Appendix A

Modeling Protocol

Air Dispersion Modeling

Introduction

The U.S. Environmental Protection Agency (EPA) document titled "Updated Guidance for Area Designations for the 2010 Primary Sulfur Dioxide National Ambient Air Quality Standard" released March 20, 2015, provides information on the recommended process for designating areas under the 2010 revised SO_2 NAAQS[1]. The guidance recommends the use of the AERMOD modeling system, EPA's preferred near-field dispersion model, for the purpose of modeling to support area recommendations. The Air Program utilized the AERMOD dispersion modeling system to characterize the air quality around the Sikeston, Sibley, and Labadie facilities. These sources are affected by the March 2015 federal consent decree due to their SO_2 emissions and emissions rates. This protocol outlines the AERMOD system and the approaches used by the Air Program in the modeling analyses performed to support the recommendations for the Sikeston Power Station, the Sibley Generating Station, and the Ameren Labadie Energy Center.

The AERMOD system was developed through a collaborative effort between the American Meteorological Society (AMS) and the EPA. AERMOD is a steady-state plume model that employs Gaussian and bi-Gaussian probability density functions to characterize the structure of the planetary boundary layer. AERMOD can predict the concentration distribution of pollutants from surface and elevated releases located within simple or complex terrain. The model allows for the input of multiple sources, terrain elevations, structure effects, various grid receptors, wet and dry depletion calculations, urban or rural terrain, and averaging periods ranging from one hour to one year.

The AERMOD modeling system was used to determine compliance with the 1-hour SO_2 NAAQS. AERMOD is the preferred model for determining pollutant impacts from industrial source complexes where emissions are released from a variety of source types. The most recently available model versions (v) were used in these analyses, the versions used are as follows: AERMOD v14134, AERMET v14134, AERMAP v11103, AERSURFACE v13016, AERMINUTE v14337, and BPIP v04274.

Modeling Conditions

Staff executed AERMOD and its corresponding preprocessors in a disk operating system (dos) windows interface. The regulatory default options within the modeling system were set using the MODELOPT keyword contained within the control pathway of the air quality model. Staff included terrain elevation data and stack-tip downwash calculations.

AERMOD contains a modeling option for urban areas that experience a nighttime heat island effect that creates a "convective-like" boundary layer with increased dispersion. The Guideline on Air Quality Models, Appendix W (Nov 2005) section 7.2.3 instructs users to define the urban or rural classification of the area considering land use and population density. The area surrounding Sibley is in Jackson County, Missouri which contains the northeast portion of the

[1] http://www.epa.gov/airquality/sulfurdioxide/pdfs/20150320SO2designations.pdf

Kansas City urban area. However, the Sibley plant is located at the far eastern boundary of Jackson County on the Missouri river. This part of the county is removed from the Kansas City urban area and is dominated by agricultural land use. The land use procedure in Appendix W 7.2.3(c) classifies urban areas based on industrial, commercial, residential land use over 50% within a 3 km radius of the source. The 3 km radius surrounding Sibley has less than 20% in these urban land use types. Similarly, the population density threshold of the 3 km radius is below the urban threshold of 750 people per square kilometer. Both the land use and population density guidelines in Appendix W indicate Sibley should be modeled as a rural area. The same assessment performed for the areas around Labadie and Sikeston yield similar results. The 3 km radius surrounding Labadie has less than 20% in the urban land use types. The 3 km radius surrounding Sikeston has less than 35% in the urban land use types. And both areas have a population density below the urban threshold. These findings support all three areas being modeled as rural areas.

The AERMOD Implementation Guide (March 2009) section 5.1 guides users to apply the urban option as in Appendix W, but provides additional guidance. Urban complexes should be considered together when making the urban determination, even if single sources would be considered rural. When the urban heat island effect is expected to influence the full modeling domain, the urban option is recommended to capture the regional nature of the nighttime dispersion effect. The western portion of the modeling domain around Sibley contains the far eastern portion of the Kansas City urban area, and Sibley itself is located over 15 km (~10 miles) from the outermost developed suburb of Independence. It is unlikely that the urban heat island effect extends the distance from Sibley, especially given the extensive agricultural land use between Sibley and Independence. The guidance also considers tall stacks, such as Sibley, to be transported above an urban heat island boundary layer height. Both Appendix W and the Implementation Guide support the determination to model Sibley using rural nighttime dispersion characteristics. These guidance documents also support the determination to model Sikeston and Labadie as rural areas with the rural nighttime dispersion characteristics. Further justification was provided for Sibley as it is the closest of all three areas to a major population center.

Modeling Database Development

Refined air quality analyses include SO_2 sources, within each modeling domain, determined to have an impact near the area of interest and that were not accounted for as part of the established background concentration. All permitted SO_2 sources, located within 20 km and up to 50 km of the affected source, were evaluated for a potential impact on the area being modeled based on the level of their actual emissions and their proximity to the primary source. Department staff developed ambient air quality inputs based upon the criteria outlined in 40 CFR Part 51 Appendix W, “Guideline on Air Quality Models.” The following paragraphs outline the procedures used to ensure consistent and comprehensive air quality reviews. The modeling source inventories and source parameters used in the modeling evaluations for each area is discussed in Sections A, B, and C of the main document. Appendix E includes all AERMOD input files, excerpted hourly emissions files, and excerpted output files for each modeling evaluation. For all three modeling analyses, the modeled source inventories are based on emission years 2012-2014, which was the most recent 3-year period available at the start of the modeling evaluations.

Site Specific Data Collection

Detailed information characterizing the sources of interest and all interactive sources was collected from either the Missouri Emission Inventory System (MoEIS) or directly from facilities to be verified. This information includes but is not limited to the following:

1. Facility wide SO_2 equipment list,
2. Reported actual emission rates for each piece of equipment identified in item #1, including continuous emissions monitoring system data, if applicable,
3. A description of equipment usage in order to identify sources that fall into the intermittent source category,
4. Release parameters and source locations for each process unit or stack,
5. Property boundary, and
6. Building locations and heights.

Source Emission Rates

As laid out in EPA's technical assistance document[2], modeling for designation purposes should be done using actual emissions to act as a surrogate for monitoring data. Hourly emissions, recorded by Continuous Emissions Monitoring Systems (CEMS), are the best option for source characterization, but for sources without hourly recorded emissions, additional justification is required.

The emission rates utilized in the air quality model reflect recent actual emissions for the Sibley, Sikeston, and Labadie plants. Actual hourly emissions were obtained through CEMS data reported to EPA's Clean Air Markets Division (CAMD) and paired with hourly meteorological data to simulate actual conditions. Interactive sources, if applicable, were modeled using annual actual emissions as reported to MoEIS for 2014, unless CEMS data was available or otherwise noted.

Emission Release Parameters

Accurate emission release parameters are required inputs to the air quality model to predict pollutant dispersion. The document titled "User's Guide for the AMS/EPA Regulatory Model AERMOD" outlines the source classification system that is used by the AERMOD modeling system in order to characterize emission releases within the input file.

In these SO_2 modeling analyses, the majority of emissions releases are stack driven releases with parameters based upon information provided by the facility or obtained from the MoEIS.

[2] http://www.epa.gov/oaqps001/sulfurdioxide/pdfs/SO2ModelingTAD.pdf

Point source emissions are vented through stacks or isolated vents. In order to assign the point source release parameters, the model requires the following information regarding the location and the nature of the emission releases:

1. Stack height,
2. Stack exit temperature,
3. Stack exit velocity, and
4. Stack diameter.

Stack parameters were provided and verified by the primary facilities and are included for reference in each area analysis as part of the main document. Additionally, Sikeston provided recorded hourly flow and temperature data to be input into the model. All other sources relied on static release parameters.

When stack data was unavailable, the release point was characterized as a volume source within the model input file. Each volume source release is limited to the size of openings from which emissions escape, such as doorways. If no site-specific release characteristics are available, parameters for common volume sources were assigned, such as emergency generators, heaters, etc. The model input files contained in Appendix E include the specific parameters utilized.

Model Domain & Receptor Grid

Each modeling domain is centered on the affected source in each analysis. The modeling domains extend a sufficient distance, at least to 20 kilometers (km) and up to 50 km, in an effort to define the impact from any source that may cause or contribute to a violation of the 1-hour SO_2 NAAQS near the sources of interest.

The receptor grid utilized in the air quality model has a fine resolution to identify the area of maximum impact from fugitive and point source releases and to encompass the full extent of any modeled NAAQS violations that occur. Receptor grid spacing increases with distance from the primary emission source. Specifically, receptors were placed using the below tiered structure for the Sibley and Labadie modeling evaluations. The Sikeston modeling evaluation utilized an extended receptor grid to encompass all of Scott County. The same tiered grid spacing was used for Sikeston, except the last tier was extended to the North and East to encompass all of Scott County. In all modeling analyses, fence line receptors were spaced at 50 meter intervals with onsite receptors removed.

- Origin to 1 km, 100 m spacing
- 1 km to 3.5 km, 250 m spacing
- 3.5 km to 10 km, 500 m spacing
- 10 km to 20 km, 1000 m spacing

Terrain Elevations

In addition to assigning receptor locations, the AERMOD system allows the user to input information regarding the terrain surrounding the facility. AERMOD is capable of calculating

air pollutant concentrations for terrain that can be classified as simple, flat, complex or mountainous land. To calculate concentrations in complex or mountainous terrain situations, AERMOD must have information about the surrounding terrain and its features. To aid in the definition of the terrain features, EPA developed a pre-processor, AERMAP (version 11103) to search terrain data for base elevations and features that may influence the dispersion of pollutants within the modeling domain. Outstanding features are assigned an elevation that is referred to as the hill height scale and that value must be included in the AERMOD input file.

National Elevation Data (NED) in the GeoTIFF format from the United States Geological Survey (USGS) Seamless Data Server was processed through the AERMAP program to obtain the base elevation for each receptor and source within the modeling domain. In addition, the hill height scale for each receptor was extracted to determine terrain influences within the modeling domain.

Determination of Surface Characteristics & Meteorological Data Selection

Because AERMOD does not accept raw meteorological data, it must be processed through AERMET (version 14134), the meteorological data pre-processor for the AERMOD modeling system. AERMET extracts and processes meteorological data to calculate the boundary layer parameters that are used to estimate pollutant concentrations within the atmosphere.

AERMET must have information about the land use to calculate meteorological variables that influence dispersion. To provide a consistent method for determining surface characteristics, the EPA developed a mathematical tool, AERSURFACE, to determine surface roughness, Bowen ratio, and albedo values for input into AERMET. Air Program staff used AERSURFACE (version 13016) with the default values described below:

Bowen ratio

- 10 km x 10 km domain centered on the site.

Albedo

- 10 km x 10 km domain centered on the site.

Surface Roughness Length

- Default upwind distance of one kilometer centered on the site.
- Twelve, 30 degree meteorological sectors.

Where onsite meteorological data are collected for the facility being modeled; no additional surface characteristics analysis is needed. In the case of Sibley, Sikeston, and Labadie, no onsite (or not sufficient onsite) data is available. The nearest meteorological stations operated by the National Weather Service (NWS) were examined.

Because these surface characteristics influence the dispersion profiles within AERMOD, the user must determine if the surface characteristics at the meteorological site are representative of the conditions at the facility site.

The department developed surface characteristics for multiple airports across the state for each moisture condition: average, dry and wet conditions. The results from the AERSURFACE analysis for each airport were summarized in an excel template. This template enables the user to input facility surface characteristics from AERSURFACE for comparison to each airport based upon characteristics of surface roughness, albedo, Bowen ratio, land use classifications, proximity and aerial photography.

Meteorological data

For the three source evaluations, the meteorological data utilized in the air quality model was selected based upon the proximity of the collection site to the modeling domain, the complexity of the terrain, the exposure of the meteorological sensor, and temporal variations in the local climate.

Most National Weather Service (NWS) stations record 1-minute Automated Surface Observing System (ASOS) wind data. The 1-minute ASOS data was obtained from the National Climatic Data Center in the TD-6405 data format that includes the 2-minute average wind speed and direction for each minute within an hour. The use of 1-minute ASOS data more accurately depicts the average hourly wind flow than single instantaneous readings of wind speed and direction that are used in other air quality modeling analyses. The 1-minute ASOS data was processed through AERMINUTE (v14337) prior to input into the AERMET processor.

An Air Program staff meteorologist performed the meteorological evaluation for each source and developed a recommendation memorandum for the chosen meteorological dataset. These memorandums are included in Appendices B, C, and D, for reference.

Building Downwash

Building downwash is calculated using the Building Profile Input Program (BPIP) with plume rise model enhancements (PRIME), version 04274. Information required to execute BPIP PRIME includes the heights and locations of structures which may contribute to building downwash and the stack locations in relation to these structures. Based upon facility configuration, the Air Program determined if a stack is subjected to wake effects from a surrounding structure(s). If structure wake effects are evident, flags were set to indicate which stacks are affected by building wake zones. For stacks influenced by a structure, BPIP PRIME calculates the building heights and widths to be included in the dispersion model so that building downwash effects are considered. Staff evaluated building parameter information for all three sources of interest in the modeling analyses.

Background Concentration

According to 40 CFR Part 51, Appendix W, background concentrations must be considered when determining compliance with the NAAQS. To account for natural source impacts, sources that are not explicitly modeled, and unidentified sources, recent monitoring data was used to establish background concentrations that were incorporated into the modeled results. The following paragraphs outline the procedures used to determine representative background concentrations.

The Air Program recently developed Nonattainment Area (NAA) plans for the two first round NAAs: portions of Jackson and Jefferson Counties. During the development of these plans, thorough background concentration analyses were performed, as described in detail in the following paragraphs. These analyses yielded an urban background concentration of 13 ppb used for Jackson County and a rural background concentration of 9 ppb used for Jefferson County. These established 'rural' and 'urban' concentrations will be used for areas of each respective classification.

The land use classification determination for each area was discussed in the Modeling Conditions section of this Appendix. As mentioned, all three areas were determined to exhibit rural characteristics and therefore modeled as such. The choice of background SO_2 concentration is dependent on many factors other than the urban heat island effect (or land use classification), so the determination to model Sibley as a rural area in AERMOD does not necessarily dictate background concentration. The dominant sources upwind of Sibley include those in the Kansas City urban area. With general westerly flow regimes over Missouri, the established background concentration characteristic of urban areas was chosen for modeling at Sibley. The areas surrounding Sikeston and Labadie were determined to fit the rural classification; therefore, the established background concentration characteristic of rural areas was chosen for modeling at Sikeston and Labadie.

EPA guidance notes that ambient air quality data should generally be used to account for background concentrations. During NAA plan development, staff used 1-hour design value data for the latest 3-year period (2010-2012) to develop background concentrations and to perform a thorough background analysis using monitored values. Monitored background values are based on the design value of the nearest representative air quality monitor that is the least influenced by nearby SO_2 sources.

Background concentrations include impacts attributable to natural sources, nearby sources (excluding the major sources and interactive sources), and unidentified sources. This derived background concentration includes all sources of SO_2 not already included in the model runs. Emissions from any nearby interactive point source facilities are included in the interactive source model run for each area, and as such, are not included in the background concentration.

In general, the background value was calculated similarly to design values at air quality monitors, in order to be comparable to the SO_2 NAAQS. A monitoring site near but outside the immediate area of source impact, that has SO_2 concentrations and wind direction measurements for the most recent certified three-year period, was selected for further analysis. Threshold concentrations were used to limit the monitored value sample size (and associated back trajectories). Statistical analysis including an Excel pivot table and chart were used to visualize the frequency of the measured concentrations from certain wind directions. This is helpful in targeting a sector with the least amount of monitored days above the threshold concentration, which can most likely be attributed to the major source(s). Using the Linux-based Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model script, back trajectories were plotted to show where certain air parcels originated on days that monitored concentrations are above the threshold concentration. Impacts from sources are evident with groupings of

trajectories. A sector with little to no source influence was chosen for further analysis. Considering measured concentrations from the chosen sector, the fourth highest (or 99th percentile) value is chosen as representative of the area's background concentration. The plotted trajectories, pivot chart, and table excerpt used to establish the area background concentration are included below for ease of reference.

Due to the limited number of SO_2 air quality monitoring sites located within Missouri, staff reviewed the regional characteristics within five kilometers of the area to determine what monitoring station best represents the observed land use in and around the nonattainment area. Since an urban monitor site was selected for both background analyses, staff determined which meteorological corridors are not influenced by explicitly modeled sources. The meteorological corridors are defined according to ten degree wind direction sectors. Staff reviewed the 1-hour profile for each meteorological corridor in order to determine a representative background value. Statistical measures were employed in the determination of each background concentration.

A background concentration must be included that represents the contribution from natural sources and from sources that are not explicitly modeled. The most recent air quality design value (i.e., the three-year average of the 99th percentile of the daily maximum 1-hour concentrations) of a representative monitoring site should be used as the background concentration for the area.

Jackson County Nonattainment Area Specific Background Analysis

The Kansas City metropolitan area includes two ambient SO_2 monitoring sites, the Troost Avenue monitor in Missouri and the JFK monitor in Kansas. The Troost Avenue monitor located in Jackson County is not representative of SO_2 background concentrations because there are direct source influences from nearby sources. In addition, the Troost Avenue monitor is in violation of the 1-hour SO_2 standard, which made it inappropriate for background analysis consideration. The JFK air quality monitor on the Kansas side of the Kansas City metropolitan area was chosen as the representative monitor for the Jackson County nonattainment area. It was the least impacted by SO_2 sources in the Kansas City metropolitan area compared to nearby monitors, and therefore is more representative of background concentrations. However, the JFK monitor no longer records hourly wind directional data, so another monitoring site was required to supplement the analysis. The JFK monitor recorded hourly wind direction and wind speed measurements from 1/1/2001 to 12/31/2007. Hourly wind data recorded at Richards-Gebaur South (RGS), an ozone monitor south of the Kansas City area in Cass County, Missouri, was chosen to supplement the background analysis. Missouri maintains that RGS data is representative of meteorological patterns throughout the Kansas City area. Specific monitor site information is included in Table 1.

Table 1 – Jackson County NAA Background Monitor Information

Monitor Information		
Monitor Name	JFK	Richards-Gebaur South
AQS Site ID	20-209-0021	29-037-0003
County	Wyandotte	Cass
Latitude	+39.1175	+38.75976

Longitude	-94.635556	-94.57997
Area Represented	Kansas City, MO-KS	Kansas City, MO-KS

Monitoring data from the JFK site was obtained for the most recent certified three-year period, 2010-2012. Monitored values above 10 ppb, 15 ppb, and 20 ppb were selected to run back trajectories using the HYSPLIT model. Twenty-four (24) hour back trajectories were plotted for the selected high monitored days to evaluate where air parcels originated/passed through on the days of interest. The trajectories had a starting height of ten (10) meters to be consistent with monitor height. A sector with little to no influence from either Missouri or Kansas SO_2 sources was chosen to represent background concentrations. The sector with the least source influence was chosen as 180-200 degrees. Due North is assumed as zero degrees concerning wind direction. The plotted trajectories are included in Figures 2 and 3. Figure 2 depicts the trajectories and NAA boundary with relation to the background and violating monitors. Figure 3 depicts the trajectories with relation to SO_2 emission sources in the area. Frequency of higher monitored values is plotted by wind direction in Figure 1 below. This aids in identifying sectors with less direct source influence. Once a representative sector was a chosen, the highest monitoring values from that sector were evaluated. The four highest values are included below in Table 2. The fourth high monitored value chosen in the representative sector was 13 ppb. Therefore, an SO_2 concentration of 13 ppb or 34.09 µg/m^3 was used as the modeled background concentration for all Jackson County SO_2 nonattainment area SIP purposes.

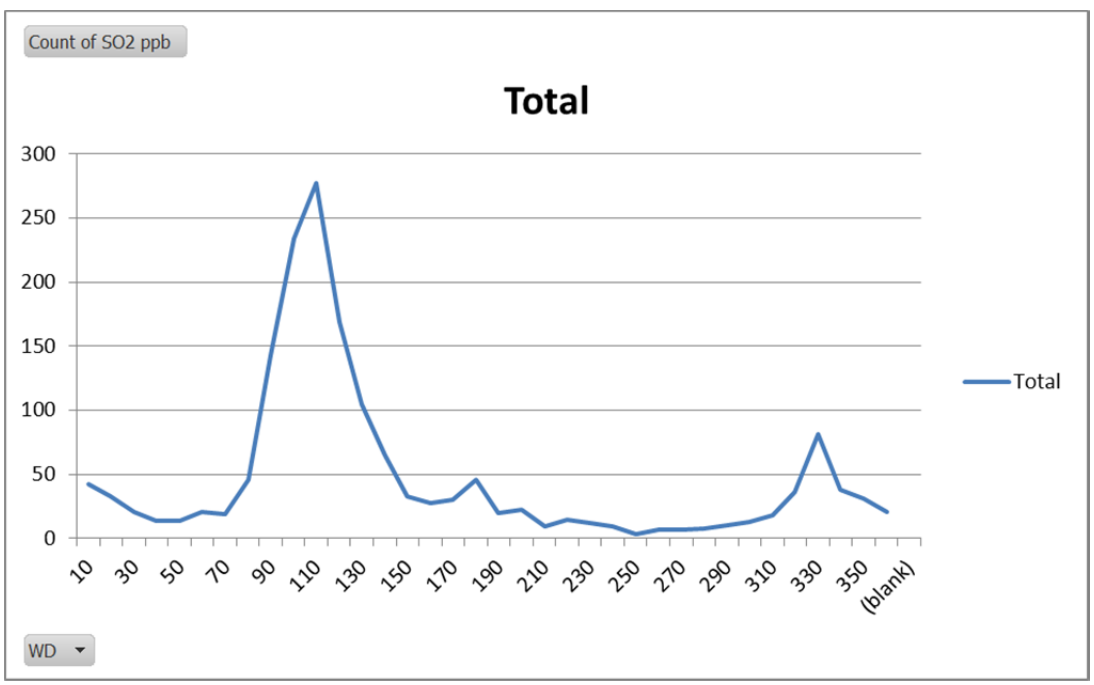

Figure 1 - Chart showing number of hits per 10 degrees in Wind Direction, to depict areas of source influence

Note: The dominant source in the Jackson County NAA, Veolia Energy, is located in the wind sector, 110-115 degrees, from where most of the monitored highs originate, as depicted in the pivot chart [Figure 1] above and the following HYSPLIT plots [Figures 2 and 3].

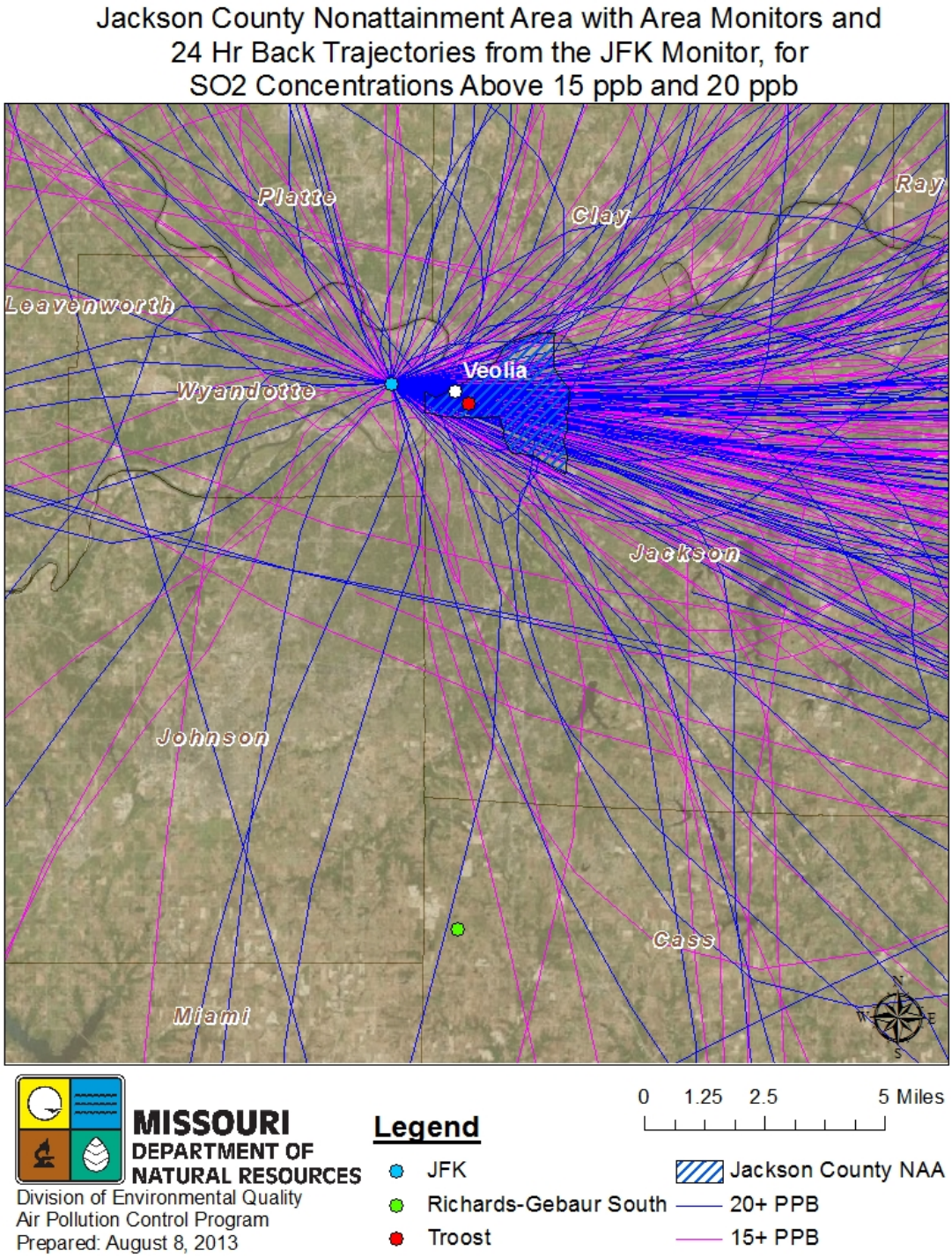

Figure 2 - Plotted Back Trajectories with Jackson County NAA & Monitors used for Background Analysis

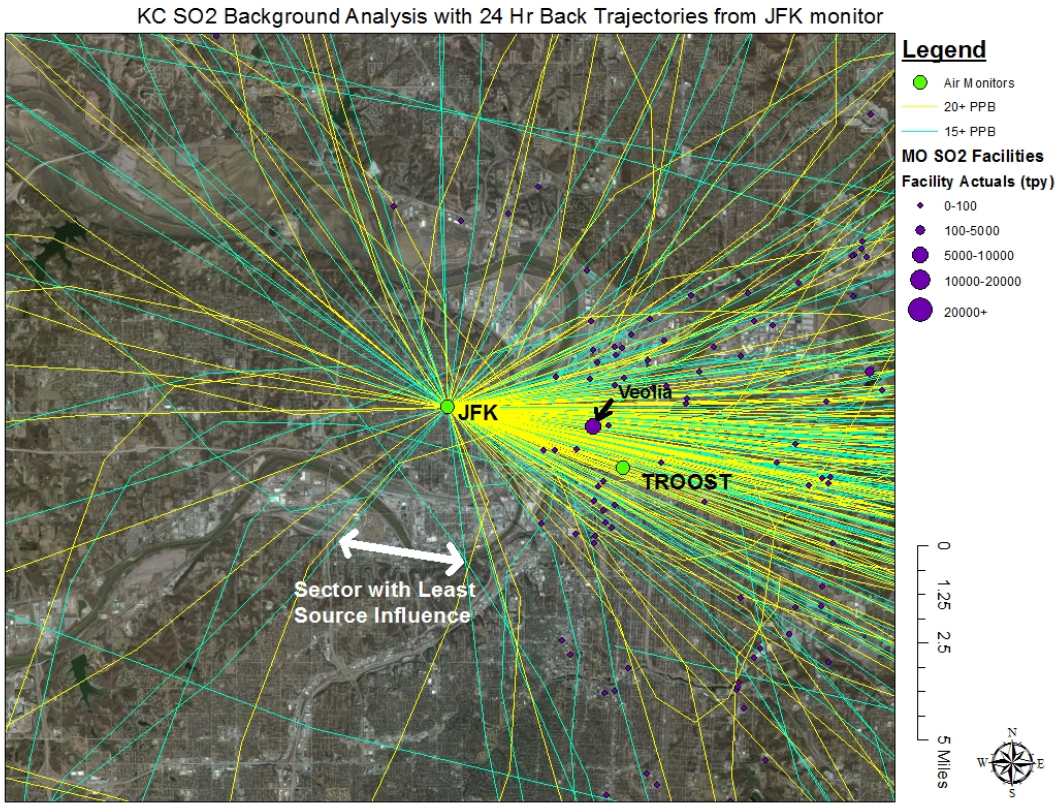

Figure 3 - Plotted Back Trajectories depict areas of source influence and the chosen background sector

Table 2 - Wind and Monitor Data for Chosen Sector (180-200 Degrees) Used to Derive the Fourth High Value to be the Representative Background Concentration for the Area

Date	Start Time	Richards Gebaur-South WD (Degree)	**JFK (Wyandotte) SO_2 Conc. (ppb)**
20100210	17	193	19
20100712	17	184	18
20110104	13	195	13.5
20100818	17	197	13

Jefferson County Nonattainment Area Specific Background Analysis

The Jefferson County NAA is located along the Mississippi River to the south southwest of the St. Louis area. The St. Louis metropolitan area includes six SO_2 monitoring sites. Missouri SO_2 monitoring sites in the St. Louis area include one in Jefferson County and two in the City of St.

Louis. Illinois SO_2 monitoring sites in the area include one in St. Clair County and two in Madison County. The Herculaneum - Mott Street monitor located in Jefferson County was not representative of SO_2 background concentrations because there were direct source influences from nearby sources, namely the smelter. In addition, the Mott Street monitor was in violation of the 1-hour SO_2 standard, at the time of evaluation, which made it inappropriate for background analysis consideration. The East St. Louis air quality monitor located in St. Clair County, Illinois (near the Jefferson County SO_2 NAA) was chosen as the representative background monitor for the area based on proximity to the sources being modeled, similarity of surrounding sources, and limited potential impacts from surrounding SO_2 sources. Specific monitor site information is included in Table 3.

Table 3 – Jefferson County NAA Background Monitor Information

Specific Background Monitor Information	
Monitor Name	East St. Louis
AQS Site ID	17-163-0010
County	St. Clair
Latitude	+38.61203448
Longitude	-90.16047663
Area Represented	St Louis, IL-MO

This monitor is less impacted by primary SO_2 sources in the St. Louis metropolitan area compared to other nearby monitors, and therefore is more representative of background concentrations. The East St. Louis monitor records hourly SO_2 concentrations as well as hourly wind directional data. Hourly SO_2 concentration data and wind directional data from the East St. Louis site were obtained for the most recent certified three-year period, 2010-2012. Monitored values above 5 ppb, and 10 ppb were selected to run back trajectories using the HYSPLIT model. 24-Hour back trajectories, with a starting height of 10 meters (to be consistent with monitor height), were plotted for the selected high monitored days. The plotted trajectories are included in Figure 5. Figure 5 depicts the trajectories and NAA boundary with relation to the background and violating monitors. Frequency of higher monitored values is plotted by wind direction in Figure 4 below. This aids in identifying sectors with less direct source influence. Once a representative sector was a chosen, the highest monitoring values from that sector were evaluated. A sector with little to no source influence was chosen to represent background concentrations. The sector with the least source influence was chosen as 40-110 degrees. This is also indicated on the map in Figure 5. Due North is assumed as zero degrees concerning wind direction. As included in Table 4, the fourth high monitored value (highlighted) chosen in the representative sector was 9 ppb. Therefore, an SO_2 concentration of 9 ppb or 23.607 $\mu g/m^3$ was used as the modeled background concentration for all Jefferson County SO_2 NAA plan purposes.

Table 4 - Wind and Monitor Data for Chosen Sector (40-110) Used to Derive the Fourth High Value to be the Representative Background Concentration for the Area

Date	Time	SO2Conc	WD		Date	Time	SO2Conc	WD
20100207	14:00	19	71		20110725	11:00	6	83
20100112	15:00	10	97		20100112	13:00	5	47
20101214	12:00	10	83		20100411	13:00	5	58
20100514	15:00	9	40		20101005	18:00	5	88

20110125	16:00	9	51		20101116	9:00	5	104
20110825	21:00	9	79		20101215	9:00	5	109
20110329	13:00	8	60		20101215	8:00	5	101
20110329	12:00	8	49		20110125	19:00	5	104
20110725	8:00	8	100		20110125	18:00	5	56
20100925	10:00	7	55		20110329	11:00	5	47
20120411	8:00	7	44		20110601	16:00	5	87
20121216	15:00	7	74		20110704	21:00	5	101
20100925	11:00	6	72		20110704	20:00	5	56
20101116	10:00	6	106		20120315	8:00	5	86

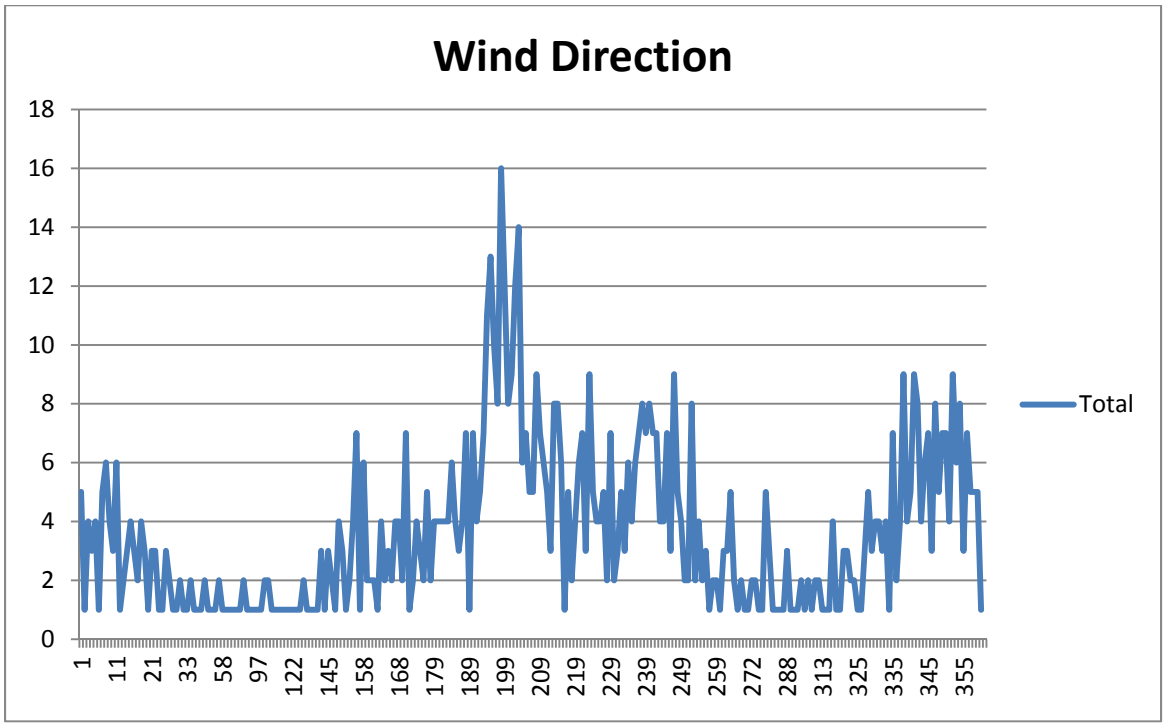

Figure 4 - Chart showing number of hits per degrees in Wind Direction, to depict areas of source influence

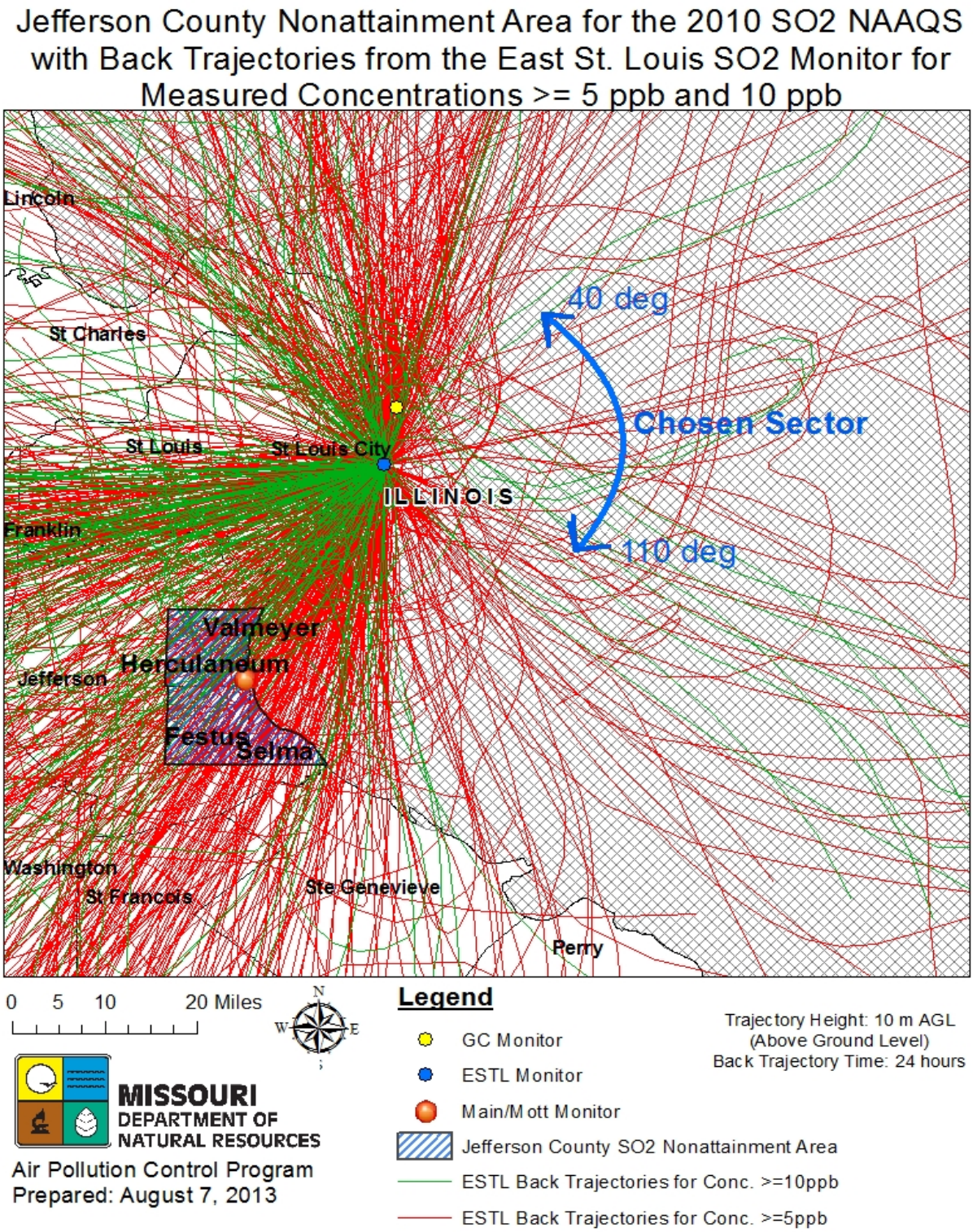

Figure 5 - Plotted Back Trajectories depict areas of source influence and the chosen background sector