region to St. Louis 8-hour ozone ≥ 85 ppb for August 3.

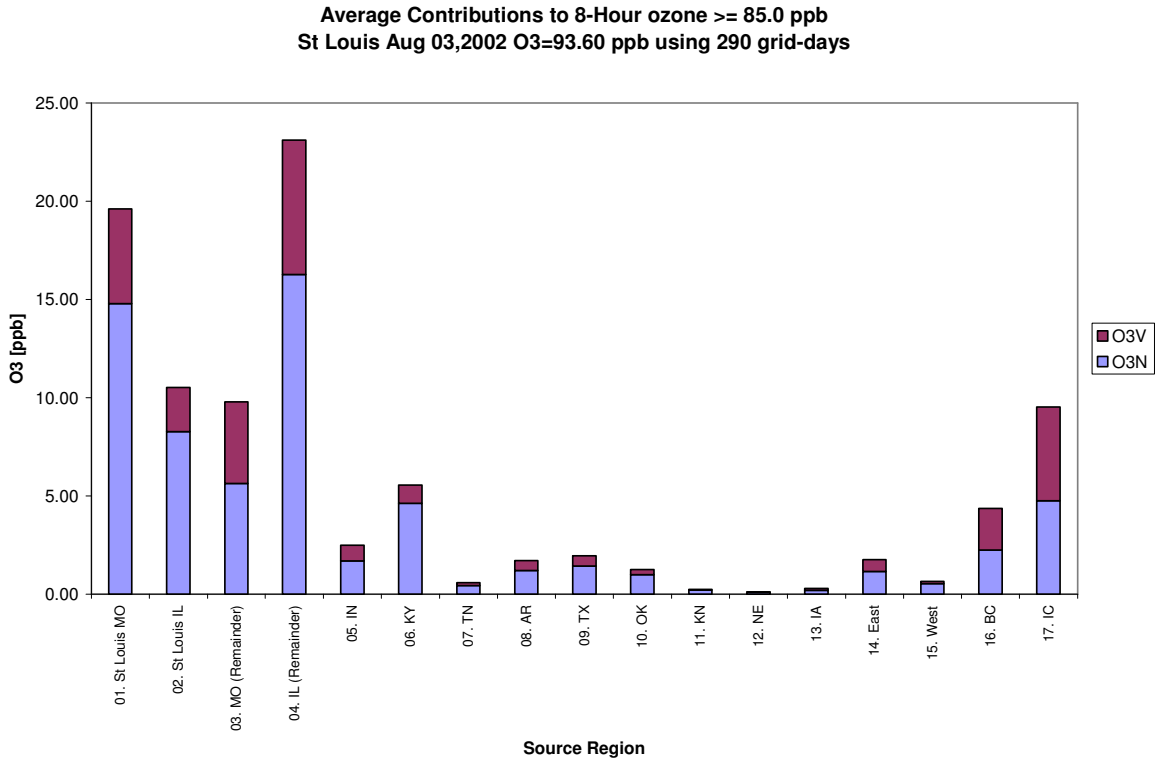


Figure 6-11. Average contribution from each source region to St. Louis 8-hour ozone ≥ 85 ppb for August 3. Dark red portion of bar represents contribution ozone formed under VOC limited conditions, and light blue portion of bar represents the contribution from ozone formed under NOx-limited conditions.

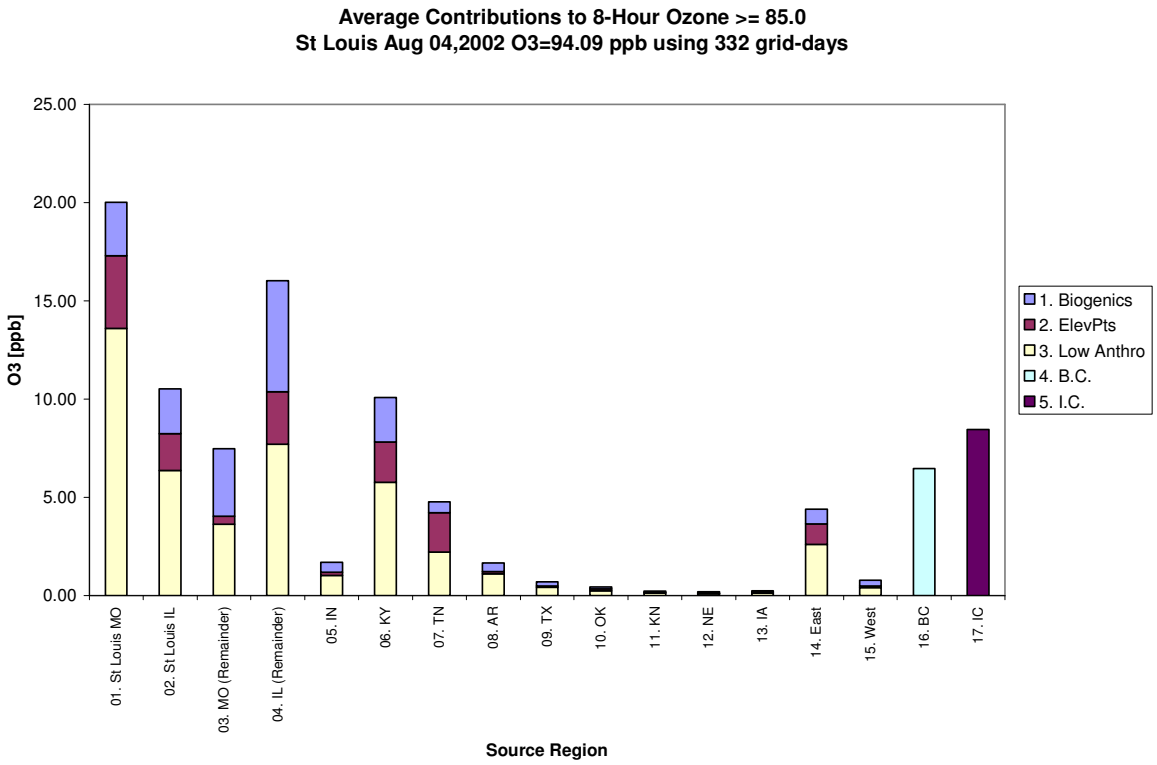


Figure 6-12. Average contribution from each source region to St. Louis 8-hour ozone ≥ 85 ppb for August 4.

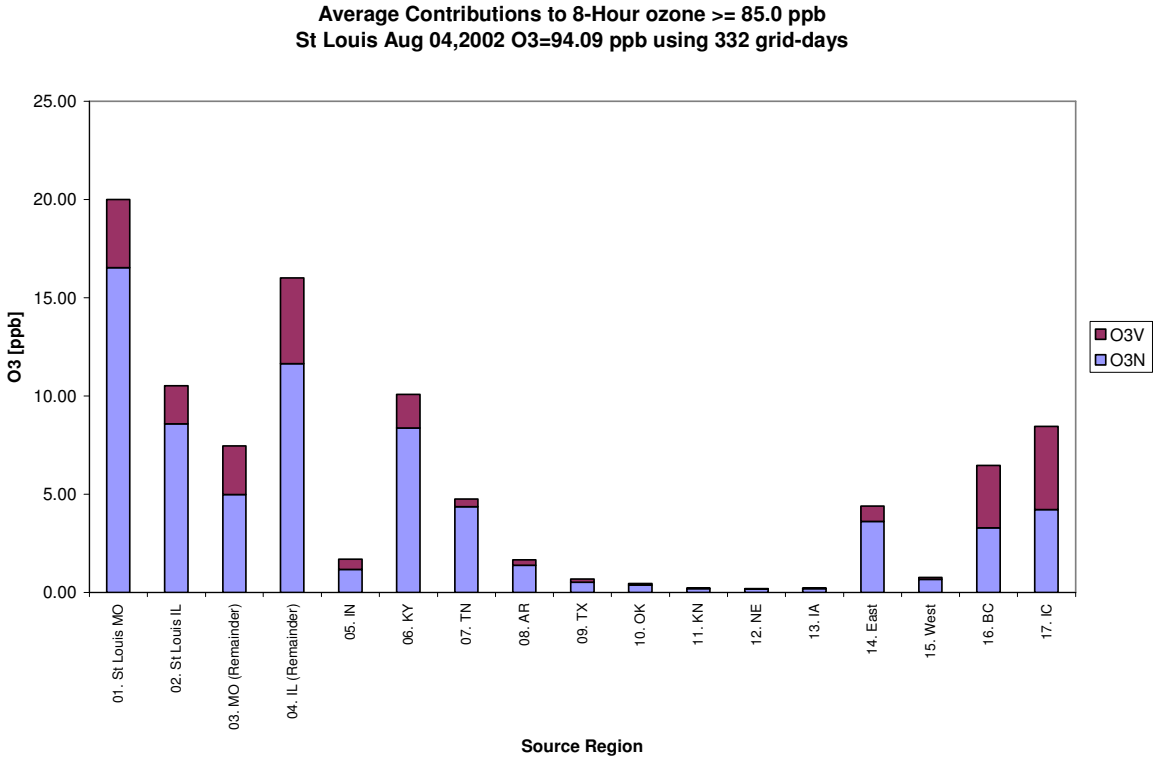


Figure 6-13. Average contribution from each source region to St. Louis 8-hour ozone ≥ 85 ppb for August 4. Dark red portion of bar represents contribution ozone formed under VOC limited conditions, and light blue portion of bar represents the contribution from ozone formed under NOx-limited conditions.

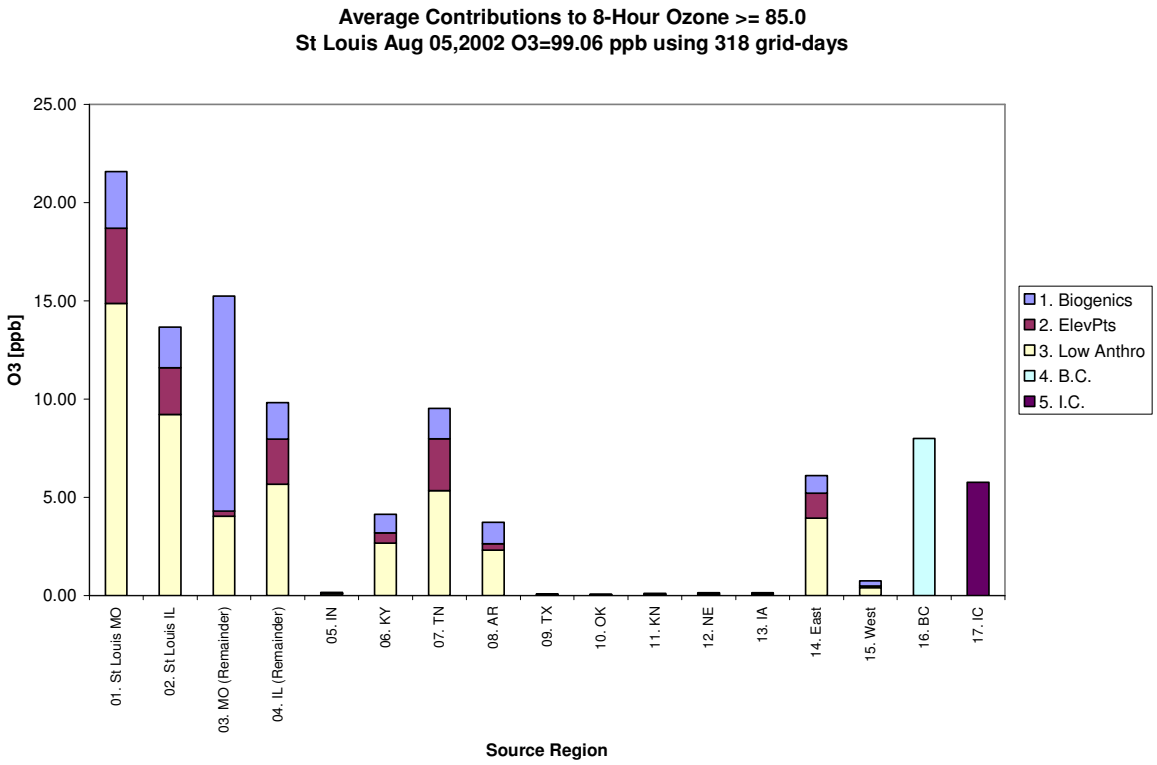


Figure 6-14. Average contribution from each source region to St. Louis 8-hour ozone ≥ 85 ppb. August 5.

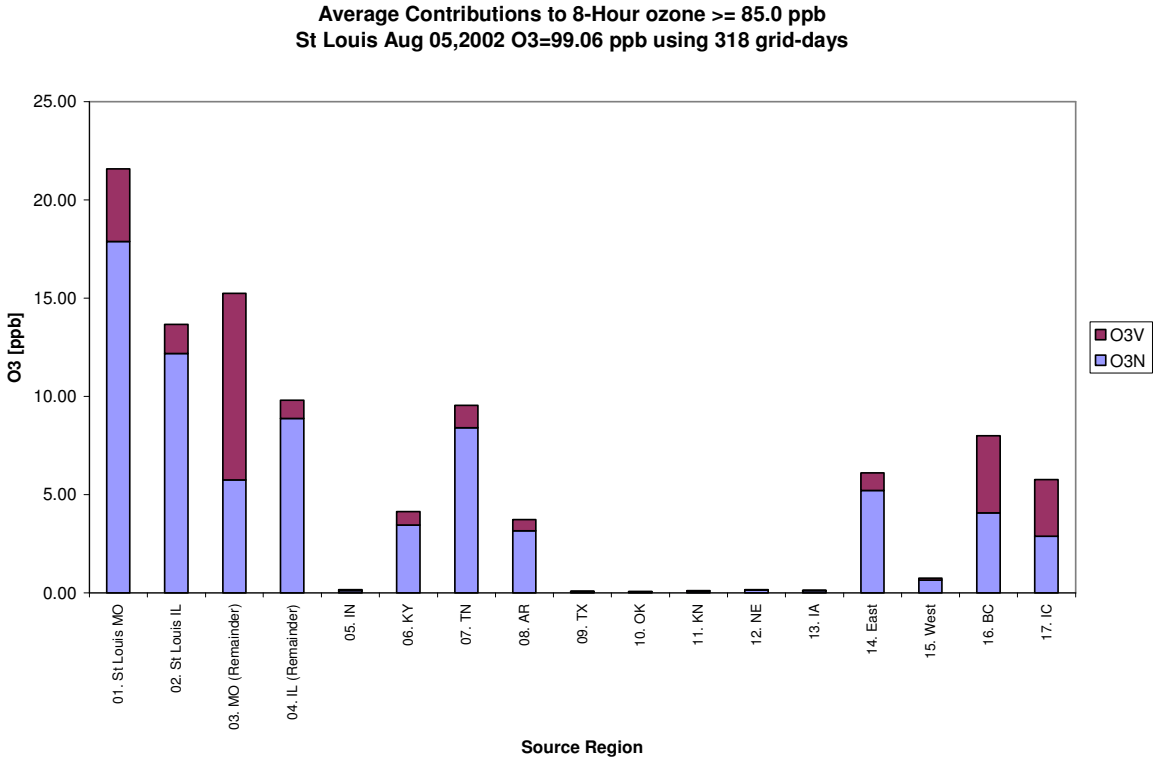


Figure 6-15. Average contribution from each source region to St. Louis 8-hour ozone ≥ 85 ppb for August 5. Dark red portion of bar represents contribution ozone formed under VOC limited conditions, and light blue portion of bar represents the contribution from ozone formed under NOx-limited conditions.

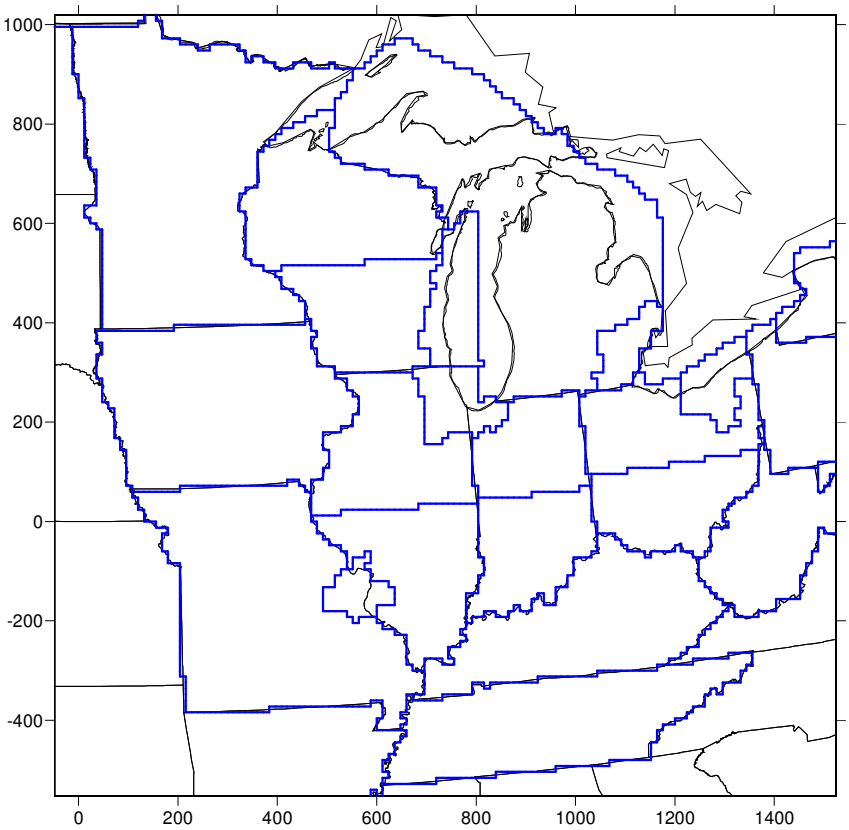


Figure 6-16. Source regions for ozone source apportionment used in the 5-State Stakeholder Study OSAT analysis.

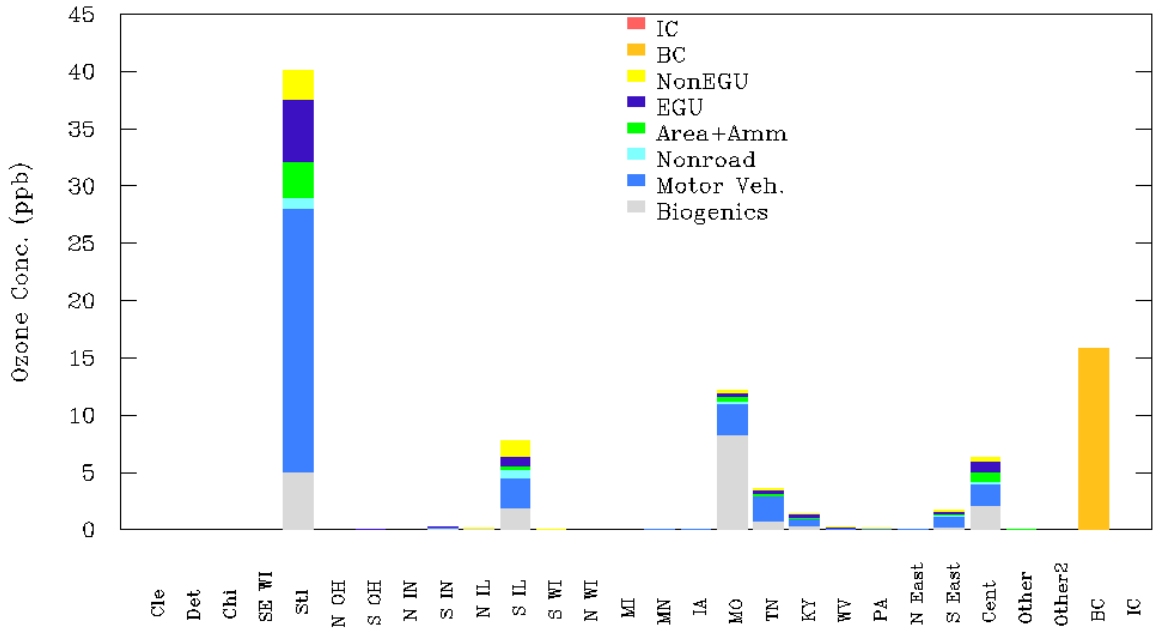


Figure 6-17. 5 State Stakeholder OSAT Study St. Louis June-August average contribution to 8-hour ozone > 85 ppb

6.8 TRENDS IN AMBIENT AIR QUALITY

The trends in 8-hour ozone ambient air quality concentration for the St. Louis area continue on a downward trend since the middle 1990s. This trend is demonstrated effectively in Figure 6-18 that shows not only the 8-hour design value trend, but also the number of ozone conducive days in the St. Louis area. This is designed to understand the impact of meteorology on the overall design value for the area. The more recent trends are illustrated on a monitor-specific basis in Table 6-12 and again demonstrate decreasing design values. These trends clearly are consistent with the other weight of evidence analysis that supports the conclusion that St. Louis will attain the 8-hour ozone standard by 2009.

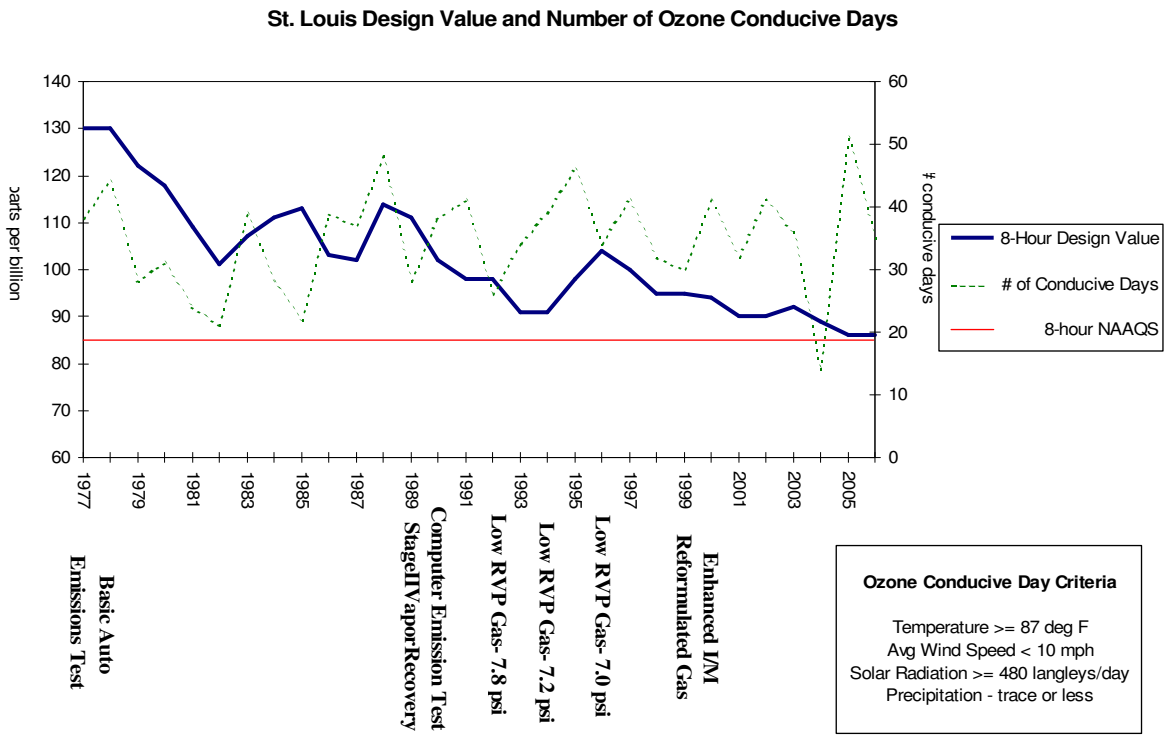


Figure 6-18. St. Louis 8-Hour Ozone Design Value and Number of Ozone Conducive Days

Figure 6-19 illustrates the trend in the 8-hour ozone design values at individual monitors for selected critical monitors. The Arnold, West Alton, Sunset Hills, and St. Ann/Breckenridge sites provide geographic diversity of some of the longest running monitors in the St. Louis area. This trend is supportive of the conclusion that St. Louis will attain the 8-hour ozone standard by 2009.

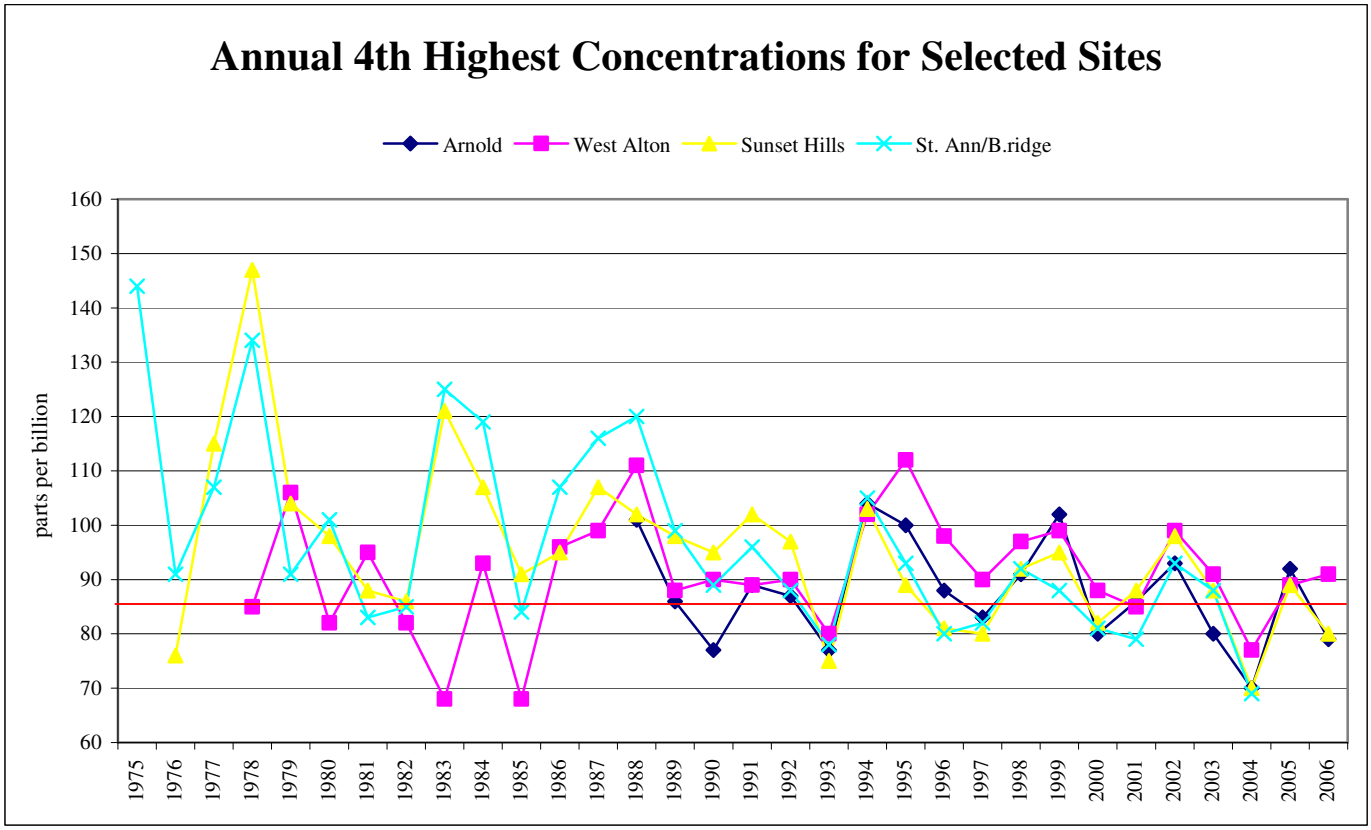


Figure 6-19. Trend in 8-hour ozone design values at selected monitoring sites.

Table 6-12. Monitor-specific Design Value Trends

	8-hour Design Values								
ST. LOUIS MISSOURI	**96-98**	**97-99**	**98-00**	**99-01**	**00-02**	**01-03**	**02-04**	**03-05**	**04-06**
Arnold	87	92	91	89	86	87	81	81	80
West Alton	95	95	94	90	90	91	89	85	85
Orchard Farm	90	90	91	90	90	92	88	86	86
S. Broadway	79	79	81	81	82	83			
Clark	75	78	74	73	73	74	70		
Margaretta	81	83	86	83	88	89	86	84	79
Sunset Hills	84	89	89	88	89	91	85	82	79
Queeny Park	82	85	90	88	88	88	82	78	
Ladue	81	82	83	81	84	85	81		
Ferguson	87	89	88	85	86	88	83		
Breckenridge	84	87	87	82	84	86	83		
Bonne Terre	85	88	90	85	84	83	81	79	77
ILLINOIS									
Alton	86	86	81	82	84	88	85	84	81
Maryville	87	85	82	78	80	83	85	84	81
Wood River	87	85	82	80	80	81	80	81	79
Houston	78	78	80	78	79	79	75	71	70
East St. Louis	76	80	82	82	85	83	81	82	81
Jerseyville	85	91	91	89	89	89	85	79	77
Nilwood	78	83	81	80	80	78	76	74	71
Edwardsville	86	87	86	81	81	82	80		

6.9 TRENDS IN EMISSIONS

- The 1990-2001 emissions data pertaining to Missouri's St. Louis Nonattainment Area were collected from EPA's Air and Radiation's AirData website (http://www.epa.gov/air/data/index.html). The AirData website presents annual emissions summaries from the NEI (National Emission Inventory) database for calendar years 1990, 1996, 1997, 1998, 1999, 2000, and 2001.

The annual 2002 and 2009 emissions data were based on the St. Louis Base 4 2002 typical and 2009 on-the-books emissions for area, offroad mobile, onroad mobile, and point sources. The onroad mobile source data was based on tons per day emissions. Therefore, it was adjusted to tons per year by multiplying it by 365 days.

As shown in Figure 6-20, total anthropogenic NOx and VOC emissions in the St. Louis nonattainment area are decreasing from 1990-2009. This downward trend in ozone precursor emissions supports the conclusion that the region will attain the standard by 2009.

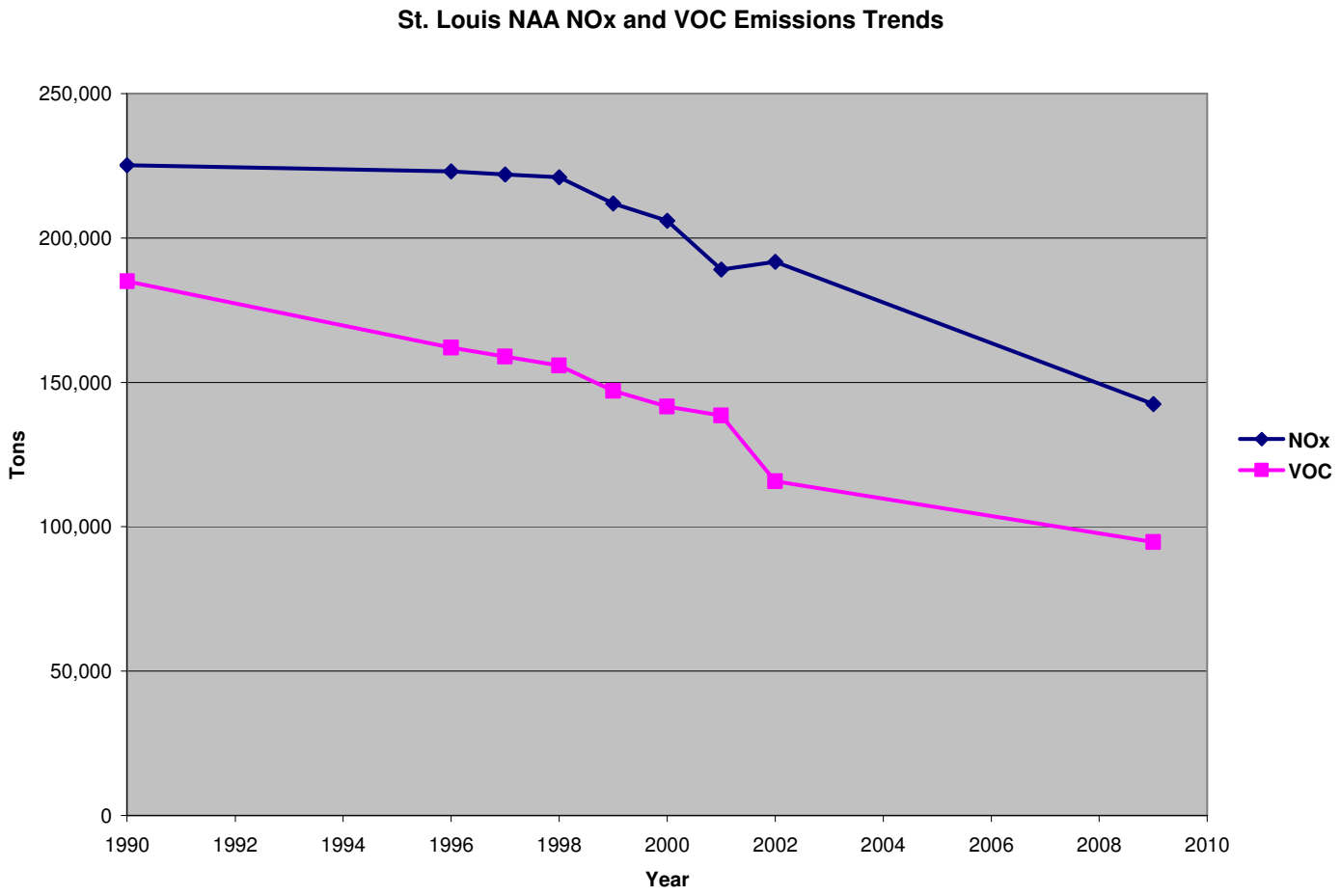


Figure 6-20. 1990 – 2009 trend in anthropogenic NOx and VOC emissions in the St. Louis nonattainment area.

6.10 CONCLUSIONS OF ST. LOUIS WOE

Current air quality, trends in air quality, emission trends, corroborative modeling analysis, additional modeling metrics, and 2009 8-hour ozone design value projections of observed 8-hour ozone DVs for three summer episodes all indicate the St. Louis area will attain the 8-hour ozone standard in 2009. The continued downward trend in emissions in the St. Louis NAA indicates that the 8-hour ozone standard would be maintained after 2009 (see Figure 6-19).

In Sections 1- 5, we have described a fully-evaluated, high quality modeling analysis for the St. Louis Nonattainment Area that projects future (2009) design values that are within the NAAQS. The model performance evaluation presented in Section 4 suggests that the model simulates near-surface ozone concentrations with reasonable fidelity on the high-ozone days used in the attainment demonstration. The design value analysis (Section 5) shows that On the Books Control Strategies are sufficient to bring the St. Louis NAA into attainment by 2009. We ascribe the most weight to this part of the WOE determination, as it includes detailed emission inventories specific to the St. Louis area as well as fully evaluated air quality, emissions, and meteorological modeling databases.

The additional modeling metrics measure how much estimated elevated 8-hour ozone concentrations are reduced from the current year base case by the future-year control strategy.

All three of these metrics were reduced by more than 70%, indicating substantial reductions in future year ozone consistent with the conclusion of attainment reached in the modeled attainment demonstration.

The Independent Corroborative Modeling Analysis showed future year design value projections from two independent modeling studies that forecast that the St. Louis NNA will be in attainment of the NAAQS by 2009 (LADCO) and 2010 (CAIR). Additionally, the CAIR results predict that the St. Louis area will remain in attainment through 2015. Comparison of 2009/2002 emission reductions for the St. Louis NAA with emissions reductions for similar time periods in other comparable studies shows reasonable agreement in both the magnitude and type of reductions, with reductions in on-road mobile sources playing an important role.

The CAMx OSAT analysis showed that local emissions in the St. Louis NAA are the largest contributor to St. Louis ozone on high ozone days, and that this ozone is primarily (80%) from low-level anthropogenic sources (this category include on-road mobile sources). The next most important sources are other emissions in the remainder (i.e. regions outside St. Louis) of Illinois and Missouri (25%).

This analysis suggests that the St. Louis area will be responsive to local controls. The results of the CAMx OSAT analysis are similar to the results of the 5-State Stakeholder OSAT analysis, which was performed independently of the St. Louis modeling effort. As in the present study, St. Louis is the largest contributor to its own 8-hour ozone concentrations. Onroad mobile sources constituted the largest St. Louis source category. The remainder of southern Illinois and the remainder of Missouri source regions were the next largest contributors after St. Louis. The results of the Five States Stakeholder OSAT analysis suggest that local controls in Missouri and Illinois would be most cost-effective, and are consistent with the results of the present study.

The analyses presented above lead to a conclusive determination that the St. Louis area will be in attainment of the NAAQS by 2009. Every one of the analyses presented is consistent in predicting attainment for St. Louis; not a single study suggests that the St. Louis area will not reach attainment. This evidence is overwhelming and conclusive.

7.0 REFERENCES

Alpine and ENVIRON. 2006. 5 States Stakeholder Modeling Ozone Source Apportionment (work in progress).

Amar, P., D. Chock, A. Hensen, M. Moran, A. Russell, D. Steyn, and W. Stockwell. 2005. "Second Peer-Review of the CMAQ Model: Final Report", prepared for the Community Modeling and Analysis System (CMAS) Center, Carolina Environmental Program, University of North Carolina, Chapel Hill, NC

Anthes, R.A. and T.T. Warner. 1978. "The Development of Mesoscale Models Suitable for Air Pollution and Other Mesometeorological Studies", *Mon. Wea. Rev.*, Vol. 106, pp, 1045-1078.

Baker, K. 2004. Presentations on latest MRPO modeling results at November 11, 2004 MRPO meeting in Chicago, Illinois. Available at: www.ladco.org/tech/photo/photochemical.html.

Bennett, J.D., Froning, D.M., Mefrakis, R. 2003. "Technical Support Document for Determination of Nonattainment Boundaries in Missouri for the 8-hr Ozone National Ambient Air Quality Standard."

Boylan, J. W. 2004. "Calculating Statistics: Concentration Related Performance Goals", paper presented at the EPA PM Model Performance Workshop, Chapel Hill, NC. 11 February.

Byun, D.W., and J.K.S. Ching. 1999. "Science Algorithms of the EPA Models-3 Community Multiscale Air Quality (CMAQ) Modeling System", EPA/600/R-99/030.

Byun, D. W., et al. 2005a. "Parallel Computation of the Air Quality Forecasting System for Eastern Texas", prepared by the Institute for Multidimensional Air Quality Studies (IMAQS)-University of Houston, April.

Byun, D. W., et al. 2005b. "Development and Operational Evaluation of the Eastern Texas Air Quality (ETAQ) Forecasting System Based on MM5/SMOKE/CMAQ", presented at the 4th Annual CMAS Models-3 User's Conference, University of North Carolina, Chapel Hill, NC. 26-28. http://cf.cmascenter.org/html/2005_conference/conf_agenda.cfm

Coats, C.J., 1995. "Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System", MCNC Environmental Programs, Research Triangle Park, NC.

Dudhia, J. 1993. "A Non-hydrostatic Version of the Penn State/NCAR Mesoscale Model: Validation Tests and Simulation of an Atlantic Cyclone and Cold Front", *Mon. Wea. Rev.*, Vol. 121. pp. 1493-1513.

Emery, C., E. Tai, and G. Yarwood. 2001. "Enhanced Meteorological Modeling and Performance Evaluation for Two Texas Episodes", report to the Texas Natural Resources Conservation Commission, prepared by ENVIRON, International Corp, Novato, CA.

ENVIRON. 2006. User's Guide – Comprehensive Air-quality Model with extensions, Version 4.4. ENVIRON International Corporation, Novato, California. (http://www.camx.com).

ENVIRON and Alpine. 2006. Preliminary 8-Hour Ozone Projections for the Association for Southeastern Integrated Planning (ASIP). (work in progress).

ENVIRON, Alpine Geophysics, UC Riverside and UC Davis. 2003a. "VISTAS Emissions and Air Quality Modeling – Phase I Task 4a/b Report: Review of Model Sensitivity Simulations and Recommendations of Initial CMAQ Model Configurations and Sensitivity Tests." Revised Draft July 25.

ENVIRON, Alpine Geophysics, UC Riverside and UC Davis. 2003b. "VISTAS Emissions and Air Quality Modeling – Phase I Task 3 Report: Review and Assessment of Available Ambient Air Quality Data to Support Modeling and Modeling Performance Evaluation for the Three VISTAS Phase I Episodes." Revised Draft July 22.

ENVIRON. 2002. "User's Guide Comprehensive Air Quality Model With Extensions (CAMx) Version 3.10." ENVIRON International Corporation, Novato, California (available at www.camx.com) April.

ENVIRON. 2003a. "Development of an Advanced Photochemical Model for Particulate Matter: PMCAMx." ENVIRON International Corporation, Novato, CA. Prepared for Coordinating Research Council, Inc. Project A-30 (available at www.crcao.com).

ENVIRON. 2003b. "VISTAS Emissions and Air Quality Modeling – Phase I Task 2 Report: Recommended Model Configurations and Evaluation Methodology for Phase I Modeling." Prepared by ENVIRON International Corporation, Alpine Geophysics, LLC and University of California at Riverside. Novato, California. (available at: http://pah.cert.ucr.edu/vistas/docs.shtml). August 4.

ENVIRON. 2003c. "VISTAS Emissions and Air Quality Modeling – Phase I Task 3 Report: Review and Assessment of Available Ambient Air Quality Modeling and Performance Evaluation for the Three VISTAS Phase I Episodes." Prepared by ENVIRON International Corporation, Alpine Geophysics, LLC and University of California at Riverside. Novato, California. (available at: http://pah.cert.ucr.edu/vistas/docs.shtml). July 22.

ENVIRON. 2003d. "VISTAS Emissions and Air Quality Modeling – Phase I Task 4a/b Report: Review of Model Sensitivity Simulations and Recommendations of Initial CMAQ Model Configurations and Sensitivity Tests." Prepared by ENVIRON International Corporation, Alpine Geophysics, LLC and University of California at Riverside. Novato, California. (available at: http://pah.cert.ucr.edu/vistas/docs.shtml). July 25.

ENVIRON and Alpine Geophysics, 2005. "Draft Final St. Louis Ozone and $PM_{2.5}$ Modeling Study: Modeling Protocol" Prepared by ENVIRON International Corporation and Alpine Geophysics, LLC Prepared for Calvin Ku, Air Quality Analysis Section Chief Air Pollution Control Division, MDNR, 30 September 2005.

ENVIRON and Alpine Geophysics, 2005. "Draft Final St. Louis Ozone and $PM_{2.5}$ Modeling Study: Preliminary Ozone and $PM_{2.5}$ Model Performance Evaluation" Prepared by ENVIRON International Corporation and Alpine Geophysics, LLC Prepared for Calvin Ku, Air Quality Analysis Section Chief Air Pollution Control Division, MDNR, 30 September 2005.

EPA. 1991. "Guidance for Regulatory Application of the Urban Airshed Model (UAM), "Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, N.C.

EPA. 1999. "Draft Guidance on the Use of Models and Other Analyses in Attainment Demonstrations for the 8-hr Ozone NAAQS". Draft (May 1999), U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, N.C

EPA. 2001. "Guidance Demonstrating Attainment Air Quality Goals for $PM_{2.5}$ and Regional Haze". Draft Final (17 February 2005), U.S. Environmental Protection Agency, Atmospheric Sciences Modeling Division, Research Triangle Park, N.C.
EPA. 2001. "Guidance for Demonstrating Attainment of Air Quality Goals for $PM_{2.5}$ and Regional Haze", Draft Report, U.S. Environmental Protection Agency, Research Triangle Park, NC.

EPA. 2003a. "Guidance for Tracking Progress Under the Regional Haze Rule", U.S. Environmental Protection Agency, Research Triangle Park, NC.

EPA. 2003b. "Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule", U.S. Environmental Protection Agency, Research Triangle Park, NC.

EPA. 2004. "Technical Support Document for the Interstate Air Quality Rule Air Quality Modeling Analyses". U.S. Environmental Protection Agency, Emissions Analysis and Monitoring Division, Research Triangle Park, N.C.

EPA. 2005. "Guidance on the Use of Models and Other Analyses in Attainment Demonstrations for the 8-hr Ozone NAAQS". Draft Final (17 February 2005), U.S. Environmental Protection Agency, Atmospheric Sciences Modeling Division, Research Triangle Park, N.C.

EPA. 2006. "Guidance on the Use of Models and Other Analyses in for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze". Draft 3.2 (September 2006), U.S. Environmental Protection Agency, Atmospheric Sciences Modeling Division, Research Triangle Park, N.C.

Gery, M. W., G.Z. Whitten, J.P. Killus, and M.C. Dodge. 1989. A photochemical mechanism for urban and regional-scale computer modeling. *J. Geophys. Res.* 94, 12925-12956.

Grell, G. A., J. Dudhia, and D. R. Stauffer. 1994. "A Description of the Fifth Generation Penn State/NCAR Mesoscale Model (MM5). NCAR Tech. Note, NCAR TN-398-STR, 138 pp.

Houyoux, M.R., J.M. Vukovich, C.J. Coats, Jr. N.J.M. Wheeler, and P. Kasibhatla. 2000. Emission inventory development and processing for the seasonal model for regional air quality. *J. Geophysical Research*, **105**, (D7), 9079-9090.

Jacob, D.J. 1999. Heterogeneous chemistry and tropospheric ozone. *Atmos. Environ.*, special issue, 1999 NARSTO Assessment.

Johnson, M. 2004. "Annual 2002 MM5 v363 Simulation Evaluation." Iowa Department of natural Resources, Air Quality Bureau. November. (Available at

www.ladco.org/tech/photo/present/mm5v363_eval.pdf).

Kain, J.S., and J.M. Fritsch, 1993: Convective parameterization for mesoscale models: The Kain-Fritsch scheme. "The representation of cumulus convection in numerical models". Meteor. Monogr., No. 24, Amer. Meteor. Soc., 165-170

Koerber, M. 2005. "Regional Air Quality Planning for the Upper Midwest: Attainment Strategy options". Presented to the Lake Michigan Air Directors Consortium (LADCO) October 31, 2005.

McNally, D.E., and T.W. Tesche. 1994. "MAPS2.3 User's Guide", Alpine Geophysics, LLC, Golden, CO.

Mlawer, E. J., S. J. Taubman, P. D. Brown, M. J. Iacono, and S. A. Clough, 1997: Radiative transfer for inhomogeneous atmospheres: RRTM, a validated correlated-k model for the longwave. J. Geophys. Res., 102(D14), 16,663-16,682.

Morris, R.E., B. Koo, S. Lau, T.W. Tesche, D. McNally, C. Loomis, G. Stella, G. Tonnesen and Z. Wang. 2004a. "VISTAS Emissions and Air Quality Modeling – Phase I Task 4cd Report: Model Performance Evaluation and Model Sensitivity Tests for Three Phase I Episodes", prepared for the VISTAS Technical Analysis Committee, prepared by ENVIRON International Corporation, Alpine Geophysics, LLC, and the University of California, Riverside (CE-CERT).

Morris, R.E., B. Koo, S. Lau, T.W. Tesche, D. McNally, C. Loomis, G. Stella, G. Tonnesen and Z. Wang. 2004b. "VISTAS Emissions and Air Quality Modeling – Phase I Task 4cd Report: Model Performance Evaluation and Model Sensitivity Tests for Three Phase I Episodes", prepared for the VISTAS Technical Analysis Committee, prepared by ENVIRON International Corporation, Alpine Geophysics, LLC, and the University of California, Riverside (CE-CERT).

Morris, R.E., D. McNally, T. Tesche, G. Tonnesen, J. Boylan and P. Brewer. 2004c. "Regional Haze Modeling over the VISTAS States: Preliminary Verification of Models-3/CMAQ for the 2002 Annual Period." Presented at AWMA Visibility Conference, Asheville, North Carolina. October.

Morris, R.E., G. Mansell, and E. Tai, 2004d. "Air Quality Modeling Analysis for the Denver Early Action Compact)". Prepared for The Denver Regional Air Quality Council, January, 2004.

Morris, R.E., E. Tai, Y. Jia, M. Jimenez, 2005a. "Technical Support Document: Photochemical Modeling for the Tulsa and Oklahoma City 8-Hour Ozone Early Action Compact (EAC) State Implementation Plan (SIP)". Prepared for The Oklahoma Department of Environmental Quality, March, 2005.

Morris, R.E., D.E. McNally, T.W. Tesche, G. Tonnesen, J.W. Boylan, and P. Brewer. 2005b. Preliminary Evaluation of the CMAQ Model for 2002 and the Southeastern U.S. *Journal of the Air & Waste Manage. Association* (in press).

Morris, R.E., B. Koo, D. McNally, T.W. Tesche, G. Tonnesen, J. Boylan, and P. Brewer. 2005c. Model sensitivity evaluation for organic carbon using two multi-pollutant air quality models that simulate regional haze in the southeastern United States. *Atmospheric Environment* (in press)

Pleim, J.E. and J.S. Chang. 1992. A non-local closure model for vertical mixing in the convective boundary layer. *Atmos. Env*., **26A**, pp. 965-981.

Pun B., S-Y. Chen and C. Seigneur. 2004. "CENRAP Model Simulations and Performance Evaluations". Atmospheric and Environmental Research, Inc. (AER). August.

Reid S., S. Brown, D. Sullivan, H. Arkinson, T. Funk, and P. Stiefer. 2004a. "Research and Development of Planned Burning Emission Inventories for the Central States Regional Air Planning Association". Final Report. Sonoma Technology, Inc. (STI). July 30.

Reid, S., D. Sullivan, B. Penfold, T. Funk, T. Tamura, P. Stiefer, S. Raffuse and H. Arkinson. 2004. "Emission Inventory Development for Mobile Sources and Agricultural Dust Sources form the Central States". Final Report. Sonoma Technology, Inc. (STI). September 22.

Reisner, J.R., R.M. Rasmussen, and R.T. Bruintjes, 1998: Explicit forcing of supercooled liquid water in winter storms using the MM5 mesoscale model. Quart. J. Roy. Met. Soc., 124B, pp. 1071-1107.

Sarwar, G., D. Luecken, G. Yarwood, G.Whitten and W. Carter, 2005. "Implementing an Updated Carbon Bond Mechanism into the Community Multiscale Air Quality Model," presented at the 4th Annual CMAS Models-3 User's Conference, Chapel Hill, NC, September 26, 2005.

Seaman, N.L. 2000. "Meteorological Modeling for Air Quality Assessments", *Atmos. Environ.,* Vol. 34, No. 12-14, 2231-2260.

Seppanen, C. 2005. Recent Updates to the SMOKE emissions modeling system, 4th CMASModels-3 Conference. 18-20 October, Chapel Hill, NC.

Stauffer, D.R. and N.L. Seaman. 1990. "Use of Four-Dimensional Data Assimilation in a Limited-Area Mesoscale Model. Part I: Experiments with Synoptic Data". *Mon. Wea. Rev.,* **118**, 1250-1277.

Strait, R., S. Roe and J. Vukovich. 2004. "2002 Base Case Modeling Inventory – Work Plan." E.H. Pechan and Associates, Inc. Durham, North Carolina. July 30.

Tai, E. and G. Yarwood, 2006. "Ozone Benefits in DFW from Emission Controls in the 2009 and 2010 Future Years". Prepared for the Texas Commission on Environmental Quality, September, 2006.

Xiu, A. and J.E. Pleim. 2000. Development of a land surface model. Part I: application in a mesoscale meteorology model. *J. App. Met.*, **40**, pp. 192-209.

Yarwood, G., G. Whitten, and S. Rao, 2005. "Updates to the Carbon Bond 4 Photochemical Mechanism". Prepared for the Lake Michigan Air Directors Consortium, March, 2005.