Appendix D:
"Good Neighbor" Modeling by Alpine
(December 2017)

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Promoting a healthy environment.

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“Good Neighbor” Modeling for the 2008 8-Hour Ozone State Implementation Plans

Final Modeling Report

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December 2017
Project Number: TS-510

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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. 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) to multiple states 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 many states' infrastructure certification failed to demonstrate that emissions activities within those states will not significantly contribute to nonattainment or interfere with maintenance of the 2008 ozone NAAQS in a neighboring state.

This document serves to provide the air quality modeling results for 8-hour ozone modeling analysis in support of the revision of 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 document describes the overall modeling activities performed in order to demonstrate that states do not significantly contribute to nonattainment or interfere with maintenance of the 2008 ozone NAAQS in a neighboring state. This effort was undertaken working closely with states, other local agencies, and stakeholder groups, including the Midwest Ozone Group which funded this modeling.

A comprehensive draft Modeling Protocol for an 8-hour ozone SIP revision study was prepared and provided to EPA for comment and review relative to Kentucky's Good Neighbor SIP requirements on which this modeling is established. Based on EPA comments, the draft document was revised to include many of the comments and recommendations submitted, most importantly, but not limited to, using EPA's 2023en modeling platform (EPA, 2017a). This 2023en modeling platform represents EPA's estimation of a projected "base case" that demonstrates compliance with final CSAPR update seasonal EGU NOx budgets. A final Modeling Protocol (Alpine, 2017) was prepared and submitted to the Midwest Ozone Group and KYDAQ.

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 eastern state interstate transport, or “Good Neighbor,” responsibilities for the 2008 ozone NAAQS. Eastern states have 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 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 to support the 2008 ozone NAAQS attainment date of 2017, 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.”

Multiple upwind states’ contributions to projected downwind nonattainment area air quality was found to be over the one-percent threshold at numerous final CSAPR-identified nonattainment and maintenance (“problem”) monitors. The one percent threshold for the 2008 NAAQS is 0.75 parts per billion (ppb). These monitors and their final CSAPR update base period and modeled future year design values are shown in Table 1-1.

Table 1-1. Final CSAPR Update-identified problem monitor base period and modeled future year design values (ppb) .

Monitor ID	State	County	2009-2013 Base Period Average Design Value (ppb)	2009-2013 Base Period Maximum Design Value (ppb)	2017 Base Case Average Design Value (ppb)	2017 Base Case Maximum Design Value (ppb)
Nonattainment Monitors						
90019003	Connecticut	Fairfield	83.7	87	76.5	79.5
90099002	Connecticut	New Haven	85.7	89	76.2	79.2
480391004	Texas	Brazoria	88.0	89	79.9	80.8
484392003	Texas	Tarrant	87.3	90	77.3	79.7
484393009	Texas	Tarrant	86.0	86	76.4	76.4
551170006	Wisconsin	Sheboygan	84.3	87	76.2	78.7
Maintenance Monitors						
90010017	Connecticut	Fairfield	80.3	83	74.1	76.6
90013007	Connecticut	Fairfield	84.3	89	75.5	79.7
211110067	Kentucky	Jefferson	85.0	85	76.9	76.9
240251001	Maryland	Harford	90.0	93	78.8	81.4
260050003	Michigan	Allegan	82.7	86	74.7	77.7
360850067	New York	Richmond	81.3	83	75.8	77.4
361030002	New York	Suffolk	83.3	85	76.8	78.4
390610006	Ohio	Hamilton	82.0	85	74.6	77.4
421010024	Pennsylvania	Philadelphia	83.3	87	73.6	76.9
481210034	Texas	Denton	84.3	87	75.0	77.4
482010024	Texas	Harris	80.3	83	75.4	77.9
482011034	Texas	Harris	81.0	82	75.7	76.6
482011039	Texas	Harris	82.0	84	76.9	78.8

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

1.2.1 Current Ozone Air Quality at the Problem Monitors

Table 1-2 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 CSAPR-problem monitors. 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.

Table 1-2. Final CSAPR Update-identified problem monitor design value observations (ppb).

			4th Highest (ppb)								3-yr Avg (ppb)					
Site ID	**State**	**County**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2008-10**	**2009-11**	**2010-12**	**2011-13**	**2012-14**	**2013-15**
Nonattainment Monitors																
90019003	Connecticut	Fairfield	90	73	79	87	89	86	81	87	80	79	85	87	85	84
90099002	Connecticut	New Haven		73	79	92	90	85	69	81		81	87	89	81	78
480391004	Texas	Brazoria	75	91	88	90	87	84	71	86	84	89	88	87	80	80
484392003	Texas	Tarrant	85	90	85	97	79	80	74	76	86	90	87	85	77	76
484393009	Texas	Tarrant	77	86	83	91	86	83	73	79	82	86	86	86	80	78
551170006	Wisconsin	Sheboygan	75	74	85	84	93	78	72	81	78	81	87	85	81	77
Maintenance Monitors																
90010017	Connecticut	Fairfield	88	68	79	81	88	82	78	84	78	76	82	83	82	81
90013007	Connecticut	Fairfield	78	73	79	87	90	90	74	86	76	79	85	89	84	83
211110067	Kentucky	Jefferson			85	82	90	65	70	76			85	79	75	70
240251001	Maryland	Harford	89	83	96	98	86	72	67	74	89	92	93	85	75	71
260050003	Michigan	Allegan	73	76	73	85	95	78	77	72	74	78	84	86	83	75
360850067	New York	Richmond	64	78	85	87	78	71	72	79	75	83	83	78	73	74
361030002	New York	Suffolk	83	79	85	89	83	72	66	78	82	84	85	81	73	72
390610006	Ohio	Hamilton	86	72	80	88	87	69	70	72	79	80	85	81	75	70
421010024	Pennsylvania	Philadelphia	87	72	88	89	85	68	72	79	82	83	87	80	75	73
481210034	Texas	Denton	84	82	74	95	81	85	77	88	80	83	83	87	81	83
482010024	Texas	Harris	83	80	87	83	75	74	68	95	83	83	81	77	72	79
482011034	Texas	Harris	73	79	76	88	83	69	66	88	76	81	82	80	72	74
482011039	Texas	Harris	76	82	85	83	85	69	63	77	81	83	84	79	72	69

1.2.3 Purpose

This document serves to provide air quality modeling results for the 8-hour ozone modeling analysis in support of revisions of 2008 8-hour ozone Good Neighbor State Implementation Plans. This document demonstrates that emissions activities within eastern states 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

Individual impacted states will be the lead agency in the development of 8-hour ozone SIP revisions. Relevant EPA Regional offices will be the local regional EPA office that will take the lead in the review and approval process for this SIP revision.

1.4 OVERVIEW OF MODELING APPROACH

The GNS 8-Hour ozone SIP modeling documented here includes an ozone simulation study using the 12 km grid based on EPA's 2023en modeling platform and preliminary source contribution assessment (EPA, 2016b).

1.4.1 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 was 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.

1.4.2 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 Alpine in pre-merged CAMx ready format. Emissions processing was 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 was also be used. The setup is based on the same WRF/SMOKE/BEIS/CAMx modeling system used in the EPA 2023en platform modeling.

1.4.3 Base and Future Year Emissions Data

The 2023 future year was selected for the attainment demonstration modeling based on OAQPS Director Steven Page's October 27, 2017 memo (Page, 2017, page 4) to Regional Air Directors. In this memo, Director Page identified the two primary reasons the EPA selected 2023 for their 2008 NAAQS modeling; (1) the D.C. Circuit Court's response to *North Carolina v. EPA* in considering downwind attainment dates for the 2008 NAAQS, and (2) EPA's consideration of the timeframes that may be required for implementing further emission reductions as expeditiously as possible. The 2011 base case and 2023 future year emissions will be based on EPA's "en" inventories with no adjustment. This platform has been identified by EPA as the base case for compliance with the final CSAPR update seasonal EGU NOx emission budgets.

1.4.4 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 utilized EPA's pre-QA/QC'd emissions platform that followed a multistep emissions QA/QC approach.

1.4.5 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).

1.4.6 Initial and Boundary Conditions Development

Initial concentrations (IC) and Boundary Conditions (BCs) are important inputs to the CAMx model. We ran 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.

1.4.7 Air Quality Modeling Input Preparation and QA/QC

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

1.4.8 Model Performance Evaluation

The Model Performance Evaluation (MPE) relied 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.

1.4.9 Diagnostic Sensitivity Analyses

Since no issues were identified in confirming Alpine's CAMx runs compared to EPA's using the same modeling platform and configuration, additional diagnostic sensitivity analyses were not required.

2.0 MODEL SELECTION

This section documents the models 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 2008 Ozone NAAQS Preliminary Interstate Transport Assessment (Page, 2017; 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 used the WRF/SMOKE/MOVES2014/BEIS/CAMx-OSAT/APCA modeling system as the primary tool for demonstrating attainment of the ozone NAAQS at downwind monitors at downwind problem monitors. The utilized 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)[1] 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 was 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

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

kilometers. The effort to develop WRF has been a collaborative partnership, principally among 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)[2] 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 was used by EPA to prepare 2023en emission inputs for non-road mobile, area and point sources. These files were adopted and used as-is for this analysis.

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[3] 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 were 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[4]) 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[5]). 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

2 http://www.smoke-model.org/index.cfm
3 http://www.epa.gov/otaq/models/moves/
4 http://www.camx.com
5 http://www.camx.com/files/camxusersguide_v6-20.pdf

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 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 was 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 and was not required for this analysis.

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 used 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 used 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 represents 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 base year and 2023 base case emissions inventories for ozone modeling for this analysis were 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 the seasonal EGU NOx emission budgets outlined in 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 were 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 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 (EPA, 2017a; Page, 2017) databases. While some of the data prepared for this platform are new, many of the files are 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 year and future year base case emission inventories used for the GNS 8-hour ozone modeling study were based on EPA's "en" modeling platform (EPA, 2017a) 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 were used for all categories.

5.2.2.1 Episodic Biogenic Source Emissions

Biogenic emissions were generated by EPA 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

5.2.2.2 Point Source Emissions

2011 point source emissions were from the 2011 "en" modeling platform. Point sources were 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 were used for the 2011 base case emissions scenario. The VOC, CO and PM emissions for point sources with CEM data were 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 were converted to the LCP coordinate system used in the modeling. They were processed by EPA using 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 "en" modeling platform.

5.2.2.3 Area and Non-Road Source Emissions

2011 area and non-road emissions were from the 2011 "en" modeling platform. The area and non-road sources were spatially allocated to the grid using an appropriate surrogate distribution (e.g., population for home heating, etc.). The area sources were 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 were also used.

5.2.2.4 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.

5.2.2.5 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) were 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 generated visual displays that included spatial plots of the hourly emissions for each major species (e.g., NOX, VOC, some speciated VOC, SO2, NH3, PM and CO).

Scripts to perform the emissions merging of the appropriate biogenic, on-road, non-road, area, low-level, fire, and point emission files were 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 were processed into the day-specific hourly speciated emissions in the CAMx-ready point source format.

The resultant CAMx model-ready emissions were 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 Future-Year Emissions Modeling

Future-year emission inputs were 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 used in the GNS 8-hour ozone modeling effort.

The latest version of CAMx (Version 6.40) was used in the GNS ozone modeling. The CAMx model setup used 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 PERFORMACE 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 used in the GNS 8-hour ozone modeling effort.

7.1 FUTURE YEAR TO BE SIMULATED

As discussed in Section 1, to support the 2008 ozone NAAQS preliminary interstate transport assessment, 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 2008 ozone NAAQS in 2023.

7.2 FUTURE YEAR GROWTH AND CONTROLS

In September 2017, EPA released the revised "en" modeling platform that was the source for the 2023 future year emissions in this analysis. This platform has been identified by EPA as the base case for compliance with the final CSAPR update seasonal EGU NOx emission budgets. Additionally, there were several emission categories and model inputs/options that were 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 were not 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.

7.3 FUTURE YEAR BASELINE AIR QUALITY SIMULATIONS

A 2023 future year base case CAMx simulation was conducted and 2023 ozone design value projection calculations were made based on EPA's latest ozone modeling guidance (EPA, 2014).

7.4 CONCLUSIONS FROM 2023 CAMX MODELING

All sites identified in the final CSAPR update are predicted to be well below the 2008 ozone standard by 2023. Table 7-1 provides the GNS 2023 future year average and maximum design value modeling results from this analysis for the eastern state problem monitors identified in Section 1.

Based on these calculations, none of the problem monitors are predicted to be in nonattainment or have issues with maintenance in 2023 and therefore no states are required to estimate their contribution to these monitors.

Table 7-1. GNS Modeling results at Final CSAPR Update-identified problem monitors (ppb).

Monitor ID	State	County	2009-2013 Base Period Average Design Value (ppb)	2009-2013 Base Period Maximum Design Value (ppb)	2023 Base Case Average Design Value (ppb)	2023 Base Case Maximum Design Value (ppb)
Nonattainment Monitors						
90019003	Connecticut	Fairfield	83.7	87	72.7	75.6
90099002	Connecticut	New Haven	85.7	89	71.2	73.9
480391004	Texas	Brazoria	88.0	89	74.0	74.9
484392003	Texas	Tarrant	87.3	90	72.5	74.8
484393009	Texas	Tarrant	86.0	86	70.6	70.6
551170006	Wisconsin	Sheboygan	84.3	87	70.8	73.1
Maintenance Monitors						
90010017	Connecticut	Fairfield	80.3	83	69.8	72.1
90013007	Connecticut	Fairfield	84.3	89	71.2	75.2
211110067	Kentucky	Jefferson	85.0	85	70.1	70.1
240251001	Maryland	Harford	90.0	93	71.4	73.8
260050003	Michigan	Allegan	82.7	86	69.0	71.8
360850067	New York	Richmond	81.3	83	71.9	73.4
361030002	New York	Suffolk	83.3	85	72.5	74.0
390610006	Ohio	Hamilton	82.0	85	65.0	67.4
421010024	Pennsylvania	Philadelphia	83.3	87	67.3	70.3
481210034	Texas	Denton	84.3	87	69.7	72.0
482010024	Texas	Harris	80.3	83	70.4	72.8
482011034	Texas	Harris	81.0	82	70.8	71.6
482011039	Texas	Harris	82.0	84	71.8	73.6

Through this modeling analysis, has all upwind states identified in the final CSAPR Update demonstrated compliance with CAA Section 110(a)(2)(D)(i)(I) for the 2008 Ozone National Ambient Air Quality Standard.

8.0 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 states.

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

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