"Good Neighbor" Modeling for the Kentucky 2008 8-Hour Ozone State Implementation Plan

Final Modeling Protocol

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1.0 INTRODUCTION

1.1 OVERVIEW

Sections 110(a)(1) and (2) of the Clean Air Act (CAA) require all states to adopt and submit to the U. S. Environmental Protection Agency (EPA) any revisions to their infrastructure State Implementation Plans (SIP) which provide for the implementation, maintenance and enforcement of a new or revised national ambient air quality standard (NAAQS). The EPA revised the ozone NAAQS in March 2008 and completed the designation process to identify nonattainment areas in July 2012. The Kentucky Division for Air Quality (KYDAQ) subsequently submitted Kentucky's infrastructure SIP certification on July 17, 2012 with EPA disapproving Prong 1 (interstate transport – significant contribution) in April 2013. Additionally, through final action and rulemaking of the Cross-State Air Pollution Rule (CSAPR) (81 FR 74504), EPA has indicated its intention to issue a Federal Implementation Plan (FIP) in the absence of an approved revision to the SIP.

CAA section 110(a)(2)(D)(i)(I) requires each state to prohibit emissions that will significantly contribute to nonattainment of a NAAQS, or interfere with maintenance of a NAAQS, in a downwind state. According to EPA, Kentucky's July 2012 infrastructure certification failed to demonstrate that emissions activities within Kentucky will not significantly contribute to nonattainment or interfere with maintenance of the 2008 ozone NAAQS in a neighboring state.

This document serves as the air quality Modeling Protocol for the Commonwealth of Kentucky 8-hour ozone modeling analysis in support of the revision of the Kentucky 2008 8-hour ozone Good Neighbor State Implementation Plan (GNS). The 2008 8-hour ozone NAAQS form is the three year average of the fourth highest daily maximum 8-hour ozone concentrations with a threshold not to be exceeded of 0.075 ppm (75 ppb). On October 26, 2015, the EPA promulgated a new 8-hour ozone NAAQS with a threshold not to be exceeded of 0.070 ppm (70 ppb). Attainment of this new (2015) ozone NAAQS will be addressed in future SIP actions and may use results of this effort to inform that determination.

This Modeling Protocol describes the overall modeling activities to be performed in order to demonstrate whether or not emissions activities within Kentucky will significantly contribute to nonattainment or interfere with maintenance of the 2008 ozone NAAQS in a neighboring state. This effort is being undertaken working closely with the KYDAQ, other local agencies, and stakeholder groups, including the Midwest Ozone Group which is funding this modeling.

A comprehensive Modeling Protocol for an 8-hour ozone SIP revision study consists of many elements. Its main function is to serve as a means for planning and communicating how a modeled contribution analysis will be performed before it occurs. The protocol guides the technical details of a modeling study and provides a formal framework within which the scientific assumptions, operational details, commitments and expectations of the various participants can be set forth explicitly and means for resolution of potential differences of technical and policy opinion can be worked out openly and within prescribed time and budget constraints.

As noted in the EPA 8-hour ozone modeling guidance, the Modeling Protocol serves several important functions (EPA, 2007; 2014e):

- Identify the assistance available to the KYDAQ (the lead agencies) to undertake and evaluate the analysis needed to support a defensible attainment demonstration;
- Identify how communication will occur among State, Local and Federal agencies and stakeholders to develop a consensus on various issues;
- Describe the review process applied to key steps in the demonstration; and
- Describe how changes in methods and procedures or in the protocol itself will be agreed upon and communicated with stakeholders and the appropriate U.S. EPA Regional Office.

1.2 STUDY BACKGROUND

Section 110(a)(2)(D)(i)(I) of the CAA requires that states address the interstate transport of pollutants and ensure that emissions within the state do not contribute significantly to nonattainment in, or interfere with maintenance by, any other state. The following section is intended to address Kentucky's interstate transport, or "Good Neighbor," responsibilities for the 2008 ozone NAAQS. Kentucky has many rules and limits currently in place that control ozone precursor pollutants and emissions of these pollutants are decreasing in the state. These facts strengthen the demonstration that no further controls or emission limits may be required to fulfil Kentucky's responsibilities under the Good Neighbor Provisions for the 2008 ozone NAAQS.

On October 26, 2016, EPA published in the Federal Register a final update to the Cross-State Air Pollution Rule (CSAPR) for the 2008 ozone NAAQS. In this final update, EPA outlines its four-tiered approach to addressing the interstate transport of pollution related to the ozone NAAQS, or states' Good Neighbor responsibilities. EPA's approach determines which states contribute significantly to nonattainment areas or significantly interfere with air quality in maintenance areas in downwind states. EPA has determined that if a state's contribution to downwind air quality problems is below one percent of the applicable NAAQS, then it does not consider that state to be significantly contributing to the downwind area's nonattainment or maintenance concerns. EPA's approach to addressing interstate transport has been shaped by public notice and comment and refined in response to court decisions.

As part of the final CSAPR update, EPA released regional air quality modeling, indicating which states significantly contribute to nonattainment or maintenance area air quality problems in other states. To make these determinations, the EPA projected future ozone nonattainment and maintenance receptors, then conducted state-level ozone source apportionment modeling to determine which states contributed pollution over a pre-identified "contribution threshold."

Kentucky's contribution to projected downwind nonattainment area air quality was not found to be over the one-percent threshold at any of the final CSAPR-identified nonattainment monitors. However, it was projected to be over the one-percent threshold at four final CSAPR-identified maintenance monitors ("problem monitors") in the eastern US, and therefore identified as a significant contributor to the prevention of maintenance at these monitors. The one percent threshold for the 2008 NAAQS is 0.75 parts per billion (ppb). As shown in Table 1-1, Kentucky was shown to contribute a maximum of 10.88 ppb to a monitor in Hamilton, Ohio, 2.36 ppb to a monitor in Philadelphia, Pennsylvania, 2.18 ppb to a monitor at Harford, Maryland, and 1.03 ppb to a monitor in Richmond, New York.

Table 1-1. Final CSAPR Update-identified maintenance monitors where Kentucky is identified as a significant contribution.

Monitor	State	County	2009-2013 Base Period Average Design Value	2009-2013 Base Period Maximum Design Value	2017 Base Case Average Design Value	2017 Base Case Maximum Design Value	KY Contribution (ppb)
390610006	OH	Hamilton	82.0	85	74.6	77.4	10.88
421010024	PA	Philadelphia	83.3	87	73.6	76.9	2.36
240251001	MD	Harford	90.0	93	78.8	81.4	2.18
360850067	NY	Richmond	81.3	83	75.8	77.4	1.03

Because Kentucky's contribution to projected downwind maintenance problems is above the one percent threshold and thus significant, additional analyses are required to fulfil Kentucky's responsibilities under the Good Neighbor Provisions for the 2008 ozone NAAQS.

1.2.1 Current Ozone Air Quality at the Maintenance Monitors

Figure 1-1 displays the maximum 8-hour ozone Design Values from 2008-2015 along with the highest fourth highest daily maximum 8-hour ozone concentration at the four CSAPR-maintenance monitors (See Figure 1-2 that follows) to which Kentucky is associated as a significant contributor. The fourth highest daily maximum 8-hour ozone concentration at these monitors exhibits high year-to-year variability that is primarily due to meteorological variations that can cause the values to change between successive years. Use of the three-year average of these fourth highest values in the ozone Design Value results in a suppression of this variability so that the differences in the maximum 8-hour ozone Design Value over this period is less pronounced.

1.2.2 EPA Final CSAPR Update Assessment Tool Results

Based on EPA's Final CSAPR Update Rule analysis using the air quality assessment tool (AQAT), the two problem monitors in Pennsylvania and Ohio that Kentucky is attributed as a significant contributor are determined to become "clean" after implementation of the CSAPR Update controls. In addition to the pending air quality modeling being conducted for this study, this determination and these sites may or may not still be considered to be "receptors" that would require Kentucky to develop control strategies designed to remove air quality problems from these locations.

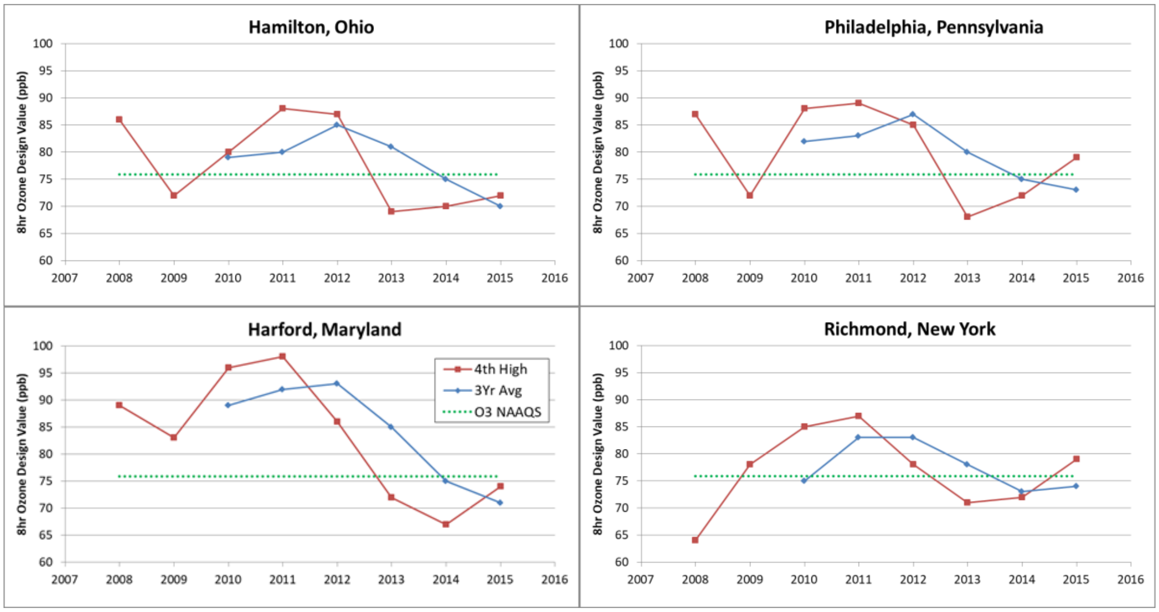

Figure 1-1. Trend in ozone concentrations at the CSAPR-identified maintenance monitors between 2008 and 2015.

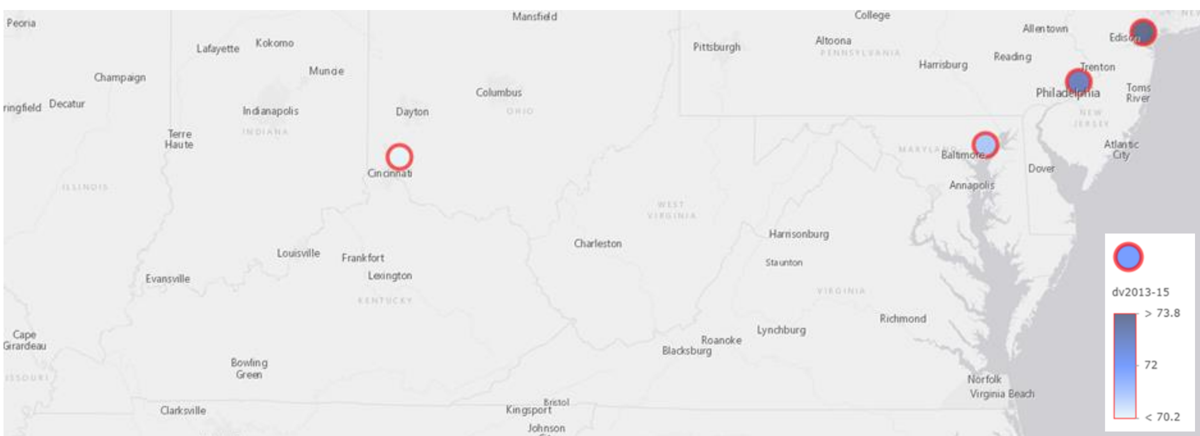

Figure 1-2. Observed 2013-2015 ozone Design Value concentrations (ppb) at CSAPR-identified maintenance monitors where Kentucky is identified as a significant contributor.

1.2.3 Purpose

This document serves as the air quality Modeling Protocol for the Commonwealth of Kentucky 8-hour ozone modeling analysis in support of the revision of the Kentucky 2008 8-hour ozone Good Neighbor State Implementation Plan (GNS). This revision will need to demonstrate that emissions activities within Kentucky will not significantly contribute to nonattainment or interfere with maintenance of the 2008 ozone NAAQS in a neighboring state with the four problem monitors identified in the final CSAPR update.

1.3 LEAD AGENCY AND PRINCIPAL PARTICIPANTS

The KYDAQ is the lead agency in the development of this 8-hour ozone SIP revision. EPA Region 4 in Atlanta is the local regional EPA office that will take the lead in the review and approval process for this SIP revision.

1.4 RELATED REGIONAL MODELING STUDIES

There are several other emission control and ozone modeling studies that are nearby and related to the Kentucky 8-hour ozone modeling analysis whose results may be useful to KYDAQ. In addition, EPA has promulgated several national rules that may affect the ozone SIP revision.

1.4.1 Federal Regional Regulatory Air Quality Programs

The federal government has implemented standards and actions to improve air quality across the entire country. These national standards have largely involved mobile or large stationary sources. Federal standards include: the Tier 2 and Tier 3 Vehicle Standards, the heavy-duty gasoline and diesel highway vehicle standards, the non-road spark-ignition engines and recreational engine standards, and the large non-road diesel engine rule. The federal government has also implemented regional control strategies for major stationary sources focusing on the eastern U.S. The following is a list of federal regulatory actions that would likely lead to emission reductions downwind of Kentucky and will need to be accounted for in the ozone SIP revision.

- Tier-3 Vehicle Emissions and Fuel Standards Program as finalized in March 2014 and beginning phase-in in 2017.
- Tier 2 Vehicle Standards with lower NOX emission tailpipe standards to be phased in during 2004-2009 and reduces the sulfur content of gasoline to 30 ppm starting in January of 2006.
- Heavy-duty Gasoline and Diesel Highway Vehicle Standards to reduce NOX and volatile organic compound (VOC) emissions from heavy-duty gasoline and diesel highway vehicles starting in 2004 with a second phase beginning in 2007 to reduce particulate matter and also reduce highway diesel fuel sulfur content to 15 ppm.
- Non-Road Spark-ignition Engines and Recreational Engines Standards effective in July 2003 regulates NOX, HC and CO for groups of previously unregulated non-road engines.
- Large Non-Road Diesel Engine Rule promulgated in May 2004 for large non-road diesel engines, such as those used in construction, agricultural, and industrial equipment, to be phased in between 2008 and 2014.

- Industrial/Commercial/Institutional Boiler MACT.
- NOX SIP Call was finalized in October, 1998 that reduces NOX emissions from large stationary sources for specific states in the eastern U.S.[1]
- Clean Air Interstate Rule (CAIR[2]) Transport Rule was promulgated in 2005 to reduce NOX and SO2 emissions from large stationary sources in the eastern U.S. to reduce their contributions to downwind ozone and PM2.5 nonattainment.[3]
- Federal Reformulated Gasoline allows for a maximum of 1 percent benzene by volume. Preliminary VOC and air toxics standards took effect with phase I of the rule in 1995 followed by Phase II in 2000. Phase II required 25 to 29 percent VOC emission reductions and 20 to 22 percent air toxics reductions.
- Federal Non-Road Spark-Ignition Engines and Equipment for spark-ignition engines used in marine vessels, including outboard engines, personal watercraft, and sterndrive/inboard engines.
- Locomotive Engines and Marine Compression-Ignition Engines Final Rule set new exhaust NO_X and PM emission standards on all types of locomotive engines and on all types of locomotive and marine diesel engines below 30 liters per cylinder displacement.
- Clean Air Act Title IV - Acid Rain Program reduces annual emissions of SO2 and NOX mainly from coal-fired power plants.
- Mercury and Air Toxics Standards (MATS[4]) that finalizes standards to reduce air pollution from coal and oil-fired power plants under sections 111 (new source performance standards) and 112 (toxics program) of the 1990 Clean Air Act amendments.
- Final Cross-State Air Pollution Rule and Update[5] that addresses interstate transport of ozone pollution under the 2008 ozone National Ambient Air Quality Standards (NAAQS) and interstate transport of fine particulate matter (PM2.5) pollution under the 1997 and 2006 PM2.5 NAAQS.

1.4.2 2015 Ozone NAAQS Preliminary Interstate Transport Assessment

To support the 2015 ozone National Ambient Air Quality Standards (NAAQS) preliminary interstate transport assessment Notice of Data Availability (NODA), EPA conducted air quality modeling to project ozone concentrations at individual monitoring sites to 2023 and to estimate state-by-state contributions to those 2023 concentrations. The projected 2023 ozone concentrations were used to identify ozone monitoring sites that are projected to be nonattainment or have maintenance problems for the 2015 ozone NAAQS in 2023. Ozone contribution information was then used to quantify projected interstate contributions from

1 http://www.epa.gov/airmarkt/progsregs/nox/sip.html

2 http://www.epa.gov/airmarkets/programs/cair/

3 http://www.epa.gov/airtransport/

4 https://www.epa.gov/mats

5 81 FR 74504

emissions in each upwind state to ozone concentrations at projected 2023 nonattainment and maintenance sites in other states (i.e., in downwind states).

At the time of preparing the draft of this protocol, we were advised that EPA was preparing to undertake new modeling of 2023 in support of its efforts to develop a FIP for states that have not yet received approval of a Good Neighbor SIP related to the 2008 ozone NAAQS. We understood that as part of its modeling effort, EPA would (1) continue to use the 2011 base year, (2) perform some assessment of modeling performance at the land/water interface, (3) may or may not be able to assess non-EGU source updates and (4) seek to update emission inventories to reflect RACT and other control programs.

This new modeling data (2023en platform[6]) was released to Kentucky in late September of 2017 and has been built into the analysis revisions proposed below. In addition to the items mentioned above, EPA confirmed that control requirements associated with the implementation of the Clean Power Plan were removed from the EGU emission projections. The documented modeling below will be conducted in parallel timeframes to EPA's projections and significant contribution calculations using the same platform.

1.5 OVERVIEW OF MODELING APPROACH

The GNS 8-Hour ozone SIP modeling proposed here will include ozone simulations and source apportionment studies using the 12 km grid based on EPA's NAAQS NODA modeling platform and preliminary source contribution assessment (EPA, 2016b).

1.5.1 Episode Selection

Episode selection is an important component of an 8-hour ozone attainment demonstration. EPA guidance recommends that 10 days be used to project 8-hour ozone Design Values at each critical monitor. The May 1 through August 31 2011 ozone season period has been selected for the ozone SIP modeling primarily due to the following reasons:

- It is aligned with the 2011 NEI year, which is the latest currently available NEI.
- It is not an unusually low ozone year.
- Ambient meteorological and air quality data are available.
- A 2011 12 km CAMx modeling platform is available from the EPA that can be leveraged for the GNS ozone SIP modeling.

More details of the summer 2011 episode selection and justification using criteria in EPA's modeling guidance are contained in Section 3.

1.5.2 Model Selection

Details on the rationale for model selection are provided in Section 2. The Weather Research Forecast (WRF) prognostic meteorological model was selected for the GNS ozone modeling using a 12 km resolution grid. Additional emission modeling is not required as the 2023en platform was provided to Kentucky in pre-merged CAMx ready format. Emissions process was

6 ftp://ftp.epa.gov/EmisInventory/2011v6/v3platform/README_2011en_2023en_package.txt

completed by EPA using the SMOKE emissions model for most source categories. The exceptions are that BEIS model was used for biogenic emissions and there are special processors for fires, windblown dust, lightning and sea salt emissions. The MOVES2014 on-road mobile source emissions model was used with SMOKE-MOVES to generate on-road mobile source emissions with EPA generated vehicle activity data provided in the NAAQS NODA. The CAMx photochemical grid model, which supports two-way grid nesting will also be used. The setup is based on the same WRF/SMOKE/BEIS/CAMx modeling system used in the EPA 2023en platform modeling.

1.5.3 Base and Future Year Emissions Data

The 2023 future year will be used for the attainment demonstration modeling as that is the attainment year for a Moderate NAA under the 2015 ozone NAAQS. The 2011 base case and 2023 future year emissions will be based on EPA's "en" inventories with no adjustment.

1.5.4 Input Preparation and QA/QC

Quality assurance (QA) and quality control (QC) of the emissions datasets are some of the most critical steps in performing air quality modeling studies. Because emissions processing is tedious, time consuming and involves complex manipulation of many different types of large databases, rigorous QA measures are a necessity to prevent errors in emissions processing from occurring. The GNS 8-Hour ozone modeling study will utilize EPA's pre-QA/QC'd emissions platform that follows a multistep emissions QA/QC approach.

1.5.5 Meteorology Input Preparation and QA/QC

The CAMx 2011 12 km meteorological inputs are based on WRF meteorological modeling conducted by EPA. Details on the EPA 2011 WRF application and evaluation are provided by EPA (EPA 2014d).

1.5.6 Initial and Boundary Conditions Development

Initial concentrations (IC) and Boundary Conditions (BCs) are important inputs to the CAMx model. We intend to run 15 days of model spin-up before the first high ozone days occur in the modeling domain so the ICs are washed out of the modeling domain before the first high ozone day of the May-August 2011 modeling period. The lateral boundary and initial species concentrations are provided by a three dimensional global atmospheric chemistry model, GEOS-Chem (Yantosca, 2004) standard version 8-03-02 with 8-02-01 chemistry.

1.5.7 Air Quality Modeling Input Preparation and QA/QC

Each step of the air quality modeling will be subjected to QA/QC procedures. These procedures will include verification of model configurations, confirmation that the correct data were used and were processed correctly and other procedures.

1.5.8 Model Performance Evaluation

The Model Performance Evaluation (MPE) will rely on the CAMx MPE from EPA's associated modeling platforms. EPA's MPE recommendations in their ozone modeling guidance (EPA, 2007; 2014e) were followed in this evaluation. Many of EPA's MPE procedures have already been performed by EPA in their CAMx 2011 modeling database being used in the GNS ozone SIP modeling. The relevant MPE from EPA's checklist related to ozone source apportionment modeling will be used in the MPE as described in Section 6.

1.5.9 Diagnostic Sensitivity Analyses

Depending on the confirmation run results of the CAMx 2011 base case modeling and MPE on Alpine's modeling system, diagnostic sensitivity tests may be conducted to try and improve model performance. The definition of these diagnostic sensitivity tests will depend on the results of the initial MPE for these domains.

1.5.11 Future Year Significant Contribution Modeling

Future-year modeling for ozone will be performed for the GNS 2023 future year attainment date. The modeling results will be used to estimate significant contribution of Kentucky's anthropogenic emission sources to the noted downwind problem monitors. The CAMx Ozone Source Apportionment Technique/Anthropogenic Precursor Culpability Assessment (OSAT/APCA) method will be utilized for this effort.

1.6 PROJECT PARTICIPANTS AND CONTACTS

The KYDAQ is the lead agency in the development of the GNS 8-hour ozone SIP. They will work closely with other local agencies, other local cities and agencies, and EPA Region 4 in the SIP development, including the sharing of interim results as they become available. The KYDAQ has contacted the Midwest Ozone Group who in turn has contracted with Alpine Geophysics, LLC (Alpine) to perform the GNS 8-hour attainment demonstration modeling under the direction and with assistance from the KYDAQ. KYDAQ will also work with local agencies and stakeholders in the GNS SIP development, where stakeholders include environmental groups and industry. Key participants in the GNS 8-hour ozone study and their contact information are provided in Table 1-2.

Table 1-2. Key participants and contact information for the GNS 8-hour ozone attainment demonstration modeling study.

Organization	Individual(s) [Roll]	Address	Contact Numbers
Kentucky Division for Air Quality			
KYDAQ			
U.S. EPA Region 4			
EPA R4			
Contractors (modeling team)			
Alpine Geophysics, LLC	Mr. Gregory Stella [Co-Principal Investigator]	Senior Scientist 387 Pollard Mine Road Burnsville, NC 28714	bus: (828) 675-9045 e-mail: gms@alpinegeophysics.com
Alpine Geophysics, LLC	Mr. Dennis McNally [Co-Principal Investigator]	Senior Scientist 7341 Poppy Way Arvada, CO 80007	bus: (303) 421- 2211 e-mail: dem@alpinegeophysics.com

1.7 COMMUNICATION

Frequent communication between the KYDAQ and the modeling team and other participants is anticipated. These communications will include e-mails, conference calls, and face-to-face meetings. The KYDAQ envisions that EPA and others will review interim products as they become available so that comments can be received during the study to allow for corrective action as necessary. These interim deliverables would include, but not be limited to, preliminary CAMx model performance evaluation, preliminary current and future-year emissions assumptions and results, and preliminary future year 8-hour ozone projections and source apportionment results.

1.8 Schedule

Table 1-3 lists the current schedule for the initial key deliverables under the GNS 8-hour ozone modeling study. As EPA has defined a June 2018 due date for the SIP, the schedule discusses the SIP modeling analysis carrying through the 2011 base case modeling and 2023 ozone source contribution analysis.

Table 1-3. Initial key deliverables and dates for the GNS 8-hour ozone modeling through the 2023 source apportionment reporting.

Deliverable (Type)	Date
Task 1: Preparation of Preliminary Draft Modeling Protocol	July 20, 2017
Task 2: Comments from KYDAQ on Preliminary Draft Modeling Protocol	July 28, 2017
Task 3: Submit Modeling Protocol reflecting KYDAQ Comments	August 4, 2017
Task 4: Comments on Modeling Protocol from EPA etc.	September 5, 2017
Task 5: Submit Revised Modeling Protocol	October 10, 2017
Task 6: Obtain EPA 2023en Modeling Platform from LADCO	September 20, 2017
Task 7: Verify EPA Platform Consistency with Summary Files	September 24, 2017
Task 8: Merge 12 km domain emissions to make CAMx-ready inputs	October 9, 2017
Task 9: CAMx/APCA 2023 12 km simulation	Late October, 2017
Task 10: Post-Process Results of CAMx/APCA 2023 Baseline	November, 2017
Task 11: Preliminary Results Shared with KY/Midwest Ozone Group	January 11, 2018
Task 12: Final Report	January 31, 2018

2.0 MODEL SELECTION

This section introduces the models to be used in the 8-hour ozone GNS SIP modeling study. The selection methodology presented in this chapter mirrors EPA's regulatory modeling in support of the 2015 Ozone NAAQS Preliminary Interstate Transport Assessment (EPA, 2016b).

Unlike some previous ozone modeling guidance that specified a particular ozone model (e.g., EPA, 1991 that specified the Urban Airshed Model; Morris and Myers, 1990), the EPA now recommends that models be selected for ozone SIP studies on a "case-by-case" basis. The latest EPA ozone guidance (EPA, 2014) explicitly mentions the CMAQ and CAMx PGMs as the most commonly used PGMs that would satisfy EPA's selection criteria but notes that this is not an exhaustive list and does not imply that they are "preferred" over other PGMs that could also be considered and used with appropriate justification. EPA's current modeling guidelines lists the following criteria for model selection (EPA, 2014e):

- It should not be proprietary;
- It should have received a scientific peer review;
- It should be appropriate for the specific application on a theoretical basis;
- It should be used with data bases which are available and adequate to support its application;
- It should be shown to have performed well in past modeling applications;
- It should be applied consistently with an established protocol on methods and procedures;
- It should have a user's guide and technical description;
- The availability of advanced features (e.g., probing tools or science algorithms) is desirable; and
- When other criteria are satisfied, resource considerations may be important and are a legitimate concern.

For the GNS 8-hour ozone modeling, we propose to use the WRF/SMOKE/MOVES2014/BEIS/CAMx-OSAT/APCA modeling system as the primary tool for demonstrating attainment of the ozone NAAQS and calculation of significant contribution to downwind monitors. The proposed modeling system satisfies all of EPA's selection criteria. A description of the key models to be used in the GNS ozone SIP modeling follows.

<u>WRF/ARW:</u> The Weather Research and Forecasting (WRF)[7] Model is a mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs (Skamarock, 2004; 2006; Skamarock et al., 2005). The Advanced Research WRF (ARW) version of WRF will be used in this ozone modeling study. It features multiple dynamical cores, a 3-dimensional variational (3DVAR) data assimilation system, and a software architecture allowing for computational parallelism and system extensibility. WRF is suitable for a broad spectrum of applications across scales ranging from meters to thousands of kilometers. The effort to develop WRF has been a collaborative partnership, principally among

7 http://www.wrf-model.org/index.php

the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (NOAA), the National Centers for Environmental Prediction (NCEP) and the Forecast Systems Laboratory (FSL), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA). WRF allows researchers the ability to conduct simulations reflecting either real data or idealized configurations. WRF provides operational forecasting a model that is flexible and efficient computationally, while offering the advances in physics, numerics, and data assimilation contributed by the research community.

SMOKE: The Sparse Matrix Operator Kernel Emissions (SMOKE)[8] modeling system is an emissions modeling system that generates hourly gridded speciated emission inputs of mobile, non-road, area, point, fire and biogenic emission sources for photochemical grid models (Coats, 1995; Houyoux and Vukovich, 1999). 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 an existing base emissions inventory data into the hourly gridded speciated formatted emission files required by a photochemical grid model. SMOKE will be used to prepare emission inputs for non-road mobile, area and point sources.

SMOKE-MOVES: SMOKE-MOVES uses an Emissions Factor (EF) Look-Up Table from MOVES, gridded vehicle miles travelled (VMT) and other activity data and hourly gridded meteorological data (typically from WRF) and generates hourly gridded speciated on-road mobile source emissions inputs.

MOVES2014: MOVES2014[9] is EPA's latest on-road mobile source emissions model that was first released in July 2014 (EPA, 2014a,b,c). MOVES2014 includes the latest on-road mobile source emissions factor information. Emission factors developed by EPA will be used in this analysis.

BEIS: Biogenic emissions were modeled by EPA using version 3.61 of the Biogenic Emission Inventory System (BEIS). First developed in 1988, BEIS estimates volatile organic compound (VOC) emissions from vegetation and nitric oxide (NO) emissions from soils. Because of resource limitations, recent BEIS development has been restricted to versions that are built within the Sparse Matrix Operational Kernel Emissions (SMOKE) system.

CAMx: The Comprehensive Air quality Model with Extensions (CAMx[10]) 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, 2015[11]). 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

8 http://www.smoke-model.org/index.cfm
9 http://www.epa.gov/otaq/models/moves/
10 http://www.camx.com
11 http://www.camx.com/files/camxusersguide_v6-20.pdf

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 including those for most recent regional rules (e.g., Transport Rule, CAIR, NO_X SIP Call, etc.). The current version of CAMx is Version 6.40 that will be used in this study.

OSAT/APCA: Ozone Source Apportionment Technique/Anthropogenic Precursor Culpability Assessment (OSAT/APCA) tool of CAMx was selected to develop source contribution and significant contribution calculations.

3.0 EPISODE SELECTION

EPA's most recent 8-hour ozone modeling guidance (EPA, 2014e) contains recommended procedures for selecting modeling episodes The GNS ozone SIP revision modeling will use the May through end of August 2011 modeling period because it satisfies the most criteria in EPA's modeling guidance episode selection discussion.

EPA guidance recommends that 10 days be used to project 8-hour ozone Design Values at each critical monitor. The May through August 2011 period has been selected for the ozone SIP modeling primarily due to being aligned with the 2011 NEI year, not being an unusually low ozone year and availability of a 2011 12 km CAMx modeling platform from the EPA NAAQS NODA.

4.0 MODELING DOMAIN SELECTION

This section summarizes the modeling domain definitions for the GNS 8-hour ozone modeling, including the domain coverage, resolution, and map projection. It also discusses emissions, aerometric, and other data available for use in model input preparation and performance testing.

4.1. HORIZONTAL DOMAIN

The GNS ozone SIP modeling will use a 12 km continental U.S. (12US2) domain. The 12 km nested grid modeling domain configuration is shown in Figure 4-1. The 12 km domain shown in Figure 4-1 represent the CAMx 12km air quality and SMOKE/BEIS emissions modeling domain. The WRF meteorological modeling was run on larger 12 km modeling domains than used for CAMx as demonstrated in EPA's meteorological model performance evaluation document (EPA, 2014d). The WRF meteorological modeling domains are defined larger than the air quality modeling domains because meteorological models can sometimes produce artifacts in the meteorological variables near the boundaries as the prescribed boundary conditions come into dynamic balance with the coupled equations and numerical methods in the meteorological model.

Figure 4-1. Map of 12km CAMx modeling domains. Source: EPA NAAQS NODA.

4.2 VERTICAL MODELING DOMAIN

The CAMx vertical structure is primarily defined by the vertical layers used in the WRF meteorological modeling. The WRF model employs a terrain following coordinate system defined by pressure, using multiple layer interfaces that extend from the surface to 50 mb (approximately 19 km above sea level). EPA ran WRF using 35 vertical layers. A layer averaging scheme is adopted for CAMx simulations whereby multiple WRF layers are combined into one CAMx layer to reduce the air quality model computational time. Table 4-1 displays the approach for collapsing the WRF 35 vertical layers to 25 vertical layers in CAMx.

Table 4-1. WRF and CAMx layers and their approximate height above ground level.

CAMx Layer	WRF Layers	Sigma P	Pressure (mb)	Approx. Height (m AGL)
25	35	0.00	50.00	17,556
	34	0.05	97.50	14,780
24	33	0.10	145.00	12,822
	32	0.15	192.50	11,282
23	31	0.20	240.00	10,002
	30	0.25	287.50	8,901
22	29	0.30	335.00	7,932
	28	0.35	382.50	7,064
21	27	0.40	430.00	6,275
	26	0.45	477.50	5,553
20	25	0.50	525.00	4,885
	24	0.55	572.50	4,264
19	23	0.60	620.00	3,683
18	22	0.65	667.50	3,136
17	21	0.70	715.00	2,619
16	20	0.74	753.00	2,226
15	19	0.77	781.50	1,941
14	18	0.80	810.00	1,665
13	17	0.82	829.00	1,485
12	16	0.84	848.00	1,308
11	15	0.86	867.00	1,134
10	14	0.88	886.00	964
9	13	0.90	905.00	797
	12	0.91	914.50	714
8	11	0.92	924.00	632
	10	0.93	933.50	551
7	9	0.94	943.00	470
	8	0.95	952.50	390
6	7	0.96	962.00	311
5	6	0.97	971.50	232
4	5	0.98	981.00	154
	4	0.99	985.75	115
3	3	0.99	990.50	77
2	2	1.00	995.25	38
1	1	1.00	997.63	19

4.3. DATA AVAILABILITY

The CAMx modeling systems requires emissions, meteorology, surface characteristics, initial and boundary conditions (IC/BC), and ozone column data for defining the inputs.

4.3.1 Emissions Data

Without exception, the 2011 and 2023 base year and base case emissions inventories for ozone modeling for this analysis will be based on emissions obtained from the EPA's "en" modeling platform. This platform was obtained from EPA, via LADCO, in late September of 2017 and represents EPA's best estimate of all promulgated national, regional, and local control strategies, including final implementation of CSAPR.

4.3.2 Air Quality

Data from ambient monitoring networks for gas species are used in the model performance evaluation. Table 4-2 summarizes routine ambient gaseous and PM monitoring networks available in the U.S.

4.3.4 Meteorological Data

Meteorological data was generated by EPA using the WRF prognostic meteorological model (EPA, 2014d). WRF was run on a continental U.S. 12 km grid for the NAAQS NODA platform.

4.3.5 Initial and Boundary Conditions Data

The lateral boundary and initial species concentrations are provided by a three dimensional global atmospheric chemistry model, GEOS-Chem (Yantosca, 2004) standard version 8-03-02 with 8-02-01 chemistry. The global GEOS-Chem model simulates atmospheric chemical and physical processes driven by assimilated meteorological observations from the NASA's Goddard Earth Observing System (GEOS-5; additional information available at: http://gmao.gsfc.nasa.gov/GEOS/ and http://wiki.seas.harvard.edu/geos-chem/index.php/GEOS-5). This model was run for 2011 with a grid resolution of 2.0 degrees x 2.5 degrees (latitude-longitude). The predictions were used to provide one-way dynamic boundary concentrations at one-hour intervals and an initial concentration field for the CAMx simulations. The 2011 boundary concentrations from GEOS-Chem will be used for the 2011 and 2023 model simulations.

Table 4-2. Overview of routine ambient data monitoring networks.

Monitoring Network	Chemical Species Measured	Sampling Period	Data Availability/Source
The Interagency Monitoring of Protected Visual Environments (IMPROVE)	Speciated PM25 and PM10 (see species mappings)	1 in 3 days; 24 hr average	http://vista.cira.colostate.edu/improve/Data/IMPROVE/improve_data.htm
Clean Air Status and Trends Network (CASTNET)	Speciated PM25, Ozone (see species mappings)	Approximately 1-week average	http://www.epa.gov/castnet/data.html
National Atmospheric Deposition Program (NADP)	Wet deposition (hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations (such as calcium, magnesium, potassium and sodium)), Mercury	1-week average	http://nadp.sws.uiuc.edu/
Air Quality System (AQS) or Aerometric Information Retrieval System (AIRS)	CO, NO2, O3, SO2, PM25, PM10, Pb	Typically hourly average	http://www.epa.gov/air/data/
Chemical Speciation Network (CSN)	Speciated PM	24-hour average	http://www.epa.gov/ttn/amtic/amticpm.html
Photochemical Assessment Monitoring Stations (PAMS)	Varies for each of 4 station types.		http://www.epa.gov/ttn/amtic/pamsmain.html
National Park Service Gaseous Pollutant Monitoring Network	Acid deposition (Dry; SO4, NO3, HNO3, NH4, SO2), O3, meteorological data	Hourly	http://www2.nature.nps.gov/ard/gas/netdata1.htm

5.0 MODEL INPUT PREPARATION PROCEDURES

This section summarizes the procedures to be used in developing the meteorological, emissions, and air quality inputs to the CAMx model for the GNS 8-hour ozone modeling on the 12 km grid for the May through August 2011 period. The 12 km CAMx modeling databases are based on the EPA "en" platform databases. To date, complete documentation on this platform has not been released and as it is largely based on the NAAQS NODA platform, more details on the NAAQS NODA 2011 CAMx database development are provided in EPA documentation as follows:

- Technical Support Document (TSD) Preparation of Emissions Inventories for the Version 6.3, 2011 Emissions Modeling Platform (EPA, 2016a).
- Meteorological Model Performance for Annual 2011 WRF v3.4 Simulation (EPA, 2014d).
- Air Quality Modeling Technical Support Document for the 2015 Ozone NAAQS Preliminary Interstate Transport Assessment (EPA, 2016b).

The modeling procedures used in the modeling are consistent with over 20 years of EPA ozone modeling guidance documents (e.g., EPA, 1991; 1999; 2005a; 2007; 2014), other recent 8-hour ozone modeling studies conducted for various State and local agencies using these or other state-of-science modeling tools (see, for example, Morris et al., 2004a,b, 2005a,b; 2007; 2008a,b,c; Tesche et al., 2005a,b; Stoeckenius et al., 2009; ENVIRON, Alpine and UNC, 2013; Adelman, Shanker, Yang and Morris, 2014; 2015), as well as the methods used by EPA in support of the recent Transport analysis (EPA, 2010; 2015b, 2016b).

5.1 METEOROLOGICAL INPUTS

5.1.1 WRF Model Science Configuration

Version 3.4 of the WRF model, Advanced Research WRF (ARW) core (Skamarock, 2008) was used for generating the 2011 simulations. Selected physics options include Pleim-Xiu land surface model, Asymmetric Convective Model version 2 planetary boundary layer scheme, KainFritsch cumulus parameterization utilizing the moisture-advection trigger (Ma and Tan, 2009), Morrison double moment microphysics, and RRTMG longwave and shortwave radiation schemes (Gilliam and Pleim, 2010). The WRF model configuration was prepared by EPA (EPA, 2014d).

5.1.2 WRF Input Data Preparation Procedures

A summary of the WRF input data preparation procedures that were used are listed in EPA's documentation (EPA, 2014d).

5.1.3 WRF Model Performance Evaluation

The WRF model evaluation approach was based on a combination of qualitative and quantitative analyses. The quantitative analysis was divided into monthly summaries of 2-m temperature, 2-m mixing ratio, and 10-m wind speed using the boreal seasons to help generalize the model bias and error relative to a set of standard model performance benchmarks. The qualitative approach was to compare spatial plots of model estimated monthly total precipitation with the monthly PRISM precipitation. The WRF model performance evaluation for the 12km domain is provided in EPA's documentation (EPA, 2014d).

5.1.3 WRFCAMx/MCIP Reformatting Methodology

The WRF meteorological model output data was processed to provide inputs for the CAMx photochemical grid model. The WRFCAMx processor maps WRF meteorological fields to the format required by CAMx. It also calculates turbulent vertical exchange coefficients (Kz) that define the rate and depth of vertical mixing in CAMx. A summary of the methodology used by EPA to reform the meteorological data into CAMx format is provided in EPA's documentation (EPA, 2014d).

5.2 EMISSION INPUTS

5.2.1 Available Emissions Inventory Datasets

The base and future year emission inventories used for the GNS 8-hour ozone modeling study will be based on EPA's "en" modeling platform without exception.

5.2.2 Development of CAMx-Ready Emission Inventories

CAMx-ready emission inputs were generated by EPA mainly by the SMOKE and BEIS emissions models. CAMx requires two emission input files for each day: (1) low level gridded emissions that are emitted directly into the first layer of the model from sources at the surface with little or no plume rise; and (2) elevated point sources (stacks) with plume rise calculated from stack parameters and meteorological conditions. For this analysis, CAMx will be operated using version 6 revision 4 of the Carbon Bond chemical mechanism (CB6r4).

EPA's 2011 base year and 2023 future year inventories from the "en" platform will be used for all categories.

5.2.2.1 Episodic Biogenic Source Emissions

Biogenic emissions will be generated using the BEIS biogenic emissions model within SMOKE. BEIS uses high resolution GIS data on plant types and biomass loadings and the WRF surface temperature fields, and solar radiation (modeled or satellite-derived) to develop hourly emissions for biogenic species on the 12 km grids. BEIS generates gridded, speciated, temporally allocated emission files

5.2.2.5 Point Source Emissions

2011 point source emissions will be used from the 2011 "en" modeling platform. Point sources will be developed in two categories: (1) major point sources with Continuous Emissions Monitoring (CEM) devices; and (2) point sources without CEMs. For point sources with continuous emissions monitoring (CEM) data, day-specific hourly NOX and SO2 emissions will be used for the 2011 base case emissions scenario. The VOC, CO and PM emissions for point sources with CEM data would be based on the annual emissions temporally allocated to each hour of the year using the CEM hourly heat input. The locations of the point sources will be converted to the LCP coordinate system used in the modeling. They will be processed by SMOKE to generate the temporally varying (i.e., day-of-week and hour-of-day) speciated emissions needed by CAMx, using profiles by source category from the EPA NAAQS NODA modeling platform.

5.2.2.6 Area and Non-Road Source Emissions

2011 area and non-road emissions will be used from the 2011 "en" modeling platform. The area and non-road sources will be spatial allocated to the grid using an appropriate surrogate distribution (e.g., population for home heating, etc.). The area sources will be temporally allocated by month and by hour of day using the EPA source-specific temporal allocation factors. The SMOKE source-specific CB6 speciation allocation profiles will also be used.

5.2.2.7 Wildfires, Prescribed Burns, Agricultural Burns

Fire emissions in 2011NEIv2 were developed based on Version 2 of the Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation (SMARTFIRE) system (Sullivan, et al., 2008). SMARTFIRE2 was the first version of SMARTFIRE to assign all fires as either prescribed burning or wildfire categories. In past inventories, a significant number of fires were published as unclassified, which impacted the emissions values and diurnal emissions pattern. Recent updates to SMARTFIRE include improved emission factors for prescribed burning.

5.2.2.8 QA/QC and Emissions Merging

EPA processed the emissions by major source category in several different "streams", including area sources, on-road mobile sources, non-road mobile sources, biogenic sources, non-CEM point sources, CEM point sources using day-specific hourly emissions, and emissions from fires. Separate Quality Assurance (QA) and Quality Control (QC) will be performed for each stream of emissions processing and in each step following the procedures utilized by EPA. SMOKE includes advanced quality assurance features that include error logs when emissions are dropped or added. In addition, we will generate visual displays that include:

- Spatial plots of the hourly emissions for each major species (e.g., NOX, VOC, some speciated VOC, SO2, NH3, PM and CO).
- Summary tables of emissions for major species for each grid and by major source category.
- This QA information will be examined against the original point and area source data and summarized in an overall QA/QC assessment.

Scripts to perform the emissions merging of the appropriate biogenic, on-road, non-road, area, low-level, fire, and point emission files will be written to generate the CAMx-ready two-dimensional day and domain-specific hourly speciated gridded emission inputs. The point source and, as available elevated fire, emissions would be processed into the day-specific hourly speciated emissions in the CAMx-ready point source format.

The resultant CAMx model-ready emissions will be subjected to a final QA using spatial maps to assure that: (1) the emissions were merged properly; (2) CAMx inputs contain the same total emissions; and (3) to provide additional QA/QC information.

5.2.3 Use of the Plume-in-Grid (PiG) Subgrid-Scale Plume Treatment

Consistent with the EPA 2011 modeling platform, no PiG subgrid-scale plume treatment will be used.

5.2.4 Products of the Emissions Inventory Development Process

In addition to the CAMx-ready emission input files generated for each hour of all days modeled in the May-August 2011 modeling period, a number of quality assurance (QA) files may be prepared and used to check for gross errors in the emissions inputs. The model-ready emissions will be imported into visualization tools and we will examine both the spatial and temporal distribution of the emission to investigate the quality and accuracy of the emissions inputs.

- Visualizing the model-ready emissions with the scale of the plots set to a very low value, we can determine whether there are areas omitted from the raw inventory or if emissions sources are erroneously located in water cells;
- Spot-checking the holiday emissions files to confirm that they are temporally allocated like Sundays;
- Producing pie charts emission summaries that highlight the contribution of each emissions source component (e.g. non-road mobile);
- Normalizing the emissions by population for each state will illustrate where the inventories may be deficient and provide a reality check of the inventories.

State inventory summaries prepared prior to the emissions processing will be used to compare against SMOKE output report totals generated after each major step of the emissions generation process. To check the chemical speciation of the emissions to CB6 species, we will compare reports generated with SMOKE to target these specific areas of the processing. For speciation, the inventory state import totals will be compared against the same state totals with the speciation matrix applied.

The quantitative QA analyses often reveal significant deficiencies in the input data or the model setup. It may become necessary to tailor these procedures to track down the source of each major problem. As such, one can only outline the basic quantitative QA steps that we will perform in an attempt to reveal the underlying problems with the inventories or processing.

5.2.5 Future-Year Emissions Modeling

Future-year emission inputs will be generated by processing the 2023 emissions data provided with EPA's "en" modeling platform without exception.

5.3 PHOTOCHEMICAL MODELING INPUTS

5.3.1 CAMx Science Configuration and Input Configuration

This section describes the model configuration and science options to be used in the GNS 8-hour ozone modeling effort. The latest version of CAMx (Version 6.40) will be used in the GNS ozone modeling.

The CAMx model setup is defined by EPA in its air quality modeling technical support document (EPA, 2016b, 2017).

6.0 MODEL PERFORMANCE EVALUATION

The CAMx 2011 base case model estimates are compared against the observed ambient ozone and other concentrations to establish that the model is capable of reproducing the current year observed concentrations so it is likely a reliable tool for estimating future year ozone levels.

6.1 EPA MODEL PERFORMANCE EVALUATION

6.1.1 Overview of EPA Model Performance Evaluation Recommendations

EPA current (EPA, 2007) and draft (EPA, 2014e) ozone modeling guidance recommendations for model performance evaluation (MPE) describes a MPE framework that has four components:

- Operation evaluation that includes statistical and graphical analysis aimed at determining how well the model simulates observed concentrations (i.e., does the model get the right answer).
- Diagnostic evaluation that focuses on process-oriented evaluation and whether the model simulates the important processes for the air quality problem being studied (i.e., does the model get the right answer for the right reason).
- Dynamic evaluation that assess the ability of the model air quality predictions to correctly respond to changes in emissions and meteorology.
- Probabilistic evaluation that assess the level of confidence in the model predictions through techniques such as ensemble model simulations.

EPA's guidance recommends that *"At a minimum, a model used in an attainment demonstration should include a complete operational MPE using all available ambient monitoring data for the base case model simulations period"* (EPA, 2014, pg. 63). And goes on to say *"Where practical, the MPE should also include some level of diagnostic evaluation.* EPA notes that there is no single definite test for evaluation model performance, but instead there are a series of statistical and graphical MPE elements to examine model performance in as many ways as possible while building a *"weight of evidence"* (WOE) that the model is performing sufficiently well for the air quality problem being studied.

Because this 2011 ozone modeling is using a CAMx 2011 modeling database developed by EPA, we include by reference the air quality modeling performance evaluation as conducted by EPA (EPA, 2016b) on the national 12km domain and will include any additional documentation provided in the future on the use of the 2011en modeling configuration.

In summary, EPA conducted an operational model performance evaluation for ozone to examine the ability of the CAMx v6.32 and v.6.40 modeling systems to simulate 2011 measured concentrations. This evaluation focused on graphical analyses and statistical metrics of model predictions versus observations. Details on the evaluation methodology, the calculation of performance statistics, and results are provided in Appendix A of that report.

Overall, the ozone model performance statistics for the CAMx v6.32 2011 simulation are similar to those from the CAMx v6.20 2011 simulation performed by EPA for the final CSAPR Update. The 2011 CAMx model performance statistics are within or close to the ranges found in other recent peer-reviewed applications (e.g., Simon et al, 2012). As described in Appendix A of the AQ TSD, the predictions from the 2011 modeling platform correspond closely to observed concentrations in terms of the magnitude, temporal fluctuations, and geographic differences for 8-hour daily maximum ozone. We fully anticipate that the MPE performed for the 2011en platform will demonstrate similar results and will document final evaluation metrics in the documentation associated with the final SIP revision. Thus, the current model performance results demonstrate the scientific credibility of the 2011 modeling platform chosen and used for this analysis. These results provide confidence in the ability of the modeling platform to provide a reasonable projection of expected future year ozone concentrations and contributions.

7.0 FUTURE YEAR MODELING

This chapter discusses the future year modeling using the May through August, 2011 modeling database.

7.1 FUTURE YEAR TO BE SIMULATED

As discussed in Section 1, to support the 2015 ozone NAAQS preliminary interstate transport assessment NODA, EPA conducted air quality modeling to project ozone concentrations at individual monitoring sites to 2023 and to estimate state-by-state contributions to those 2023 concentrations. The projected 2023 ozone concentrations were used to identify ozone monitoring sites that are projected to be nonattainment or have maintenance problems for the 2015 ozone NAAQS in 2023. Ozone contribution information was then used to quantify projected interstate contributions from emissions in each upwind state to ozone concentrations at projected 2023 nonattainment and maintenance sites in other states (i.e., in downwind states). While KY is undertaking this modeling with the 2008 ozone NAAQS in mind, they are mindful of the fact that they are also facing an October 2018 deadline for the submittal of GNS' with respect to the 2015 ozone NAAQS which also involves 2023 as the year for imposition of any new control strategies. Thus, the future year for significant contribution modeling in this analysis is 2023.

7.2 FUTURE YEAR GROWTH AND CONTROLS

In September 2017, EPA released the revised "en" modeling platform that will be the source for the 2023 future-year emissions. Additionally, there are several emission categories and model inputs/options that will be held constant at 2011 levels as follows:

- Biogenic emissions.
- Wildfires, Prescribed Burns and Agricultural Burning (open land fires).
- Windblown dust emissions.
- Sea Salt.
- 36 km CONUS domain Boundary Conditions (BCs).
- 2011 12 km meteorological conditions.
- All model options and inputs other than emissions.

The effects of climate change on the future year meteorological conditions will not be accounted. It has been argued that global warming could increase ozone due to higher temperatures producing more biogenic VOC and faster photochemical reactions (the so called climate penalty). However, the effects of inter-annual variability in meteorological conditions will be more important than climate change given the 12 year difference between the base (2011) and future (2023) years. It has also been noted that the level of ozone being transported into the U.S. from Asia has also increased. As part of the significant contribution and source apportionment analysis, boundary conditions, and their international contribution component will be analysed for their role and contribution to modeled downwind ozone concentrations and attainment.

7.3 FUTURE MODEL–READY EMISSIONS INVENTORY DEVELOPMENT AND QA

Future year emissions will be processed into the gridded speciated hourly three-dimensional emissions inputs for the CAMx photochemical model using the SMOKE emissions model using the same procedures as for the 2011 base year modeling described in Section 5.2.

Similar QA/QC procedures will be performed on the future year model-ready emissions inventories as were utilized by EPA in checking the base year datasets described in Section 5. Standard inventory assessment methods may be employed to generate the future year emissions data including, but not limited to: (a) visualizing the model-ready emissions graphically, (b) spot-checking the holiday emissions files to confirm that they are temporally allocated like Sundays, (c) producing pie charts emission summaries for each source category, and (d) normalizing the emissions by population for each state to reveal where the future year inventories may be suspect. Of particular important will be the comparison of the 2011 base year and 2023 future year emissions by source category to make sure the expected changes occurred in the modeling inventories.

7.4 FUTURE YEAR BASELINE AIR QUALITY SIMULATIONS

A 2023 future year base case CAMx simulation will be conducted and 2023 ozone design value projections and significant contribution calculations made following the procedures in Section 8 that are based on EPA's latest ozone modeling guidance (EPA, 2014).

8.0 SIGNIFICANT CONTRIBUTION CALCULATION

The ultimate objective of the GNS ozone modeling study is the development of modeling databases that can be used to identify significant contribution and define emissions control strategies for the March 2008 8-hour ozone NAAQS by 2023. This section describes the procedures typically used by EPA and that are being considered for this analysis to demonstrate downwind significant contribution of Kentucky to the 8-hour ozone NAAQS.

8.1 8-HOUR OZONE "GOOD NEIGHBOR" DEMONSTRATION PROCEDURE

Under this transport SIP revision, Kentucky is required to demonstrate how they will eliminate their significant contribution to the CSAPR identified problem monitors noted in Section 1.

As a first step, we will compare the newly calculated 2023en 8-hour ozone at each monitor (DVF) with the March 2008 8-hour ozone standard;

- If the 2023 projected average and maximum 8-hour ozone Design Values at all monitoring sites show attainment of the 75 ppb NAAQS and passes both the attainment and maintenance monitor tests, then the scenario has passed the model attainment and maintenance demonstration test and significant contribution metrics do not need to be calculated.
- If the 2023 project 8-hour ozone Design Values at any monitoring sites fails show attainment or maintenance of the 75 ppb NAAQS at any monitor, then significant contribution calculations (1% of NAAQS or 0.75 ppb) tests need to be applied to each upwind state to determine significant contribution designation.

Should the DVF for any of the downwind monitoring sites fail to demonstrate attainment or maintenance with the 2008 ozone NAAQS, the process for calculating the contribution metric uses the contribution modeling outputs in a "relative sense" to apportion the projected 2023 average design value at each monitoring location into contributions from each individual tag (e.g., region and source category) This process is similar in concept to the relative approach described above for using model predictions to calculate 2023 ozone design values. The approach used to calculate the contribution metric is described by the following steps:

- **Step 1.** Modeled hourly ozone concentrations are used to calculate the 8-hour daily maximum ozone (MDA8) concentration in each grid cell on each day.
- **Step 2**. The gridded hourly ozone contributions from each tag are subtracted from the corresponding gridded hourly total ozone concentrations to create a "pseudo" hourly ozone value for each tag for each hour in each grid cell.
- **Step 3**. The hourly "pseudo" concentrations from Step 2 are used to calculate 8-hour average "pseudo" concentrations for each tag for the time period that corresponds to

the MDA8 concentration from Step 1. Step 3 results in spatial fields of 8-hour average "pseudo" concentrations for each grid cell for each tag on each day.

- **Step 4**. The 8-hour average "pseudo" concentrations for each tag and the MDA8 concentrations are extracted for those grid cells containing ozone monitoring sites. We used the data for all days with 2023 MDA8 concentrations >=76 ppb (i.e., projected 2023 exceedance days) in the downstream calculations. If there were fewer than five 2023 exceedance days at a particular monitoring site then the data from the top five 2023 MDA8 concentration days are extracted and used in the calculations.[12]
- **Step 5.** For each monitoring site and each tag, the 8-hour "pseudo" concentrations are then averaged across the days selected in Step 4 to create a multi-day average "pseudo" concentration for tag at each site. Similarly, the MDA8 concentrations were average across the days selected in Step 4.
- **Step 6.** The multi-day average "pseudo" concentration and the corresponding multi-day average MDA8 concentration are used to create a Relative Contribution Factor (RCF) for each tag at each monitoring site.
- **Step 7.** The RCF for each tag is multiplied by the 2023 average ozone design value to create the ozone contribution metrics for each tag at each site. Note that the sum of the contributions from each tag equals the 2023 average design value for that site.
- **Step 8.** The contributions calculated from Step 7 are truncated to two digits to the right of the decimal (e.g., a calculated contribution of 0.78963 is truncated to 0.78 ppb). As a result of truncation, the tabulated contributions may not always sum to the 2023 average design value.

Table 8-1 provides an example of the calculation of contributions from two states (state A and state B) to a particular nonattainment site starting with Step 4, above. The table includes the daily "pseudo" concentrations for state A and state B and corresponding MDA8 ozone concentrations on those days with 2023 model-predicted exceedances at this site. The MDA8 ozone concentrations on these days are ranked-ordered in the table. The 2023 average design value for this example is 77.5 ppb.

12 If there are fewer than 5 days with a modeled 2023 MDA8 concentration ≥ 60 ppb for the location of a particular monitoring site, then contributions will not be calculated at that monitor.

Using the data in Table 8-1, the RCFs for state A and state B are calculated as:

(90.372 – 81.857) / 90.372 = 0.09422 for state A, and
(90.372 – 90.163) / 90.372 = 0.00231 for state B

The contributions from state A and state B to the 2023 average design value at this site are calculated as:

77.5 x 0.09422 = 7.3020 which is truncated to 7.30 ppb for state A, and
77.5 x 0.00231 = 0.1790 which is truncated to 0.17 ppb for state B.

Month	Day	Predicted MDA8 O3 on 2023 Modeled Exceedance Days	"Pseudo" 8-Hr O3 for State A	"Pseudo" 8-Hr O3 for State B
7	11	110.832	98.741	110.817
7	6	102.098	89.017	102.081
7	21	100.739	87.983	100.560
6	9	94.793	87.976	93.179
6	8	92.255	84.707	92.207
7	18	84.768	72.196	84.635
8	1	81.719	81.065	81.718
7	17	81.453	73.034	81.443
7	22	78.377	74.500	78.303
6	16	76.695	69.357	76.695
Multi-Day		90.372	81.857	90.163
2023 Average Design Value is 77.5 ppb		Relative Contribution Factors =>	0.09422	0.00231
		Contributions =>	7.3020	0.1790
		Truncated Contributions =>	7.30	0.17

Table 8-1. Example calculation of ozone contributions (units are ppb).

The average contribution metric calculated in this manner is intended to provide a reasonable representation of the contribution from individual states to the projected 2023 design value, based on modeled transport patterns and other meteorological conditions generally associated with modeled high ozone concentrations in the vicinity of the monitoring site. This average contribution metric is beneficial since the magnitude of the contributions is directly related to the magnitude of the design value at each site.

Should Kentucky be determined to be a significant contributor to any of the Section 1 identified problem monitors, the severity, location, and spatial extent of the modeled exceedances will be studied in order to postulate candidate emissions reductions strategies within and upwind of the nonattainment area. That is, should the future year modeling reveal a nonattainment or maintenance problem, then an attainment demonstration analysis including incremental controls within Kentucky will be performed that will include the 8-hour ozone modeled attainment test, specific screening analysis, and supplemental corroborative analyses set forth in the EPA guidance.

9.0 MODELING DOCUMENTATION AND DATA ARCHIVE

EPA recommends that certain types of documentation be provided along with a photochemical modeling attainment demonstration. Alpine Geophysics is committed to supplying the material needed to ensure that the technical support for this SIP revision is understood by all stakeholders, EPA and KYDAQ.

Alpine Geophysics plans to archive all documentation and modeling input/output files generated as part of the 8-hour modeling analysis and will provide a copy to KYDAQ for additional internal use and public distribution. Key participants in this modeling effort will be given data access to the archived modeling information.

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