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Technical Report

Ambient Monitoring Network Design Analysis for the San Antonio Region

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Alamo Area Council Of Governments
Natural Resources

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<tr><td colspan="3">Abstract: The purpose of a monitoring network assessment is to identify improvements that can be made to an existing network in such a way that will fulfill monitoring goals set forth not only by the Environmental Protection Agency (EPA), but state and local agencies as well. This network assessment seeks to evaluate the regional ozone, meteorology, nitrogen oxides (NO_X), and volatile organic compounds (VOC) monitoring networks, make recommendations on those existing monitoring networks, and suggest new monitoring sites if necessary. The EPA has provided guidance on conducting network assessments, including outlining monitoring objectives and listing different analysis techniques for both assessing the usefulness of an existing monitor and identifying locations where a new monitor might be needed. Monitors within the AACOG jurisdiction are examined using the guidance set forth by the EPA, who provides three broad analysis techniques for conducting a network assessment: site-by-site, bottom-up, and network optimization. Site-by-site analysis techniques help determine which monitors are the most useful by comparing monitors to each other. These analysis methods are used for all four monitoring networks in the region. Bottom-up analyses investigate the causes of high pollutant concentrations, including meteorology and emissions sources, and are also employed for each monitoring network in this report. The final analysis technique is network optimization which holistically and iteratively examines the monitoring network. This is only used for the ozone monitoring network, which due to budget constraints, is the only network that will be expanded upon. In the future, if AACOG wishes to expand its other monitoring networks, the results of this report will provide a solid base for knowing where future monitors should be placed.</td></tr>
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EXECUTIVE SUMMARY

The purpose of a network assessment is to evaluate the existing monitoring network to ensure it fulfills monitoring goals established by the Environmental Protection Agency (EPA), and other goals that may exist for state and local entities invested in pollutant monitoring.

The ozone monitoring network for the San Antonio Area has remained unchanged for over ten years, despite an increase in population and the outgrowth of urban development. With funding secured to purchase and maintain additional ozone monitors, this network assessment of ozone monitors provides the guidelines for determining their ideal future locations. This assessment is also used to determine which monitors may need to be removed from the network. This network design analysis uses guidance on monitoring network assessments from the EPA.

EPA guidance describes three types of analytic methods for conducting a network assessment: site-by-site, bottom-up, and network optimization. All three of these methods are used in assessing the ozone monitoring network in this report, but not for the meteorological, nitrogen oxides (NO_X), and volatile organic compounds (VOC) monitoring networks. These last three networks only include a site-by-site and bottom-up analysis as they will not be expanded upon at this time. Site-by-site analysis methods compare monitors in a network to each other to determine how useful or unique each monitor is. Monitor characteristics such as the length of record, the number of parameters monitored, the area and population served by each monitor, and the measured concentrations at each monitor are examined, but other factors such as meteorology and emissions are ignored.

The site-by-site analyses included in this report suggest that there may be redundancies in the ozone monitoring network in the eastern half of the region; however, it is recommended that this part of the monitoring network remain unchanged as they are useful in recording incoming ozone levels from the northeast, east, and southeast. The western half of the network, as determined by the bottom-up analyses contained in this report, is underserved by ozone monitors. Photochemical modeling results show that during high ozone events, elevated concentrations commonly spread westward into Medina County in two lobes: one into the central part of the county and the other into the northern part closer to Medina Lake. It is recommended that two new ozone monitors be installed in western Bexar County to record concentrations downwind of most of the precursor emissions associated with the urbanized area. A third monitor is being proposed in far south Bexar County based on results of the back trajectory analysis. Network optimization analysis techniques are the most advanced of the three types and are often performed iteratively. The removal bias analysis is one such method that helps corroborate the suggestion that more monitoring is needed on the west side of the network.

The above recommendations for the ozone monitoring network will improve the spatial coverage of monitors, providing a more comprehensive framework for the interpolation of ozone concentrations. The assessment of the meteorological, NO_X, and VOC monitoring networks does not include network optimization analysis techniques, but is sufficient to lay the groundwork for identifying new precursor monitoring sites in the future.

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1 INTRODUCTION

The Clean Air Act (CAA) is the comprehensive federal law that regulates airborne emissions across the United States. This law authorizes the U.S. Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) to protect public health and the environment. Of the many air pollutants commonly found throughout the country, EPA has recognized six “criteria” pollutants that can injure health, harm the environment, and/or cause property damage. Air quality monitors located throughout the country measure concentrations of these pollutants, which include particulate matter, ground-level ozone, sulfur oxides (SO_X), nitrogen oxides (NO_X), carbon monoxide, and lead. The San Antonio – New Braunfels MSA struggles to meet the standard for one of these criteria pollutants: ground-level ozone. On October 1, 2015, the EPA updated its NAAQS for ozone to a more-stringent 70 ppb, placing the region at risk of being designated nonattainment as early as October 2017.

Ozone is produced when volatile organic compounds (VOC) and nitrogen oxides (NO_X) react in the presence of sunlight, especially during the summer time. These ozone precursors can be generated by natural processes, but the majority of chemicals that form ground-level ozone originate from anthropogenic sources. According to the EPA, “ground-level ozone can cause a variety of respiratory health effects, including airway inflammation; reduced lung function; increased susceptibility to respiratory infection; and respiratory symptoms such as cough, wheezing, chest pain, and shortness of breath. Ozone exposure can decrease the capacity to perform exercise and has been associated with the aggravation of respiratory illnesses such as asthma and bronchitis, leading to increased use of medication, absences from school, doctor and emergency department visits, and hospital admissions. Studies have also found that long-term ozone exposure may contribute to the development of asthma, especially among children with certain genetic susceptibilities and children who frequently exercise outdoors.”[1] Currently, the ozone primary standard, which is designed to protect human health, is set at 70 parts per billion (ppb). The secondary standard, which is designed to protect the environment, is in the same form and concentration as the primary standard.

This report intends to assess the current air quality monitoring network for the 13-county AACOG region by determining the usefulness of each monitor in the context of the entire network. The specific monitoring networks that will be analyzed are ozone, NO_X, VOCs, and meteorology. In order to determine the usefulness of each monitor, it is necessary to understand the purpose of state and/or local monitoring operations. Title 40, Part 58, Section 10, Appendix D of the Code of Federal Regulations (40 CFR 58.10)[2] lists three air quality monitoring objectives:

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[1] U.S. Environmental Protection Agency, 2015. “America’s Children and the Environment, Third Edition.” Available online: https://www.epa.gov/sites/production/files/2015-10/documents/ace3_respiratory.pdf. Accessed August 16, 2016.

[2] U.S. Government Publishing Office, 2016. “Electronic Code of Federal Regulations.” Title 40, Part 58, Section 10, Appendix D. Available online: http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&r=PART&n=40y6.0.1.1.6. Accessed July 25, 2016.

1. Provide air pollution data to the general public in a timely manner.
2. Support compliance with ambient air quality standards and emissions strategy development.
3. Support for air pollution research studies.

To ensure the above three objectives are met, the EPA gives six different site types to consider when implementing a monitoring network:

1. Sites located to determine the highest concentrations expected to occur in the area covered by the network.
2. Sites located to measure typical concentrations in areas of high population density.
3. Sites located to determine the impact of significant sources or source categories on air quality.
4. Sites located to determine general background concentration levels.
5. Sites located to determine the extent of regional pollutant transport among populated areas; and in support of secondary standards.
6. Sites located to measure air pollution impacts on visibility, vegetation damage, or other welfare-based impacts.

The purpose of a Network Design Analysis is to optimize air quality monitor placement within a given area such that it provides the greatest possible scientific value and protects public and environmental health and welfare. The data collected from AACOG's monitoring operations supports and enhances knowledge of ambient ozone levels in the Greater San Antonio Area, assists local elected officials in their understanding of ozone transport, and assists local technical assessments related to the formation and transport of ozone in the region.

1.1 Network Assessment Guidance

The U.S. Environmental Protection Agency (EPA) amended its ambient air monitoring regulations in October 2006 requiring states and local entities to conduct a network assessment once every five years. The EPA's Ambient Air Monitoring Network Assessment Guidance document provides several methods for technical assessment of air quality monitor placement. These analytical methods are separated into three categories: site-by-site analysis, bottom-up analysis, and network optimization analysis. Site-by-site ranks individual monitors based on a specific purpose. The bottom-up analysis technique uses data other than the pollutant of interest to help select ideal locations of new monitors. This data could include meteorological data and regional emissions inventories. The network optimization analysis technique assesses different monitoring network scenarios.[3]

[3] U.S. Environmental Protection Agency, 2007. Office of Air Quality Planning and Standards. "Ambient Air Monitoring Network Assessment Guidance." p. 2-3 & 2-4. Research Triangle Park, NC. Available online: https://www3.epa.gov/ttnamti1/files/ambient/pm25/datamang/network-assessment-guidance.pdf. Accessed July 25, 2016.

The EPA considers six different spatial scales for pollutant monitoring sites. In order of scope from small to large, these categories are: microscale, middle scale, neighborhood scale, urban scale, regional scale, and national/global scale. Not all of these spatial scales will be appropriate for all pollutants. Generally, primary pollutants, those emitted directly into the atmosphere, are more appropriately monitored at micro- to neighborhood scale. Secondary pollutants like ozone, which form from reactions between primary pollutants and sunlight, are more appropriately monitored at neighborhood to regional scales due to formation times and the mixing of reactants and products over long distances. The following is a list of the spatial scales for pollutant monitoring and their definitions:

1. "Microscale – Defines the concentrations in air volumes associated with area dimensions ranging from several meters up to about 100 meters.
2. Middle scale – Defines the concentration typical of areas up to several city blocks in size with dimensions ranging from about 100 meters to 0.5 kilometer.
3. Neighborhood scale – Defines concentrations within some extended area of the city that has relatively uniform land use with dimensions in the 0.5 to 4.0 kilometers range. The neighborhood and urban scales listed below have the potential to overlap in applications that concern secondarily formed or homogeneously distributed air pollutants.
4. Urban scale – Defines concentrations within an area of city-like dimensions, on the order of 4 to 50 kilometers. Within a city, the geographic placement of sources may result in there being no single site that can be said to represent air quality on an urban scale.
5. Regional scale – Defines usually a rural area of reasonably homogeneous geography without large sources, and extends from tens to hundreds of kilometers.
6. National and global scales – These measurement scales represent concentrations characterizing the nation and the globe as a whole."[4]

When establishing monitoring sites, it is important to define which spatial scale the monitor will represent. For example, near-road NO_X monitors fit the microscale definition as they must be sited adjacent to heavily traveled roadways. Ozone monitors on the upwind boundary of an urbanized area might be thought to fit the regional definition as it helps characterize interregional ozone transport, while an ozone monitor downwind of a large urbanized area might be considered more of an urban scale monitor.

There are other considerations that must be made when choosing locations for monitors. These location criteria pertain to probe and monitoring path siting and should factor in vertical and horizontal placement, proximity to trees and other obstructions, and proximity to emissions sources such as point sources and roadways. The EPA may grant a waiver for a new monitoring site that does not meet one of the aforementioned considerations under two conditions: if the proposed monitoring site is representative of the modeling area even if not all

[4] U.S. Government Publishing Office, 2016. "Electronic Code of Federal Regulations." Title 40, Part 58, Section 10, Appendix D. Available online: http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&r=PART&n=40y6.0.1.1.6. Accessed July 25, 2016.

siting criteria are met, and if the monitor cannot be reasonably located to conform to the siting criteria due to physical constraints.[5]

1.2 Local Monitoring Goals

In addition to the federal monitoring goals listed earlier, AACOG adopted local monitoring goals just prior to implementing its ozone monitoring network in 2002. The first goal in establishing the AACOG Ozone and Meteorological Monitoring Network was:

1. To augment the existing regulatory monitoring network for ambient ozone data collection. The implementation of additional, non-regulatory ozone monitors will aid in visualizing ozone distribution across the region. Although these monitors do not determine compliance with any air quality standards, they are beneficial to air quality research pursuant to the State Implementation Plan (SIP).

The air quality monitoring provided by the AACOG Ozone and Meteorological Monitoring Network was also designed to assist both citizens and local air quality planners in accomplishing at least three additional goals:

2. Assess Population Exposure: extending the monitoring network allows a more comprehensive estimation of exposure of citizens to ambient ozone levels. Students, such as school children, are among at-risk health populations for ozone exposure;
3. Photochemical model performance verification: how well does the photochemical model predict ozone levels across the modeling region? The photochemical model is the most valuable and trusted method of predicting changes in ozone levels when various ozone control strategies are in place, and of forecasting the ozone levels in future years with and without control strategies. As such, verification of the model's accuracy is very important to achieving successful regional air quality planning; and
4. Education: extending the monitoring network allows public awareness of ozone levels and associated health risks where people work, live, and travel in the San Antonio Region. Moreover, placing this data collection equipment at host schools will facilitate increased science education on air quality/pollution issues.[6]

AACOG is responsible for the collection of ambient monitoring data at its monitoring sites and for the electronic transfer of the data to the TCEQ's Leading Environmental Analysis and Display System (LEADS) on a near-"real-time" basis during the entire ozone season.

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[5] U.S. Government Publishing Office, 2016. Washington, D.C. "Electronic Code of Federal Regulations." Title 40, Part 58, Section 10, Appendix E. Available online: http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&r=PART&n=40y6.0.1.1.6. Accessed July 27, 2016.

[6] Alamo Area Council of Governments, 2016. San Antonio, TX. "Ambient Monitoring Quality Assurance Project Plan (QAPP)." Available online: http://www.aacog.com/DocumentCenter/View/34694. Accessed November 15, 2016.

1.3 Current Monitoring Network and History

Ozone monitoring for the San Antonio Region began in 1974 at San Antonio North, four years after the Clean Air Act was passed. The San Antonio North monitor also measured NOx and had a hydrocarbon analyzer. In 1977, two additional ozone monitors were deployed: one on the northern edge of downtown San Antonio (Salinas and Camaron) that also recorded NOx and Non-Methane Hydrocarbons (NMOCs), and the other at Calaveras State Park on the far southeast side, which only recorded ozone. The latter two monitors ceased operation at the end of 1981, while San Antonio North continued operation until 1998.

Also in 1981, an EPA-regulatory ozone monitor (CAMS 23) was placed at Marshall High School and is still in operation. The ozone monitoring network went unchanged until 1998, when CAMS 59 and CAMS 58 at Calaveras Lake and Camp Bullis, respectively, commenced operation. These three monitors continue to be in operation today and are also regulatory monitors. They are owned by TCEQ and are used to determine compliance with the National Ambient Air Quality Standards (NAAQS) for ozone, the most recent of which was promulgated in October 2015.

A year later, City Public Service (CPS) Energy installed a non-regulatory ozone monitor (CAMS 678) approximately 6 km ESE of downtown San Antonio. This monitor was positioned to record emissions from electric generating units near Calaveras Lake, which are upwind of the monitor. Other criteria pollutants were monitored at this station: carbon monoxide (CO), nitrogen dioxide (NO_2) and other NO_X, sulfur dioxide (SO_2), and particulate matter (PM). Also in 1999, the University of Texas Center for Energy and Environmental Resources (UTCEER) established a temporary air quality monitor near Somerset, southwest of San Antonio, to measure background ozone and NO_X, and to measure VOCs using canister sampling. The purpose of this temporary monitoring project was to compare ozone and precursor concentrations with those at CAMS 59 and to determine what effect, if any, the proximity of CAMS 59 to major point sources had on its ozone, NO_X, and VOC measurements. This monitoring project took place between April and October 1999.

AACOG launched its first four non-regulatory ozone monitors during the 2002 ozone season to supplement the three existing regulatory monitors. CAMS 501 at Elm Creek Elementary, CAMS 502 in Fair Oaks Ranch, and CAMS 503 at Bulverde Elementary were equipped with meteorological monitoring systems, while CAMS 504 in New Braunfels was situated adjacent to the regional National Weather Service office. In March 2003, the Garden Ridge (CAMS 505) and Seguin Outdoor Learning Center (CAMS 506) monitors were deployed by AACOG. In July 2004, CPS Energy installed another non-regulatory ozone monitor at Heritage Middle School (CAMS 622) almost 9 km north of CAMS 59. In 2013, meteorological monitoring was discontinued at CAMS 503 in Bulverde. The local ozone monitoring network has not changed since 2004, despite continued population growth in the northern and western fringes of San Antonio, the addition of point sources of NO_X and VOCs, the rapid growth of oil and natural gas production in the Eagle Ford Shale, and continued reductions of mobile source emissions. These changes in regional emissions characteristics necessitate the completion of a Network

Design Analysis to determine what changes, if any, need to be made to the local air quality monitoring network.

1.4 Monitoring Inventory

The following tables provide an inventory of AACOG's air quality monitoring equipment at each monitor. Also included is an inventory of extra equipment and spare parts that may be used in additional monitoring operations (Table 1-7).

Table 1-1: Inventory List for CAMS 501 – Elm Creek Elementary School

1. Thermo Environmental Ozone Monitor	P/N: M-49c S/N: 49i-1153170070
2. Coastal Environmental Zeno-3200 Data Logger	P/N: S-1034 S/N: 2240
3. US Robotics 56K Modem-Sportster	P/N: USR5686E S/N: 1MCW23CM9249
4. APC Smart-UPS-BX1000	P/N: BACK-UPS-1000 S/N: QB0432330374
5. R.M. Young Wind Monitor	P/N: 05305 VP SN-88656
6. R.M. Young Platinum Temp Probe	P/N: 41342 VF
7. R.M. Young Multiplate Radiation Shield	P/N: 41002 P
8. R.M. Young Tipping Bucket Rain Gauge	P/N: 52203
9. Climatronics Corp. 33'	P/N: C33-GO-H1
10. Climatronics Corp. 33' Grounding Kit	P/N: 100924-G1-45
11. Cole-Parmer Inline 47-mm Filter Holder	P/N: U-06621-40
12. Activated Charcoal Scrubber	N/A
13. PS-Surge 6-Outlet Surge Protector	N/A
14. Coastal Environmental Serial Cable	N/A
15. Aluminum Zeno Mount	N/A

Table 1-2: Inventory List for CAMS 502 – City of Fair Oaks Ranch

1. Thermo Environmental Ozone Monitor	P/N: M-49c S/N: 49c-0415506572
2. Coastal Environmental Zeno-3200 Data Logger	P/N: S-1034 S/N: 2790
3. US Robotics 56K Modem-Sportster	P/N: USR5686E S/N: 1MCWX29LY612
4. APC Smart-UPS	P/N: BACK-UPS-APC –CS-350 S/N: 481118P15539
5. R.M. Young Wind Monitor	P/N: 50620 VP
6. R.M. Young Platinum Temp Probe	P/N: 41342 VF
7. R.M. Young Multiplate Radiation Shield	P/N: 41002 P
8. R.M. Young Tipping Bucket Rain Gauge	P/N: 52203
9. Climatronics Corp. 33'	P/N: C33-GO-H1
10. Climatronics Corp. 33' Grounding Kit	P/N: 100924-G1-45
11. Cole-Parmer Inline 47-mm Filter Holder	P/N: U-06621-40
12. Activated Charcoal Scrubber	N/A
13. PS-Surge 6-Outlet Surge Protector	N/A
14. Coastal Environmental Serial Cable	N/A
15. Aluminum Zeno Mount	N/A

Table 1-3: Inventory List for CAMS 503 – Bulverde Elementary School

1. Thermo Environmental Ozone Monitor	P/N: M-49c S/N: 49c-74531-376
2. Coastal Environmental Zeno-3200 Data Logger	P/N: S-1034 S/N: 2789
3. Enfora GSM-1208 Modem	P/N: GSM-1208 S/N: 1208360700305
4. APC Smart-UPS	P/N: BACK-UPS-600 S/N: FB9650305722

5. Cole-Parmer Inline 47-mm Filter Holder	P/N: U-06621-40
6. Activated Charcoal Scrubber	UKN
7. PS-Surge 6-Outlet Surge Protector	UKN
8. Coastal Environmental Serial Cable	UKN
9. Aluminum Zeno Mount	UKN

Table 1-4: Inventory List for CAMS 504 – New Braunfels Airport

1. Thermo Environmental Ozone Monitor	P/N: M-49c S/N: 49c-75375-379
2. Coastal Environmental Zeno-3200 Data Logger	P/N: S-1034T S/N: 2242
3. US Robotics 56K Modem-Sportster 5686G	P/N: 64-005686-05 S/N: 1MCWZ3CM9193
4. APC Smart-UPS	P/N: 2334GVHBC S/N: 785702945
5. Cole-Parmer Inline 47-mm Filter Holder	P/N: U-06621-40 S/N: N/A
6. Activated Charcoal Scrubber	N/A
7. PS-Surge 6-Outlet Surge Protector	N/A
8. Modem Serial Cable	N/A
9. Aluminum Zeno Mount	N/A

Table 1-5: Inventory List for CAMS 505 – City of Garden Ridge

1. Thermo Environmental Ozone Monitor	P/N: M-49c S/N: 49c 75374-379
2. Coastal Environmental Zeno-3200 Data Logger	P/N: S-1034T S/N: 2241
3. Thermo Environmental NO, NO_2, NO_X, Analyzer	P/N: 42c NO, NO_2, NO_X Analyzer S/N: 42c-67914-359 (Not Operational)
4. Dasibi Zero Air Unit	Model-5011 S/N: 607
5. Puma 120V Oilless Air Compressor	Model-LA 5721 Date 0513 S/N: 6-36084-65721-4

6. Enfora GSM-1208 (IP:10.200.4.91)	P/N: GSM-1208 S/N: 1208180500035
7. APC Smart-UPS	P/N: BACK-UPS-600 S/N: FB-9650305717
8. Cole-Parmer Inline 47-mm Filter Holder-(*3 each)*	P/N: U-06621-40 S/N: N/A
9. Glass Water Trap	N/A
10. Activated Charcoal Scrubber	N/A
11. Power Strip	N/A
12. Modem Serial Cable	N/A
13. Aluminum Zeno Mount	N/A

Table 1-6: Inventory List for CAMS 506 – Seguin Outdoor Learning Center

1. Thermo Environmental Ozone Monitor	P/N: M-49c 03 S/N: 49c-0415506573
2. Coastal Environmental Zeno-3200 Data Logger	P/N: S-1034T S/N: 2243
3. US Robotics 56K Modem-Sportster	P/N: 64-005686-05 S/N: 2ABLX67F0864
4. APC Smart-UPS	P/N: BK400 S/N: PB-9712905043
5. Cole-Parmer Inline 47-mm Filter Holder	P/N: U-06621-40 S/N: N/A
6. Activated Charcoal Scrubber	N/A
7. PS-Surge 6-Outlet Surge Protector	N/A
8. Modem Serial Cable	N/A
9. Aluminum Zeno Mount	N/A

Table 1-7: Spare AACOG Equipment Located at Dios Dado Environmental, Ltd. (Not in operation)

1. Thermo 49C O_3 Monitor	**MODEL: 49c** S/N: 49c-75376-379 (Works) S/N: 49c-75373-379 (Works) S/N: 49c-0326802161 (Works) **MODEL: 49i-A1NAA** S/N: 49i-1153170073 (NEW) S/N: 49i-1153170039 (NEW) S/N: 49i-1153170074 (NEW)
2. Thermo Environmental 43C SO_2 Analyzer	S/N: 0328002389 (Needs Repair)
3. Coastal Environmental Zeno-3200 Data Logger	P/N: S-1034T S/N: 2244 (Works)
4. Coastal Environmental Zeno-3200 Data Logger	P/N: S-1034T S/N: 2239 (Works)
5. Dasibi Multi Gas Calibrator 5008	S/N: 717 (Needs Repair)
6. R.M. Young Wind Monitor-AQ	P/N: 05305 VP S/N: 88656
7. R.M. Young Platinum Temp Probe	P/N: 41342 VF
8. R.M. Young Multiplate Radiation Shield	P/N: 41002 P
9. R.M. Young Tipping Bucket Rain Gauge	P/N: 52203
10. Climatronics Corp. 33'	P/N: C33-GO-H1
11. Climatronics Corp. 33' Grounding Kit	P/N: 100924-G1-45
12. Gas Bottle Regulator	Model: 51-15C P/N: 45100016 S/N-542529

Note: Thermo "Scrubber Assembly (49c)": (Thermo part number: 14697)

Table 1-7 reveals that AACOG has six extra ozone analyzers (three new and three existing), which are by far the most expensive component of the ozone monitoring operation. There are also two spare Zeno-3200 data loggers in AACOG's inventory. To be able to deploy an additional ozone monitor, AACOG would need to purchase or acquire a backup battery (APC Smart-UPS-BX1000 or equivalent), a modem and cable, an activated charcoal scrubber, a surge protector, a mount for the Zeno data logger, and a secured trailer to house the equipment. AACOG has all of the necessary equipment to begin meteorological monitoring at one of the existing ozone monitoring sites. The CAMS 505 site in Garden Ridge contains a NO, NO_2, and NO_X analyzer, a rack system, and associated calibration equipment that are in working condition but not in operation. AACOG also has a sulfur dioxide analyzer that is being stored at Dios

Dado Environmental, but it needs repair before beginning operation. Although not addressed in this report in depth, sulfur dioxide is currently being monitored at CAMS 59 at Calaveras Lake. Sulfur dioxide had previously been monitored at CAMS 622 and CAMS 678, but ceased monitoring in early April 2016. At this time there are no plans to begin sulfur dioxide monitoring at any of the AACOG-owned monitors as there is no danger of exceeding the 2010 NAAQS for sulfur dioxide.

2 OZONE MONITORING NETWORK

In the 13-county AACOG region, there are eleven monitors that measure ambient ozone concentrations. Three of those are regulatory monitors, shown as red markers in Figure 2-1. These three monitors are operated by TCEQ and are intended to measure compliance of the ozone NAAQS. Two of these monitors are located on the northwest side of the urban core (CAMS 23 and CAMS 58) and most commonly measure the highest ozone concentrations in the region. The other regulatory monitor, CAMS 59, is located upwind of the CPS-owned power plants around Calaveras Lake and southeast of the urban core. This monitor is ideally situated to measure incoming ozone concentrations before the influence of major sources of precursor emissions within the MSA.

Two monitors, CAMS 622 and CAMS 678, are owned by CPS Energy and do not determine NAAQS compliance. These two monitors measure emissions downwind of the CPS power plants. The remaining six monitors are owned by AACOG, do not determine NAAQS compliance, and are intended to supplement the regulatory monitors by providing a more comprehensive regional coverage for ozone measurements. Five of the six AACOG-owned ozone monitors are located northwest to northeast of the urban core. The exception is CAMS 501, located in the far southwestern corner of Bexar County. Two monitors, C1675 in San Marcos and C1604 in Lockhart (not pictured below), are located in the CAPCOG region, but are close enough to provide useful data for air quality analysis in the AACOG region, especially on those high ozone days where winds come out of the northeast.

Site conditions at the Fair Oaks Ranch monitor (CAMS 502) were deemed unsuitable for ozone monitoring at the end of the 2015 ozone season.[7] Relocation of this monitor is contingent upon the results of this network assessment. All analyses presented in this report include CAMS 502 at its current location. If the results of this study conclude that the Fair Oaks Ranch monitor is useful, it will be relocated as close as possible to its existing location.

[7] Dios Dado Environmental, Ltd., 2016. "Annual Ambient Air Quality Monitoring Report 2015." Available online: http://www.aacog.com/DocumentCenter/View/36119. Accessed July 25, 2016.

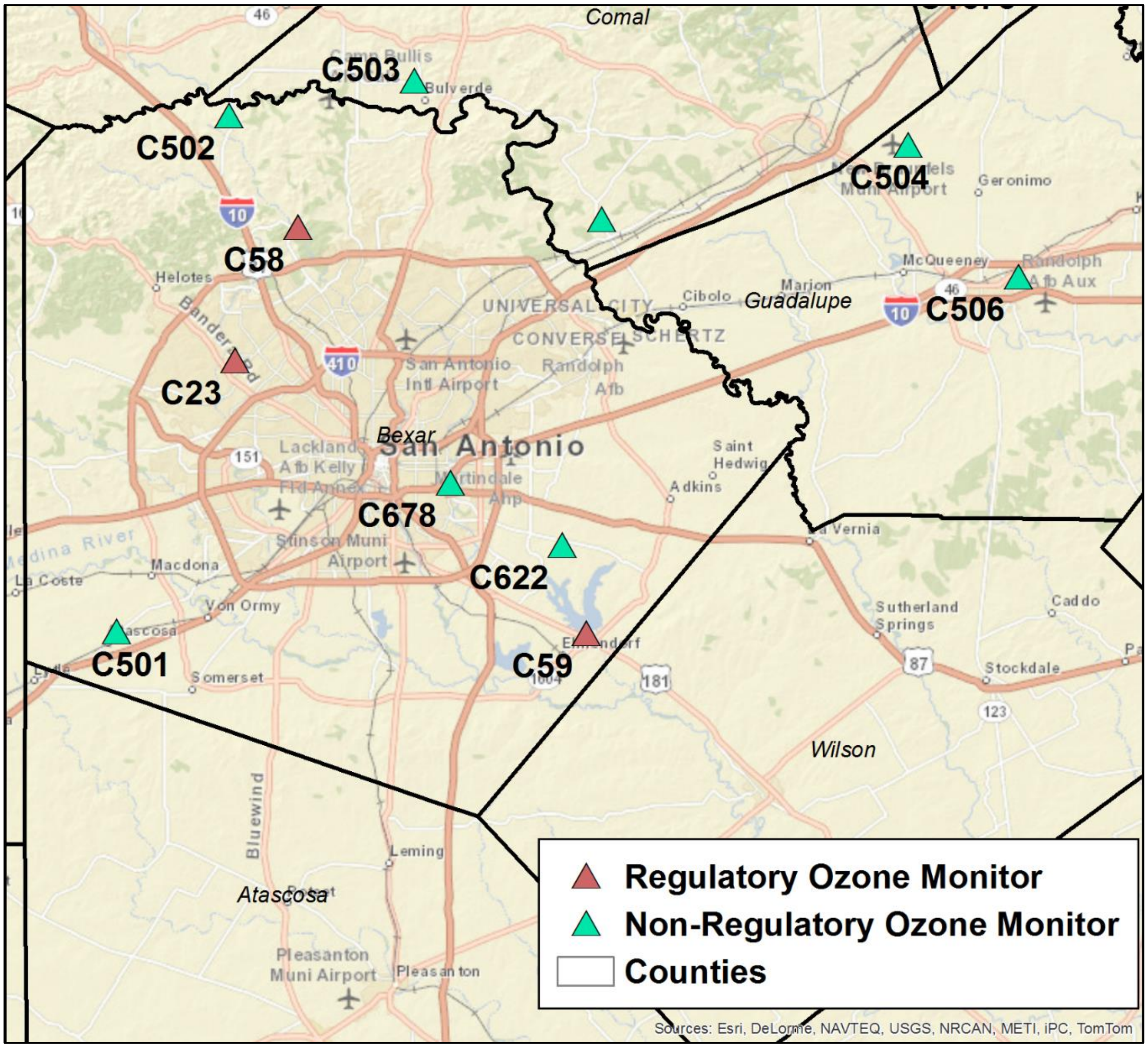

Figure 2-1: Ozone Monitors (Regulatory and Non-Regulatory) in the San Antonio Region

Figure 2-1 also shows that there are a total of seven ozone monitors in Bexar County and two each in Guadalupe and Comal Counties. None of the remaining five counties in the San Antonio – New Braunfels MSA have ozone monitors. Table 2-1 below provides a list of the ozone monitors in the San Antonio Region, along with their general location, other parameters measured at that location, the date it began measuring ozone, and the agency that operates the monitor.

Table 2-1: List of Ozone Monitors in the San Antonio Region, Locations, Data Measured, and Date/Agency of Operation (Red for Regulatory, Teal for Non-Regulatory)

Designation / Site Name	Location Description	Data Measured	First date of operation, Currently maintained by
CAMS 23 San Antonio Northwest	San Antonio, Bexar County	NO_X, Ozone, Meteorology, $PM_{2.5}$	July 1,1981 TCEQ and San Antonio Metro Health District
CAMS 58 Camp Bullis	San Antonio, Bexar County	Auto-GC, Ozone, NO_X, Meteorology	August 10, 1998 Orsat and TMSI
CAMS 59 Calaveras Lake	San Antonio, Bexar County	SO_2, NO_X, Ozone, Meteorology, $PM_{2.5}$	May 12, 1998 San Antonio Metro Health District
CAMS 501 Elm Creek Elementary	Atascosa, Bexar County	Ozone, Meteorology	June 17, 2002 Dios-Dado for AACOG
CAMS 502 Fair Oaks Ranch	Fair Oaks Ranch, Bexar County	Ozone, Meteorology	June 27, 2002 Dios-Dado for AACOG
CAMS 503 Bulverde Elementary	Bulverde, Comal County	Ozone	August 27, 2002 Dios-Dado for AACOG
CAMS 504 New Braunfels Airport	New Braunfels, Guadalupe County	Ozone	August 30, 2002 Dios-Dado for AACOG
CAMS 505 Garden Ridge	Garden Ridge, Comal County	Ozone	March 25, 2003 Dios-Dado for AACOG
CAMS 506 Seguin Outdoor Learning Center	Seguin, Guadalupe County	Ozone	March 26, 2003 Dios-Dado for AACOG
CAMS 678 CPS Pecan Valley	San Antonio, Bexar County	Ozone, Meteorology	March 4, 1999 Dios-Dado for CPS
CAMS 622 Heritage Middle School	San Antonio, Bexar County	Ozone, Meteorology, $PM_{2.5}$	July 29, 2004 Dios-Dado for CPS

2.1 Site-by-Site Analysis

The EPA states that “site-by-site analyses are those that assign a ranking to individual monitors based on a particular metric. These analyses are good for assessing which monitors might be candidates for modification or removal.”[8] These analysis methods are not particularly advanced, so they should be used in conjunction with more advanced analytical methods described later in

[8] U.S. Environmental Protection Agency, 2007. Office of Air Quality Planning and Standards. “Ambient Air Monitoring Network Assessment Guidance.” Research Triangle Park, NC. P. 2-4. Available online: https://www3.epa.gov/ttnamti1/files/ambient/pm25/datamang/network-assessment-guidance.pdf. Accessed July 25, 2016.

the network assessment to determine which monitors, if any, are good candidates for removal from the network.

2.1.1 Number of Parameters Monitored

In general, monitors that measure more pollutants are more valuable to the monitoring network. However, there are other factors that should be considered when using this analysis technique, such as the relative importance of measuring a certain type of pollutant, budgetary constraints, and the purpose of the monitor.

Table 2-2: Number of Parameters Monitored at Each Ozone CAMS Site in the San Antonio Region (High values in bold, low values in italics)

Monitor	Number of Parameters	Parameter Score	Rank
CAMS 23	18	30.5	3
CAMS 58	**59**	**100.0**	**1**
CAMS 59	20	33.9	2
CAMS 501	8	13.6	6
CAMS 502	8	13.6	6
CAMS 503	*1*	*1.7*	*9*
CAMS 504*	14	23.7	4
CAMS 505	*1*	*1.7*	*9*
CAMS 506	*1*	*1.7*	*9*
CAMS 622	10	16.9	5
CAMS 678	8	13.6	6

*Monitor is located less than 2 km from the National Weather Service station in New Braunfels (CAMS 5004), which reports 13 meteorological parameters.

Equation 1: CAMS Parameters Score

$$CAMSx\ Parameters\ Score = \frac{Parameters_{CAMS\ x}}{Parameters_{CAMS\ 58}}\ x\ 100$$

Using the number of parameters monitored as a measure of a monitor's usefulness, as shown in Table 2-2, suggests that CAMS 58 is the most important monitor in the network. Indeed, it is the only monitor in the AACOG region that records ozone, NO_X, and VOCs continuously. This analysis also suggests that the three monitors north and east of San Antonio (CAMS 503 in Bulverde, CAMS 505 in Garden Ridge, and CAMS 506 in Seguin) are less valuable to the monitoring network because they only measure one pollutant: ozone. However, because ozone is the only criteria pollutant for which the San Antonio – New Braunfels MSA is in danger of violating the NAAQS, it may be useful to have monitors that only measure ozone, especially from a cost perspective. In addition, these two monitors are currently positioned such that they measure upwind ozone concentrations on days when winds are out of the east or northeast. As discussed in Section 1.4, there is equipment available to set up meteorological monitoring at one of the sites that are currently without it. Note that CAMS 504, despite only measuring ozone, is located less than 2 km from the meteorological tower at the regional National Weather Service office for San Antonio and Austin. Meteorological parameters that are helpful in describing the conditions under which ozone forms and is transported can be used in conjunction with this ozone monitor.

2.1.2 Trend Impacts

Trend impacts analysis takes into consideration the length of time a monitor has been in operation and ranks each monitor from longest history to shortest history. The trend impacts score is calculated against the regional monitor that has been in operation the longest (CAMS 23 since July 1, 1981). The EPA suggests that monitors with a longer history are more useful in depicting air quality trends and that lower-ranked monitors using this analysis method may be top candidates for removal from the network.

Table 2-3: Duration of Operation and Trend Impacts Score for Each Ozone CAMS Site in the San Antonio Region (High values in bold, low values in italics)

Monitor Number	Duration of Operation (as of 1/1/16)	Trend Impacts Score	Rank
CAMS 23	**34 years, 6 months**	**100.0**	**1**
CAMS 58	17 years, 5 months	50.5	3
CAMS 59	17 years, 8 months	51.1	2
CAMS 501	13 years, 6 months	39.3	5
CAMS 502	13 years, 6 months	39.2	6
CAMS 503	13 years, 4 months	38.6	7
CAMS 504	13 years, 4 months	38.6	8
CAMS 505	12 years, 9 months	37.0	9
CAMS 506	12 years, 9 months	37.0	10
CAMS 622	*11 years, 5 months*	*33.1*	*11*
CAMS 678	16 years, 10 months	48.7	4

The weight of the trend impacts score will not be that great in the overall network assessment due to the simplicity of the analysis. Trend impacts do not account for meteorological variations from year to year or changes in emissions patterns over time. Monitors with a longer historical record might be more influenced by changes in surrounding land uses that affect pollutant concentrations at that monitor over time. Furthermore, the usefulness of the trends impact analysis may be questioned because only nine months separate the oldest and the newest of AACOG-owned monitors. Table 2-3 shows that the lowest trend impacts score of AACOG-owned monitors is 37.0, while the highest is 39.3. Equation 2 shows how the trends impact scores were calculated.

Equation 2: CAMS Trend Impacts Score

$$CAMS\ x\ Trend\ Impacts\ Score = \frac{Duration_{CAMS\ x}}{Duration_{CAMS\ 23}}\ x\ 100$$

2.1.3 Measured Concentrations

To determine compliance with the ozone NAAQS, the EPA uses the fourth highest average daily eight-hour ozone averaged over three years at each regulatory monitor. This metric is known as the "design value" and can be compared among monitors and ranked based on which monitor has the highest design value. Because the monitors owned by AACOG and CPS are not regulatory, they do not have design values, but the equivalent metric, referred to here as the "three-year average," can still be used to determine a monitor's usefulness. The scoring method is presented in the following equation.

Equation 3: CAMS Measured Concentrations Score

$$Score = \frac{(Three\ year\ average_{CAMS\ x} - Three\ year\ average_{minimum})}{(Three\ year\ average_{maximum} - Three\ year\ average_{minimum})}\ x\ 100$$

Table 2-4: Three Year Average Ozone (2013-2015) at Each CAMS Site in the San Antonio Region and Associated Scores (High values in bold, low values in italics)

Monitor Name and Number	2013	2014	2015	Three-year Average	Score
CAMS 23	76	69	79	74	69.2
CAMS 58	**83**	**72**	**80**	**78**	**100.0**
CAMS 59	69	63	68	66	7.7
CAMS 501	71	69	67	69	30.8
CAMS 502	76	64	74	71	46.2
CAMS 503	74	64	75	71	46.2
CAMS 504	69	63	67	66	7.7
CAMS 505	73	60	74	69	30.8
CAMS 506	*69*	*65*	*62*	*65*	*0.0*
CAMS 622	73	70	67	70	38.5
CAMS 678	76	69	67	70	38.5

The measured concentrations analysis in Table 2-4 reveals which ozone monitors could be classified as site type number 1 in the Code of Federal Regulations, referenced in the introduction of this report: "Sites located to determine the highest concentrations expected to occur in the area covered by the network." These monitors are useful because they show the intensity and extent of the urban ozone plume. A weakness of this analysis method is that it assigns lower scores to monitors that commonly record background ozone levels such as CAMS 504 in New Braunfels and CAMS 506 in Seguin because they have lower three-year averages. Monitors that record background ozone are no less valuable to the monitoring network as a whole and in fact, are listed by the EPA as site type number 4 in the Introduction of this report.

2.1.4 Area and Population Served

The area and population that a monitor serves can be represented by Thiessen polygons. This technique shows areas that are located closest to one point relative to other points. Any location inside the Thiessen polygon enclosing CAMS 502 is closer to CAMS 502 than to any other monitor. In the 13-county AACOG jurisdiction, there are six monitors located outside the region whose area served extends into the boundary. Three Austin Area monitors (CAMS 614 in Dripping Springs, CAMS 1675 in San Marcos, and CAMS 1604 in Lockhart), two Corpus Christi/Victoria area monitors (CAMS 664 in Violet and CAMS 87 in Victoria) and CAMS 44 at Laredo Vidaurri all have Thiessen Polygons that extend into the AACOG region. Combined, these six monitors serve 10,886 people in Gillespie, Comal, Guadalupe, Karnes, and McMullen Counties. The Thiessen polygons are shown in Figure 2-2.

The monitors on the edge of the network serve a larger area and are ranked higher, according to EPA guidance. This is one of the limitations of using the Thiessen Polygons technique to rank monitors by the area that they serve. This can be seen in Figure 2-2 with CAMS 501, CAMS 502, and CAMS 59 having such a large service area. Using Thiessen polygons is a very basic assessment of area served and does not take into consideration other factors such as meteorology, proximity to emissions sources, and topography. For example, western Karnes County is served by CAMS 59 according to the Thiessen polygons technique. Under southeasterly flow, western Karnes County might be better represented by the Victoria monitor given the direction of pollutant transport.

To determine the population served by each monitor, 2010 census block data was used. The EPA suggests using census tract or block group data, but because McMullen County is one census block group that is divided between four different ozone monitors, a finer detail was chosen. If the centroid of a census block falls within a Thiessen polygon, that census block is assigned to that polygon. The population and area served for each monitor is shown in Table 2-5 and Table 2-6, along with the ranking of each site by population and area served.

CAMS 23 serves the largest population due to its location on the highly-developed northwest side, with its service area extending from near downtown out to Medina Lake. The area served by CAMS 678 includes downtown San Antonio and the eastern half of the urban core inside Interstate 410. It has the second-most populated service area, but is the 10^{th}-largest in area. CAMS 501 at Elm Creek Elementary serves the largest area at nearly 10,000 km^2 and portions of six AACOG counties. Monitors that serve a large area or a large population are ranked higher than other monitors.

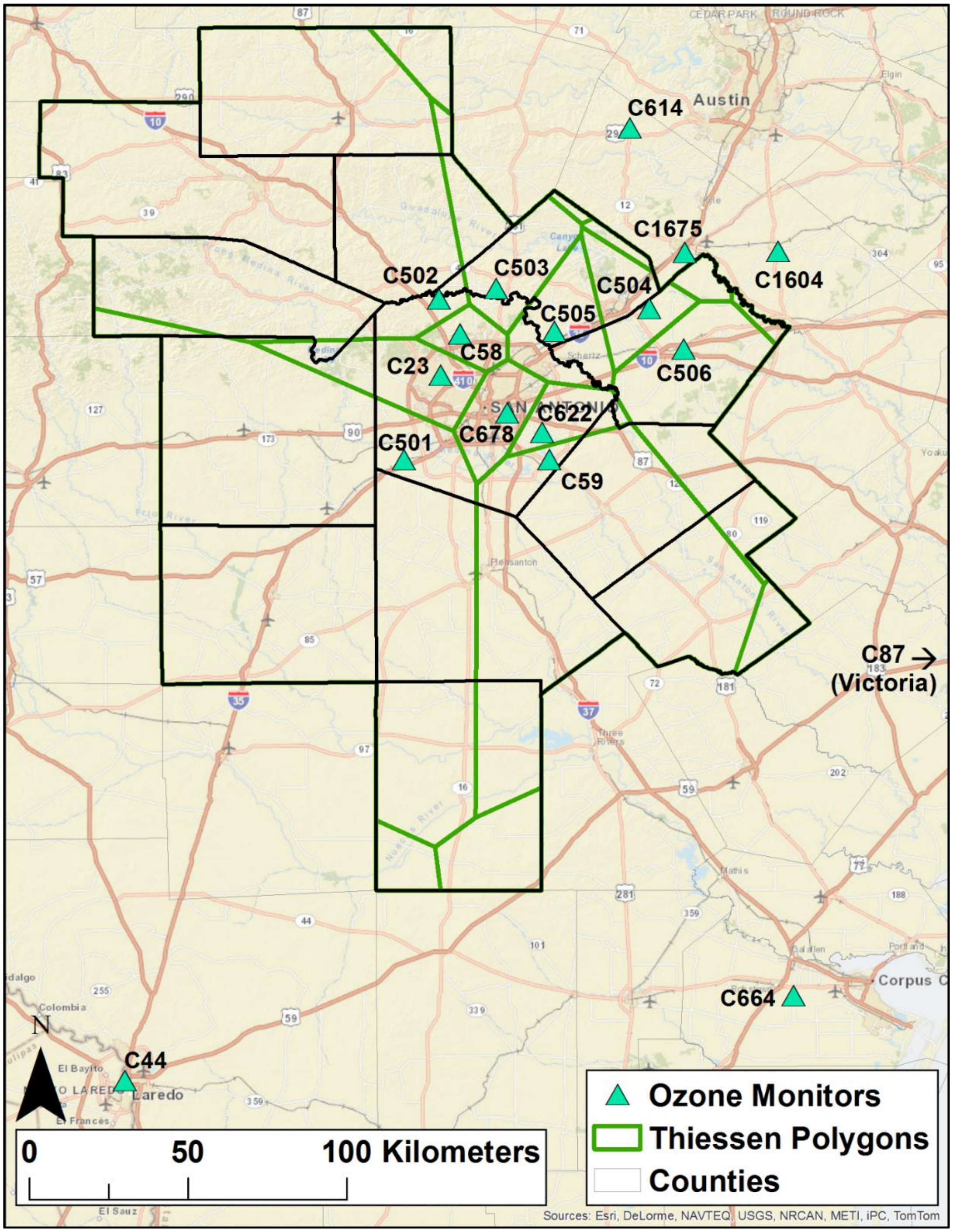

Figure 2-2: Thiessen Polygons Surrounding Area Ozone Monitors

Table 2-5: Population Served by Ozone CAMS Sites in and around the San Antonio Region

Ozone Monitor Name	Monitor ID	Population Served (2010)	Population Served Score	Rank
San Antonio Northwest	C23	628,030	100.0	1
Camp Bullis	C58	187,744	29.9	4
Calaveras Lake	C59	90,909	14.5	7
Elm Creek Elementary	C501	175,561	28.0	5
City of Fair Oaks Ranch	C502	143,884	22.9	6
Bulverde Elementary	C503	70,240	11.2	9
New Braunfels Airport	C504	80,858	12.9	8
City of Garden Ridge	C505	232,245	37.0	3
Seguin Outdoor Learning Center	C506	48,771	7.8	10
Heritage Middle School	C622	30,313	4.8	11
CPS Pecan Valley	C678	550,252	87.6	2
* Dripping Springs School	C614	1,172	0.2	14
* CAPCOG San Marcos	C1675	8,107	1.3	12
* Lockhart	C1604	361	0.1	15
* Victoria	C87	1,210	0.2	13
* Violet	C664	32	0.0	16
* Laredo Vidaurri	C44	4	0.0	17

* Monitor is located outside of the 13-county AACOG region

Table 2-6: Area Served by Ozone CAMS Sites in and around the San Antonio Region

Ozone Monitor Name	Monitor ID	Area Served (km^2)	Area Served Score	Rank
San Antonio Northwest	C23	899.7	9.2	6
Camp Bullis	C58	293.8	3.0	14
Calaveras Lake	C59	5,442.7	55.7	3
Elm Creek Elementary	C501	9,779.0	100.0	1
City of Fair Oaks Ranch	C502	8,834.5	90.3	2
Bulverde Elementary	C503	1,089.9	11.1	5
New Braunfels Airport	C504	638.0	6.5	9
City of Garden Ridge	C505	826.9	8.5	7
Seguin Outdoor Learning Center	C506	1,929.6	19.7	4
Heritage Middle School	C622	432.9	4.4	11
CPS Pecan Valley	C678	522.3	5.3	10
* Dripping Springs School	C614	363.9	3.7	12
* CAPCOG San Marcos	C1675	223.3	2.3	16
* Lockhart	C1604	66.9	0.7	17
* Victoria	C87	253.2	2.6	15
* Violet	C664	699.7	7.1	8
* Laredo Vidaurri	C44	301.0	3.1	13

* Monitor is located outside of the 13-county AACOG region

2.1.5 Monitor-to-Monitor Correlation

The EPA suggests, as part of a network assessment, that pollutant concentrations at each monitoring site be correlated with pollutant concentrations at other sites in the region to determine the uniqueness of each monitor. Maximum daily average 8-hour ozone concentrations at one monitor were compared with maximum daily average 8-hour ozone concentrations at every other monitor to determine how well each monitor pairing correlates temporally. Monitor pairs with a high correlation (EPA suggests $R^2 > 0.75$) are potentially redundant and might warrant removing of one of them. Monitor pairs with lower correlations tend to provide more unique data relative to one another.

A monitor-to-monitor correlation was performed using data from all days between 2005 and 2015. The results in Table 2-9 show that the vast majority of monitor pairing correlations, 85%, are above the EPA-recommended threshold of redundancy. Those monitor pairs that are below $R^2 = 0.75$ are highlighted in green. These less-correlated monitor pairings are between upwind and downwind monitors. Of the AACOG-owned monitors, CAMS 501, CAMS 502, and CAMS 503 are the most useful according to this analysis, as they have the lowest correlation coefficients among all monitor pairs. CAMS 502 has the lowest average correlation among all regional monitor pairings; however, as previously mentioned, the Fair Oaks Ranch site is no longer suitable for ozone monitoring. The monitor pairing with the strongest correlation is CAMS 59 and CAMS 622. This makes sense considering they are both located on the southeastern periphery of the city. Since neither of these monitors are AACOG-owned, it would be more difficult to re-site them. The monitor pairing with the second-highest correlation is CAMS 504 and CAMS 506, which commonly function as upwind monitors under an easterly flow regime. The R^2 value of 0.94 suggests there may be some redundancy in monitor coverage on the eastern quadrant of the MSA.

This same analysis was conducted using only days that had at least one regional monitor record ozone over 70 ppb (Table 2-10). The range of R^2 values for monitor pairings on days over 70 ppb is much larger than that for all days. Although no monitor pairings had an R^2 of 0.75 or more, the CAMS 59 and CAMS 622 pairing came close with $R^2 = 0.74$. The monitor pairing with the second-highest correlation was CAMS 502 and CAMS 503, followed by CAMS 504 and CAMS 506. The monitor pairing with the weakest correlation was CAMS 502 and CAMS 622 with an R^2 value of 0.00, followed by CAMS 503 and CAMS 622. CAMS 502 and CAMS 503 are often downwind from the urban core and thus experience higher ozone readings than monitors on the southeast side like CAMS 59 and CAMS 622 or in the middle of the urban core like CAMS 678 where NO_X scavenging likely suppresses ozone levels. For days over 70 ppb, CAMS 506 had the highest average correlation of the AACOG-owned monitors, followed by CAMS 504. CAMS 678 had the highest average correlation overall, mostly because of the pairings between that monitor and CAMS 59 and CAMS 622.

Table 2-7 and Table 2-8 provide the average R^2 values and each monitor's correlation score, calculated using the following equation, for each non-regulatory monitor in the San Antonio Region.

Equation 4: CAMS Correlation Score

$$CAMSx\ Correlation\ Score = (1 - Average\ Correlation)\ x\ 100$$

Table 2-7: Average Monitor-to-Monitor Correlation for Each Non-Regulatory Monitor in the San Antonio Region for All Ozone Season Days, 2005-2015 (High values in bold, low values in italics)

Monitor	Average Correlation	Correlation Score	Rank
CAMS 23	0.848	15.2	8
CAMS 58	0.818	18.2	3
CAMS 59	0.836	16.4	5
CAMS 501	0.819	18.1	4
CAMS 502	**0.778**	**22.2**	**1**
CAMS 503	0.812	18.8	2
CAMS 504	0.851	14.9	10
CAMS 505	0.841	15.9	7
CAMS 506	0.849	15.1	9
CAMS 622	0.839	16.1	6
CAMS 678	*0.862*	*13.8*	*11*

Table 2-8: Average Monitor-to-Monitor Correlation for Each Non-Regulatory Monitor in the San Antonio Region for Days > 70 ppb, 2005-2015 (High values in bold, low values in italics)

Monitor	Average Correlation	Correlation Score	Rank
CAMS 23	0.243	75.7	6
CAMS 58	0.214	78.6	3
CAMS 59	0.316	68.4	10
CAMS 501	0.218	78.2	4
CAMS 502	**0.168**	**83.2**	**1**
CAMS 503	0.213	78.7	2
CAMS 504	0.307	69.3	8
CAMS 505	0.234	76.6	5
CAMS 506	0.315	68.5	9
CAMS 622	0.292	70.8	7
CAMS 678	*0.327*	*67.3*	*11*

The monitor-to-monitor correlation analysis, like other site-by-site analysis techniques, are simplistic methods to determine a monitor's usefulness within the network. Meteorological phenomena are not taken into consideration even though they are an important contributing factor in the results of each analysis technique. Nor do site-by-site analyses provide insight into where new monitors may be placed. In the following chapter covering bottom-up analysis techniques, meteorology is taken into consideration, allowing for a basic understanding of where new monitors may be located.

Table 2-9: Monitor-to-Monitor Correlations of 8-Hour Average Ozone on All Days (2005-2015) (High values in red, low values in green)

2005-2015 All Days	C23	C58	C59	C501	C502	C503	C504	C505	C506	C622	C678	Average R-squared
C23	1.000											0.848
C58	0.926	1.000										0.818
C59	0.805	0.742	1.000									0.836
C501	0.844	0.746	0.879	1.000								0.819
C502	0.839	0.901	0.689	0.697	1.000							*0.778*
C503	0.837	0.892	0.743	0.738	0.904	1.000						0.812
C504	0.826	0.781	0.894	0.843	0.765	0.815	1.000					0.851
C505	0.844	0.816	0.849	0.820	0.780	0.846	0.887	1.000				0.841
C506	0.833	0.782	0.897	0.849	0.751	0.797	0.936	0.859	1.000			0.849
C622	0.827	0.755	0.951	0.889	0.693	0.738	0.889	0.841	0.899	1.000		0.839
C678	0.896	0.835	0.909	0.882	0.760	0.806	0.875	0.865	0.886	0.911	1.000	**0.862**

Table 2-10: Monitor-to-Monitor Correlations of 8-Hour Average Ozone on Days with at Least One Monitor > 70 ppb (2005-2015)
(High values in red, low values in green)

2005-2015 > 70 ppb	C23	C58	C59	C501	C502	C503	C504	C505	C506	C622	C678	Average R-squared
C23	1.000											0.243
C58	0.538	1.000										0.214
C59	0.133	0.050	1.000									0.316
C501	0.241	0.036	0.441	1.000								0.218
C502	0.192	0.451	0.016	0.013	1.000							*0.168*
C503	0.171	0.405	0.053	0.057	0.644	1.000						0.213
C504	0.159	0.076	0.478	0.252	0.112	0.226	1.000					0.307
C505	0.261	0.201	0.220	0.155	0.108	0.304	0.355	1.000				0.234
C506	0.184	0.157	0.477	0.221	0.122	0.174	0.633	0.285	1.000			0.315
C622	0.187	0.049	0.740	0.369	0.000	0.011	0.357	0.194	0.461	1.000		0.292
C678	0.370	0.181	0.554	0.398	0.018	0.088	0.420	0.257	0.435	0.554	1.000	**0.327**

2.2 Bottom-Up Analysis

"Bottom-up methods examine the phenomena that are thought to cause high pollutant concentrations and/or population exposure, such as emissions, meteorology, and population density. For example, emission inventory data can be used to determine the areas of maximum expected concentrations of pollutants directly emitted (i.e., primary emissions). Emission inventory data are less useful to understand pollutants formed in the atmosphere (i.e., secondarily formed pollutants). Multiple data sets can be combined using spatial analysis techniques to determine optimum site locations for various objectives. Those optimum locations can then be compared to the current network. In general, bottom-up analyses indicate where monitors are best located based on specific objectives and expected pollutant behavior. However, bottom-up techniques rely on a thorough understanding of the phenomena that cause air quality problems. The most sophisticated bottom-up analysis techniques are complex and require significant resources (time, data, tools, and analytical skill). Site-by-site and bottom-up analyses are best performed in combination. Site-by-site analyses typically identify network redundancies while bottom-up analyses identify network 'holes' or deficiencies."[9]

The bottom-up analysis for the AACOG ozone monitoring network focuses on meteorological characteristics that lead to high ozone, namely transport patterns and source regions. Photochemical modeling results are also used to locate potential new ozone monitoring sites. Later in the report, the bottom-up analysis will focus on using emissions inventories in conjunction with typical air transport patterns to assess the NO_X and VOC monitoring networks for the region.

2.2.1 Back Trajectories

"Within an urban area, not all ozone formation is caused by emissions produced locally because anthropogenic precursors, along with ozone formed by them, are often transported over long distances. Therefore, tracking wind parcels coming to the region plays important role in identifying the source of transported ozone. The Air Resources Laboratory of NOAA maintains the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model and allows public use via the Internet at their Realtime Environmental Applications and Display System (READY) webpage.[10] This versatile model can be run as a trajectory (parcel displacement) or air dispersion model, using either forecast or archived meteorological data. The model and database are applicable across the United States, which provides a national reference for air trajectory and dispersion modeling needs. The back trajectories needed for the analyses of transport were created using this model."[11]

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[9] U.S. Environmental Protection Agency, 2007. Office of Air Quality Planning and Standards. "Ambient Air Monitoring Network Assessment Guidance." Research Triangle Park, NC. P. 2-5. Available online: https://www3.epa.gov/ttnamti1/files/ambient/pm25/datamang/network-assessment-guidance.pdf. Accessed September 8, 2016.

[10] NOAA, October 2013. "Realtime Environmental Applications and Display System (READY)". Available online: http://www.arl.noaa.gov/ready.html. Accessed May 26, 2016.

[11] Alamo Area Council of Governments, 2015. "Conceptual Model Ozone Analysis of the San Antonio Region Updates through Year 2014." San Antonio, TX. P. 5-7. Available online: http://www.aacog.com/DocumentCenter/View/34654. Accessed September 8, 2016.

The HYSPLIT model was run for every day during ozone season from 2009 through 2015, originating at CAMS 58 at Camp Bullis. The back trajectories generated from these runs were of a 48-hour duration, beginning at the hour of the day that recorded the peak ozone at CAMS 58. Figure 2-3 shows these back trajectories, providing an assessment of most common wind flow patterns during ozone season. As evidenced in Figure 2-3, air parcels usually originate from the north, clockwise to the south, with the southeasterly direction being the most common. To quantify these results, the region of Central Texas within a 160-km radius of C58 was partitioned into octants, then further subdivided by distance boundaries: within 80 km of C58 and between 80 and 160 km of C58. The total for each distance sub-division of these octants will be referred to as “bin counts”. This requires that the back trajectory paths be symbolized as hourly points. The number of hourly back trajectory points that fall within a particular bin determine the bin counts.

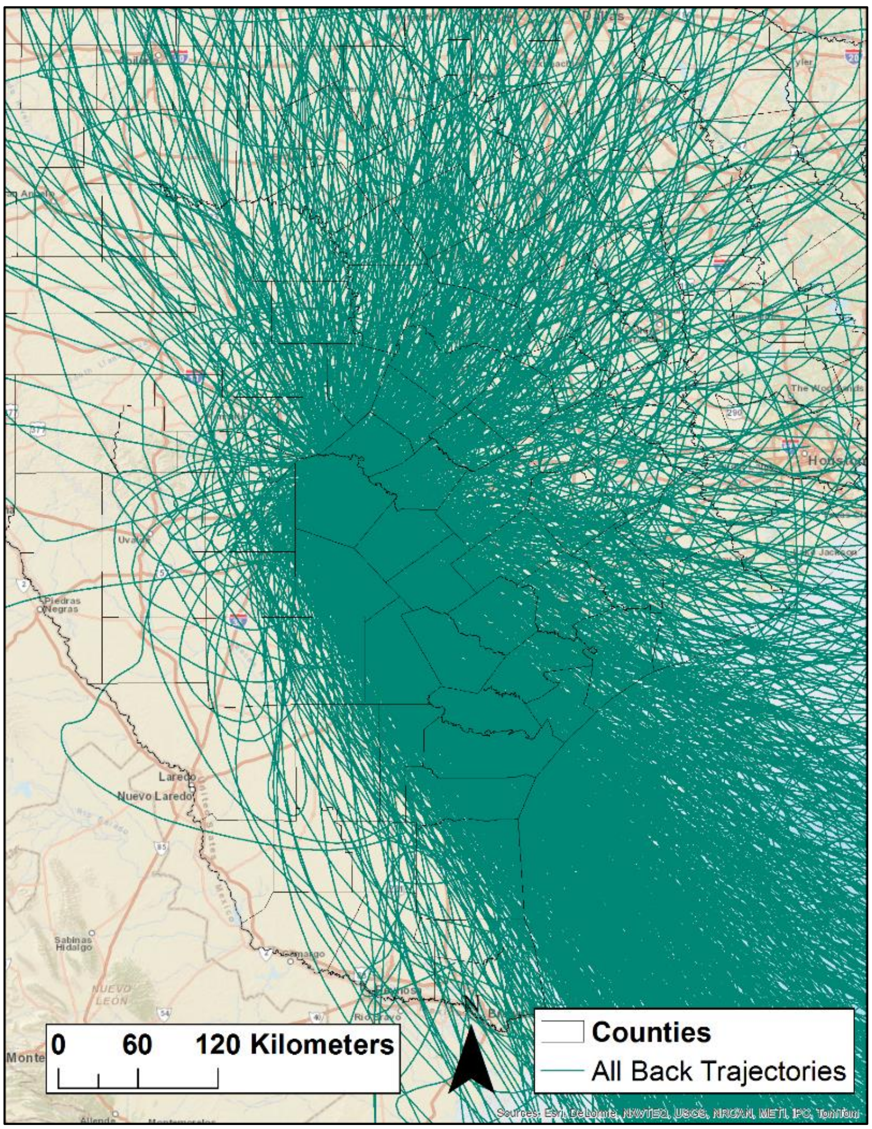


Figure 2-3: 48-Hour HYSPLIT Back Trajectories for All Ozone Season Days, 2009-2015

The bin counts for each octant subdivision can be seen in Figure 2-4, along with the percentage of total hourly back trajectory points for each octant displayed outside of the outer circle. The majority, 58.8%, of the hourly back trajectory points came from the south and southeast octants. The dominant wind flow pattern for the San Antonio Region during the ozone season is out of the southeast, especially in the first half of the season. Around August and through the end of the season, northeasterly winds become more common as frontal boundaries begin to push through the area more frequently.

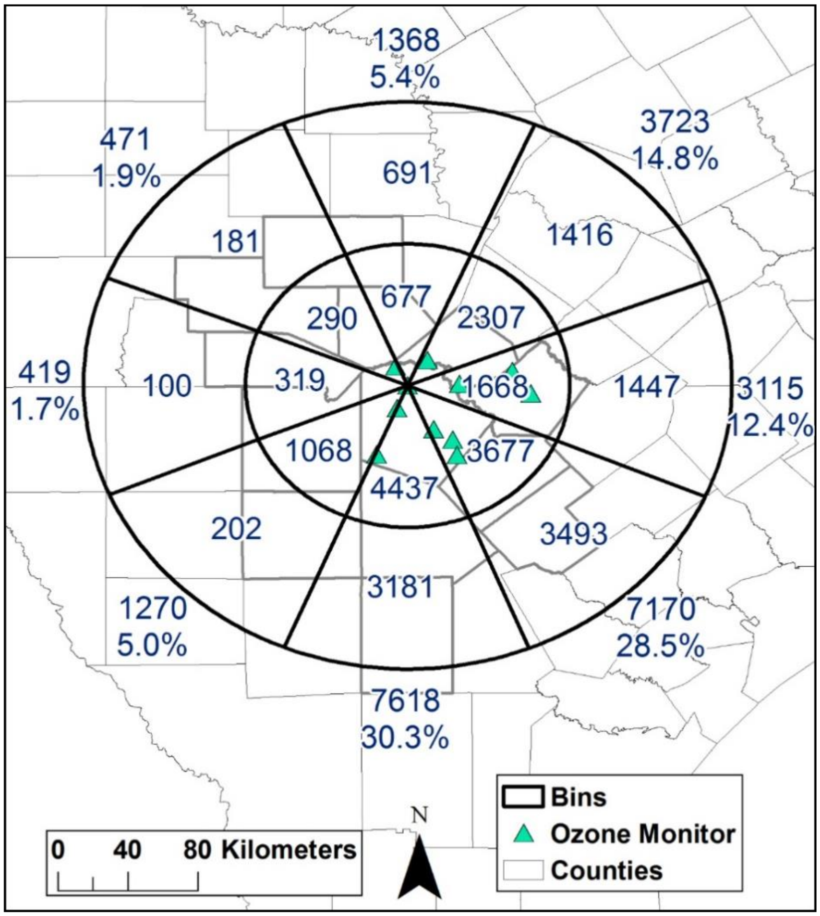


Figure 2-4: Bin Counts by Directional Octant, All Back Trajectories, 2009-2015

The back trajectories were then filtered according to the peak eight-hour ozone for each day. Days with ozone over 70 ppb were chosen for another bin count analysis to determine the most common wind flow patterns on days that exceed the 2015 ozone NAAQS. Figure 2-5 below shows the back trajectory paths on high ozone days over 70 ppb. There does not appear to be as great a concentration of back trajectories in the south to east octants as there was in the figure representing all ozone days. The distribution of back trajectory paths appears more even among the northeasterly clockwise through southerly octants. To quantify this, bin counts were again calculated for high ozone days. Those bin counts can be seen in Figure 2-6, which shows that only 42.8% of hourly back trajectory points fell in the southerly and southeasterly octants. This is 16% less than what the bin counts for all ozone days showed. On high ozone days, 21.1% of hourly back trajectory points were in the northeast octant, which is 6.3% more than those for all ozone days. That the vast majority of bin counts occurred in the eastern semicircle on high ozone days suggests that monitors in those areas are well-suited to record background ozone levels when ozone is over 70 ppb. Air quality monitors that frequently record background ozone levels include regulatory CAMS 59 at Calaveras Lake, CAMS 501 at Elm Creek

Elementary, CAMS 504 in New Braunfels, CAMS 505 in Garden Ridge, CAMS 506 in Seguin, and to a lesser extent, CAMS 503 in Bulverde. These monitors are on the periphery of the regional monitoring network. CAMS 622 and CAMS 678, while they are in the southeastern octant, are not necessarily on the periphery of the monitoring network. Thus, they do not likely record background concentrations of ozone due to their locations downwind of ozone precursors emitted from the CPS-owned power plants around Calaveras Lake.

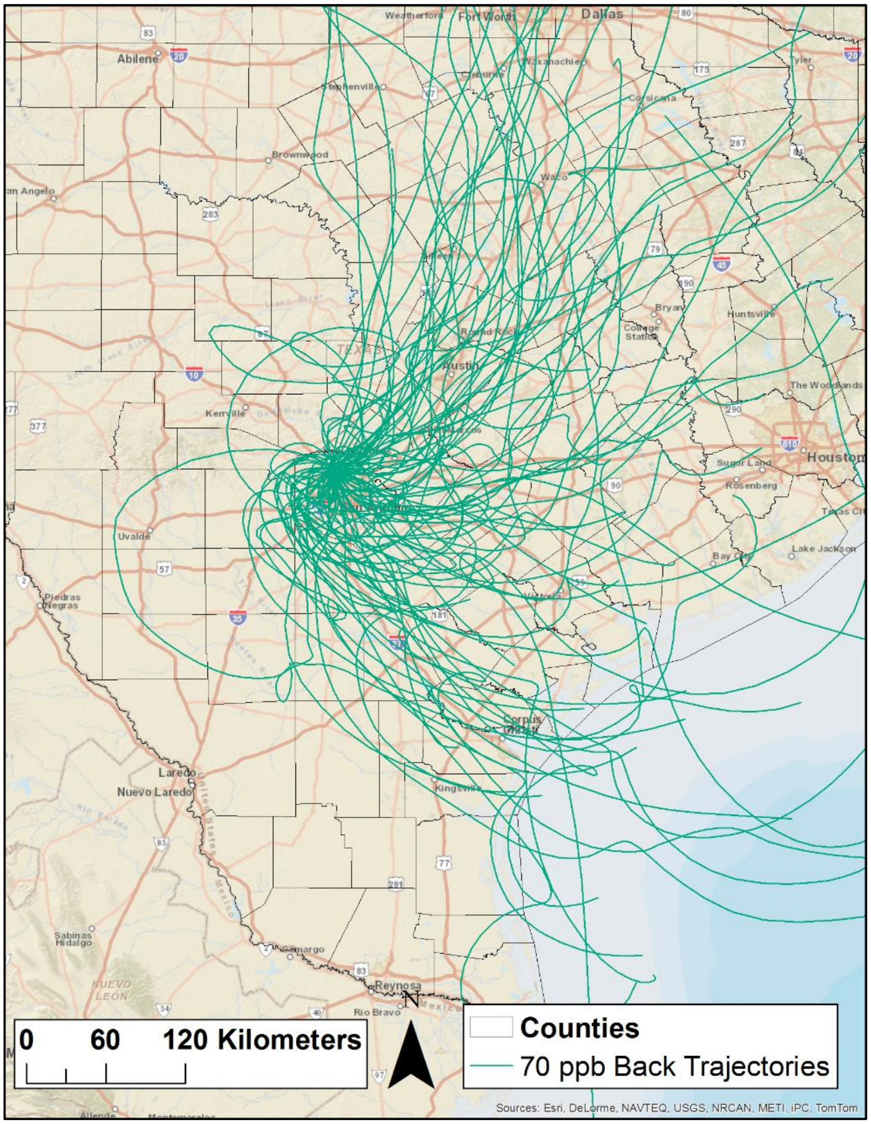


Figure 2-5: 48-Hour HYSPLIT Back Trajectories on Days where Ozone > 70 ppb at Any Monitor, 2009-2015

Of the five ozone monitors regularly recording background concentrations on high ozone days, four are AACOG-owned, and the back trajectory analysis suggests that there is sufficient ozone monitor coverage for capturing those background concentrations, with the exception of the area due south of San Antonio. Three monitors, CAMS 23 at Marshall High School, CAMS 58 at Camp Bullis, CAMS 502 at Fair Oaks Ranch, and in some cases CAMS 503 in Bulverde, regularly record ozone concentrations downwind of the urban core.

The back trajectory analysis indicates that upwind monitors, those that record background or boundary ozone conditions, are well-represented in the regional monitoring network. Five or six ozone monitors are situated such that they record ozone concentrations coming from outside the San Antonio Region. By contrast, there is less representation among monitors that record downwind ozone concentrations, or those that frequently record the highest ozone levels in the region. Three or four ozone monitors are situated to capture the maximum concentrations in the San Antonio Region. Monitors along a NE to SW axis, such as CAMS 503 in Bulverde and CAMS 501 at Elm Creek Elementary could be both upwind and downwind monitors depending on the prevailing wind direction. If winds are out of the northeast, CAMS 501 is downwind of the urban core. If winds are out of the south or south-southwest, then CAMS 501 is an upwind monitor and CAMS 503 is downwind of the urban core. The south octant bin closest to CAMS 58 has the highest bin count, but the closest monitor (CAMS 501) is on the border of the south and the southwest octant. The fact that there are no monitors in the south octant suggests that there might be a slight upwind monitoring deficiency due south of San Antonio.

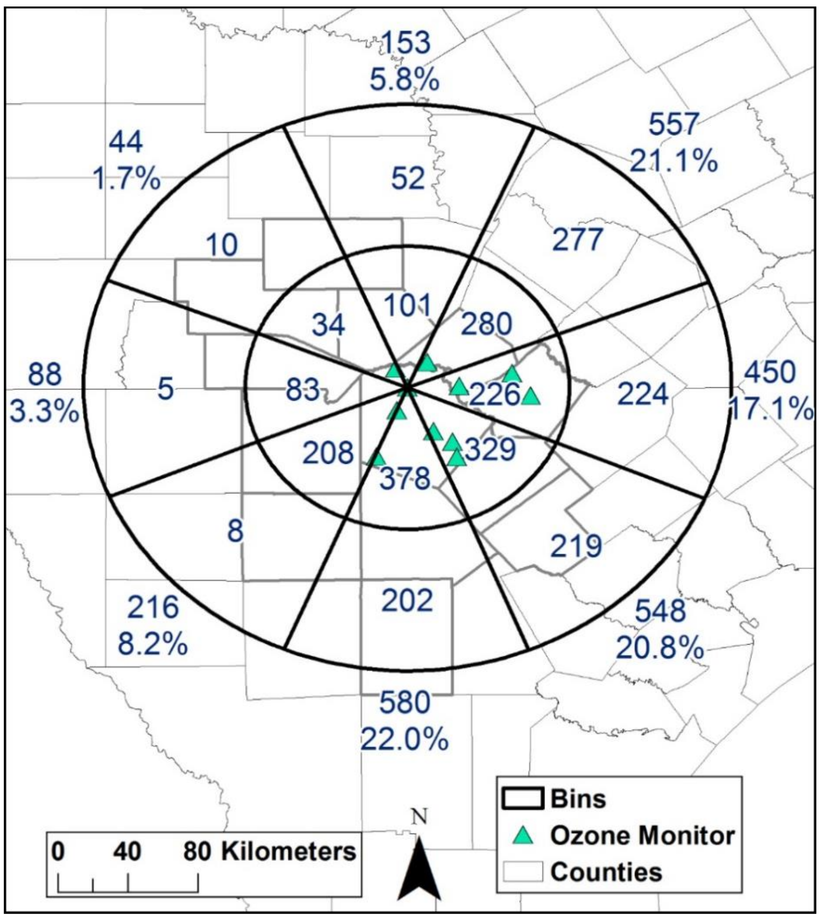


Figure 2-6: Bin Counts by Directional Octant, Back Trajectories on Days > 70 ppb, 2009-2015

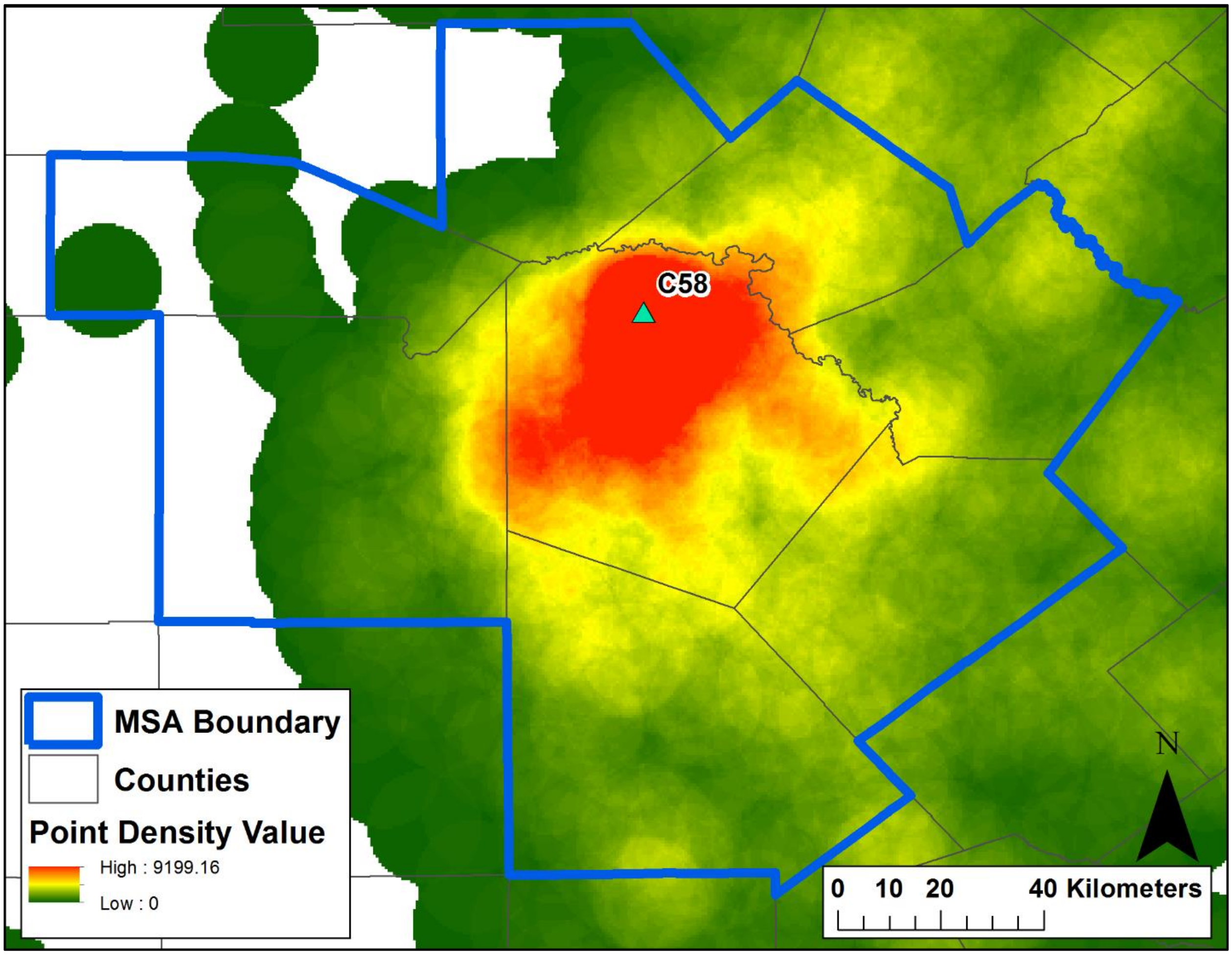


Figure 2-7: Point Density of Hourly Back Trajectory Points on Days with Ozone > 70 ppb

Figure 2-7 provides a graphical representation of the bin counts above in the form of a point density map. It clearly shows that back trajectories typically come into the area from the northeast clockwise to the south and even southwest on high ozone days.

The back trajectory analysis suggests a monitoring deficiency in the western half of the San Antonio Region. There is a relative lack of downwind ozone monitors compared to those that are upwind. The next bottom-up analysis focuses on photochemical modeling results which predict where the areas of greatest ozone concentration might occur during high ozone events.

2.2.2 Photochemical Modeling

Photochemical model results are a useful tool in air quality planning efforts. AACOG conducts ozone analysis using photochemical models that simulate actual high-ozone episodes which prevailed in the region over the course of several days. The most recent modeling episode that has been completed for the San Antonio Region is based on the May 24 to July 2, 2006 (June 2006) time period.

To perform the network assessment using photochemical modeling results, the model output was imported into Microsoft Excel and then reformatted to facilitate joining to the 4-km modeling domain grid in ArcGIS. The centroid of each 4-km grid cell was calculated and assigned the value of the corresponding grid cell. From there, a smoothed surface was created using an inverse distance weighted interpolation method. This was done for any day during the June 2006 photochemical modeling episode that had predicted ozone concentrations above 70 ppb anywhere in the MSA.

Figure 2-8 shows how many days were predicted to have greater than 70 ppb max ozone. Based on meteorological conditions during the June 2006 high ozone episode, with emissions levels projected out to 2012, areas west and northwest of the San Antonio urban core experienced the most cases of high ozone. East-central Medina County had as many as five days of predicted max ozone greater than 70 ppb, while portions of northwestern Bexar County had as many as seven. CAMS 23 is the monitor with the most predicted days over 70 ppb, followed by CAMS 58. This is to be expected as both are regulatory monitors and were situated to consistently capture the region's highest ozone levels. Other areas where additional monitors could be located that would capture the most frequent high ozone occurrences are far western Bexar County and the Medina Lake area. Because CAMS 23 is currently on the western periphery of the regional ozone monitoring network, having a monitor farther downwind would be beneficial in determining the intensity and geographic scope of the urban ozone plume. It would also meet the local monitoring goal of photochemical model verification, discussed in Section 1.2.

The TCEQ is currently developing a photochemical model based on a more recent high ozone event. The new model originally was based on the June 2012 event, but has been expanded to include May – September 2012. This report only assesses the June 2012 component of the photochemical modeling episode, using emissions projections for the year 2017. The same process used to create an interpolated ozone surface for the June 2006 episode was used for the June 2012 episode. The number of days a given area had predicted ozone over 70 ppb from the June 2012 episode can be seen in Figure 2-9. The most frequent high ozone days occur along a NE to SW axis through the San Antonio urban core. East central Medina County experienced five predicted high ozone days, while the greatest number of high ozone days was predicted along a strip in the northern portion of Bexar County. As many as ten high ozone days were predicted in a very small part of extreme northeastern Bexar County along the Comal County line. Both photochemical modeling results suggest that a new monitor would be useful in extreme northwestern Bexar County, downwind from CAMS 23.

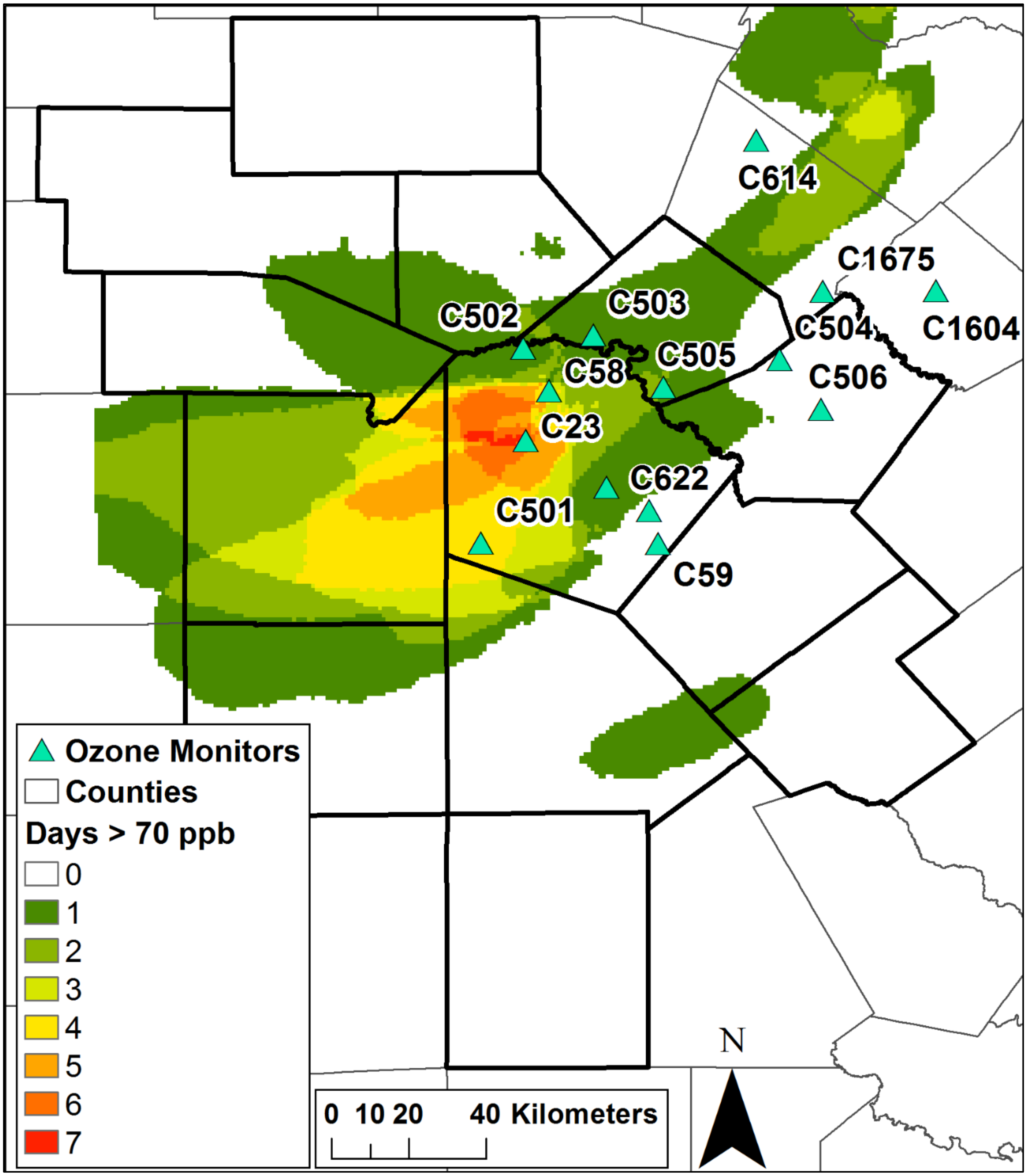


Figure 2-8: Maximum Ozone Predictions from the June 2006 Photochemical Modeling Episode

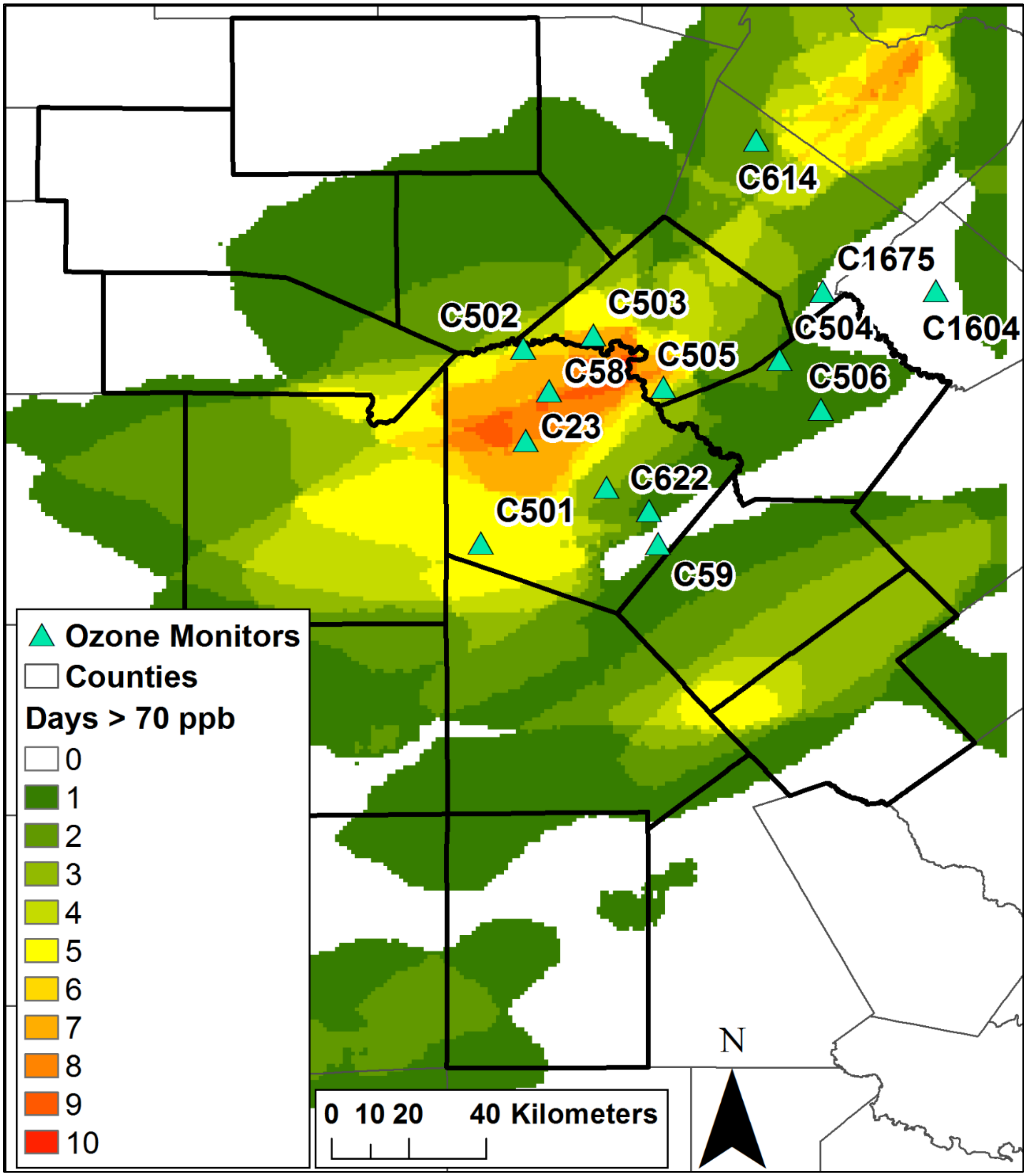


Figure 2-9: Maximum Ozone Predictions from the June 2012 Photochemical Modeling Episode

Having ozone monitors present in these locations would fulfill the local monitoring goal of verifying photochemical model output. It is important to know the extent to which high ozone reaches outlying areas of the San Antonio Region. Furthermore, the secondary standard of the ozone NAAQS exists to protect animals, crops, vegetation, and buildings from its harmful effects. According to the 2012 Census of Agriculture (Table 2-11), Medina County is the most productive in the San Antonio – New Braunfels MSA in terms of market value of products, and more than half of that value is from crop production. For these reasons, the new monitor with the highest priority will be on the western edge of Bexar County, as close to the Medina County line as possible.

Table 2-11: 2012 Census of Agriculture Data for Counties in the AACOG Region (MSA Counties in Blue)[12]

County	Number of Farms	Market Value Products Sold	Crop Sales
Atascosa	1,987	$84,999,000	$27,793,000
Bandera	1,002	$11,188,000	$1,263,000
Bexar	2,457	$72,387,000	$54,705,000
Comal	1,104	(D)	(D)
Frio	651	$183,672,000	$109,089,000
Gillespie	1,847	$46,140,000	$11,311,000
Guadalupe	2,241	$61,591,000	$30,332,000
Karnes	1,288	$27,599,000	$10,705,000
Kendall	1,387	$12,530,000	$2,115,000
Kerr	1,034	$10,803,000	$1,313,000
McMullen	238	$8,336,000	$430,000
Medina	1,976	$115,519,000	$64,889,000
Wilson	2,444	$102,098,000	$27,914,000

(D) Withheld to avoid disclosing data for individual operations

[12] United States Department of Agriculture, National Agricultural Statistics Service, 2012. “Census of Agriculture Table 2: Market Value of Agricultural Products Sold Including Direct Sales: 2012 and 2007.” Available online: https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/Texas/st48_2_002_002.pdf. Accessed September 19, 2016.

2.3 Network Optimization Analysis

Network optimization analyses look at other network designs scenarios compared to the current monitoring network, often using an iterative process. Scores are typically assigned to the other monitoring scenarios. Some of the most complex analysis techniques fall under the category of network optimization. For the purposes of this report, the only network optimization tool that will be used is the removal bias analysis.

2.3.1 Removal Bias

A removal bias analysis helps determine how useful each monitor is to the entire network in interpolating concentrations across a region. To perform a removal bias analysis, an interpolated surface is created from measured ozone concentrations on a given day. One monitor is then removed from the network and the surface is re-interpolated. The difference between the measured concentration at the monitor and the interpolated concentration at that location with the monitor removed is known as the removal bias. This interpolation process is repeated, this time by removing a different monitor. Monitors with a low removal bias may be considered for removal from the network or relocation. By removing the monitor, one can still interpolate pollutant concentrations at that location with reasonable accuracy. Monitoring sites with a high removal bias provide essential data for interpolation of pollutant concentrations across a region. This analysis uses an inverse distance weighted interpolation method. The four highest ozone days for each of the last three years (2013-2015) were chosen for the removal bias analysis. Table 2-12 shows the daily absolute removal bias for each non-regulatory monitor.

The summarized results of the removal bias analysis, shown in Table 2-13, suggest that CAMS 501 in southwestern Bexar County is the most important monitor in the non-regulatory network for interpolation of ozone values across the region. For nine of the twelve days selected for analysis, that monitor had the highest removal bias. CAMS 502 in Fair Oaks Ranch had the second-highest average removal bias. The monitor with the lowest average removal bias is CAMS 504 in New Braunfels, followed by the CPS-owned CAMS 622 in southeastern Bexar County. Each of those monitors had the lowest removal bias on three of the twelve selected days. CAMS 506 in Seguin also had the lowest removal bias for three out of twelve days. The removal bias analysis suggests that there may be an over-supply of monitors recording background ozone, which corresponds to the lower-ranked monitors. However, it is worth noting that even CAMS 506 had a removal bias greater than 8.0 ppb on 7/23/2014 and 8/29/2015.

Table 2-12: Removal Bias Analysis for Non-Regulatory Monitors in the San Antonio Region

Monitor	6/4/2013		7/4/2013		7/5/2013		9/25/2013		5/10/2014		7/23/2014	
	Actual	Interpolate	Actual	Interpolate	Actual	Interpolate	Actual	Interpolate	Actual	Interpolate	Actual	Interpolate
C501	64	72.0	65	70.3	65	72.6	67	76.2	61	62.9	58	58.3
C502	85	78.8	73	76.2	76	77.3	78	81.7	69	66.1	52	60.7
C503	79	75.8	75	72.9	74	74.6	84	78.8	64	63.6	54	57.8
C504	60	64.4	67	67.8	69	69.6	73	74.9	51	51.3	61	54.9
C505	66	71.2	69	70.6	68	72.1	81	76.9	54	61.0	55	56.5
C506	60	63.8	67	67.7	69	69.5	74	74.1	50	52.3	50	58.5
C622	66	64.0	63	66.4	64	68.8	73	72.3	64	59.7	50	48.7
C678	65	68.8	68	67.2	70	68.9	76	74.4	59	62.7	58	53.4

Monitor	8/14/2014		9/30/2014		8/3/2015		8/27/2015		8/28/2015		8/29/2015	
	Actual	Interpolate	Actual	Interpolate	Actual	Interpolate	Actual	Interpolate	Actual	Interpolate	Actual	Interpolate
C501	72	63.6	49	58.2	66	68.9	64	74.7	66	76.2	67	76.3
C502	54	62.4	67	63.2	70	73.9	74	80.5	81	81.8	81	81.9
C503	54	60.4	58	61.3	70	70.7	79	75.4	81	78.8	80	78.7
C504	58	59.2	52	49.7	61	63.9	64	66.7	72	71.9	70	69.5
C505	56	60.8	53	56.7	67	67.4	70	72.8	74	75.8	74	74.9
C506	62	58.4	47	52.0	62	63.0	62	66.7	68	72.8	63	71.1
C622	63	62.5	54	53.3	63	62.3	66	67.8	69	69.9	67	68.8
C678	69	62.4	51	56.2	62	66.3	70	70.3	69	73.0	67	72.4

Table 2-13: Difference Between Actual and Interpolated Ozone at Each Non-Regulatory Monitor in the San Antonio Region, Average, and Rank

Monitor	6/4/2013	7/4/2013	7/5/2013	9/25/2013	5/10/2014	7/23/2014	8/14/2014
C501	8.0	5.3	7.6	9.2	1.9	0.3	8.4
C502	6.2	3.2	1.3	3.7	2.9	8.7	8.4
C503	3.2	2.1	0.6	5.2	0.4	3.8	6.4
C504	4.4	0.8	0.6	1.9	0.3	6.1	1.2
C505	5.2	1.6	4.1	4.1	7.0	1.5	4.8
C506	3.8	0.7	0.5	0.1	2.3	8.5	3.6
C622	2.0	3.4	4.8	0.7	4.3	1.3	0.5
C678	3.8	0.8	1.1	1.6	3.7	4.6	6.6

Monitor	9/30/2014	8/3/2015	8/27/2015	8/28/2015	8/29/2015	Average	Rank
C501	9.2	2.9	10.7	10.2	9.3	**5.8**	**1**
C502	3.8	3.9	6.5	0.8	0.9	**4.9**	**2**
C503	3.3	0.7	3.6	2.2	1.3	**3.1**	**5**
C504	2.3	2.9	2.7	0.1	0.5	**2.2**	**8**
C505	3.7	0.4	2.8	1.8	0.9	**4.0**	**3**
C506	5.0	1.0	4.7	4.8	8.1	**2.8**	**6**
C622	0.7	0.7	1.8	0.9	1.8	**2.4**	**7**
C678	5.2	4.3	0.3	4.0	5.4	**3.2**	**4**

3 METEOROLOGICAL MONITORING NETWORK

Meteorological monitors are integral to a region's ambient monitoring network as they provide data on the dispersion of pollutants and the conditions under which secondary pollutants like ozone are more-readily formed. Having an extensive regional meteorological monitoring network provides a better understanding of local-scale weather conditions not captured by a more sparse network, like those weather phenomena influenced by elevation changes or the urban heat island effect. Meteorological characteristics and trends are analyzed to determine the ideal temperature, atmospheric pressure, solar radiation, wind speed and wind direction under which high ozone days occur.

There are 14 monitors in the AACOG region (Figure 3-1) that measure meteorological phenomena. While all of these monitors measure temperature, scalar wind speed, resultant wind speed, resultant wind direction, peak wind gust, and standard deviation of wind speed, there are a handful of monitors that measure additional meteorological parameters. CAMS 58 reports solar radiation, which is required in the formation of ozone. CAMS 501, CAMS 502, CAMS 622, and CAMS 678 report precipitation. CAMS 5004 at the New Braunfels Airport measures dew point, relative humidity, precipitation, present weather obscuration, present weather (type of precipitation), extinction coefficient, and visibility, for a total of 13 parameters. This is also the site of the Austin/San Antonio National Weather Service Office and is just 1.66 km west of the CAMS 504 ozone monitor.

As discussed in Section 1.4, AACOG has the resources available to deploy an additional meteorological monitor at CAMS 503 in Bulverde, CAMS 505 in Garden Ridge, CAMS 506 in Seguin, or at a new monitoring site. CAMS 503 in Bulverde used to have a collocated meteorological monitor, but it ended operation at the end of the 2012 ozone season. Table 3-1 lists the monitors in the San Antonio Region that report meteorological conditions, along with other parameters measured at each location and the duration of operation of meteorological monitoring.

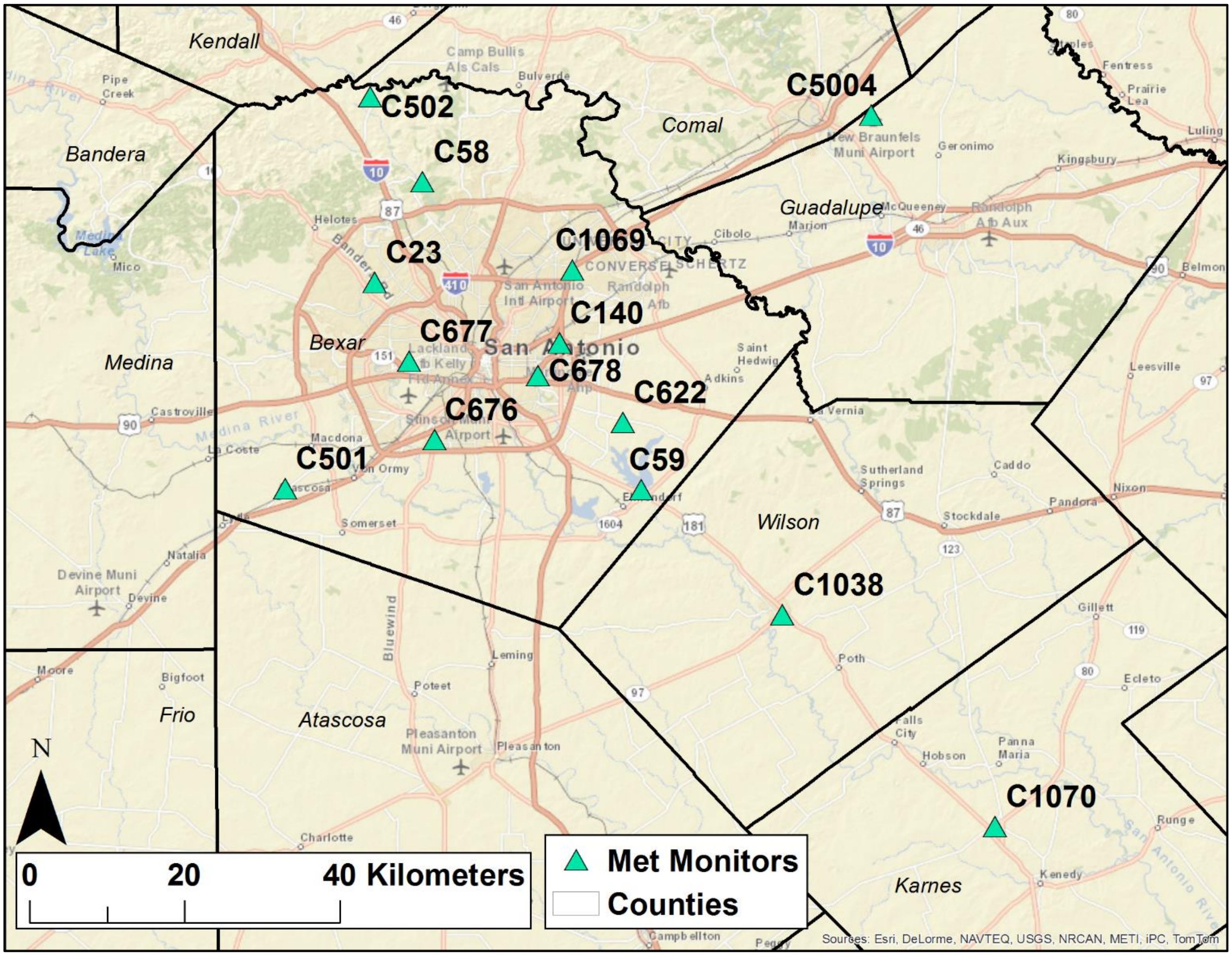


Figure 3-1: Meteorological Monitors in the San Antonio Region

Table 3-1: List of Meteorological Monitors in the San Antonio Region, Locations, Data Measured, and Date/Agency of Operation

Designation / Site Name	Location Description	Data Measured	First date of operation, Currently maintained by
CAMS 23 San Antonio Northwest	San Antonio, Bexar County	NO_X, Ozone, Meteorology, $PM_{2.5}$	January 25, 1982 TCEQ and San Antonio Metro Health District
CAMS 58 Camp Bullis	San Antonio, Bexar County	Auto-GC, Ozone, NO_X, Meteorology	August 10, 1998 Orsat and TMSI
CAMS 59 Calaveras Lake	San Antonio, Bexar County	SO_2, NO_X, Ozone, Meteorology, $PM_{2.5}$	May 12, 1998 San Antonio Metro Health District
CAMS 140 San Antonio Seale	San Antonio, Bexar County	Meteorology	May 23, 1997 TCEQ
CAMS 501 Elm Creek Elementary	Atascosa, Bexar County	Ozone, Meteorology	June 17, 2002 Dios-Dado for AACOG
CAMS 502 Fair Oaks Ranch	Fair Oaks Ranch, Bexar County	Ozone, Meteorology	June 27, 2002 Dios-Dado for AACOG
CAMS 622 Heritage Middle School	San Antonio, Bexar County	Ozone, Meteorology, $PM_{2.5}$	July 29, 2004 Dios-Dado for CPS
CAMS 676 Palo Alto	San Antonio, Bexar County	Meteorology, $PM_{2.5}$	August 1, 2006 San Antonio Metro Health District
CAMS 677 Old Hwy 90	San Antonio, Bexar County	Air Toxics, $PM_{2.5}$, Meteorology	October 9, 2006 San Antonio Metro Health District
CAMS 678 CPS Pecan Valley	San Antonio, Bexar County	Ozone, Meteorology	March 4, 1999 Dios-Dado for CPS
CAMS 1038 Floresville Hospital Blvd	Floresville, Wilson County	Auto-GC, NO_X, Meteorology	July 17, 2013 Orsat and UTCEER
CAMS 1069 San Antonio IH-35	San Antonio, Bexar County	NO_X, Meteorology	January 8, 2014 TCEQ
CAMS 1070 Karnes County Courthouse	Karnes City, Karnes County	Auto-GC, NO_X, Meteorology	December 17, 2014 Orsat
CAMS 5004 New Braunfels Airport KBAZ	New Braunfels, Guadalupe County	Meteorology	January 22, 2003 National Weather Service

3.1 Site-by-Site Analysis

The site-by-site analysis for meteorological monitors is not as extensive as it was for ozone monitors. Number of parameters measured, trends analysis, and area and population served are the only analysis techniques used in this report to assess the meteorological monitoring network.

3.1.1 Number of Parameters Monitored

Most meteorological monitors report on at least one pollutant, the exception being CAMS 140 at San Antonio Seale, which currently only reports meteorological parameters. Meteorological monitoring is often collocated with pollutant monitoring to determine source regions of high pollutant concentration. CAMS 677 at Old Highway 90 reports the most pollutants with its canister samples every six days. These canister samples measure the concentration of dozens of air toxics and volatile organic compounds (VOCs). Table 3-2 lists each meteorological monitor along with the total number of parameters measured at that site. Because CAMS 677 measures the most parameters, it ranks the highest on this list. The next three highest-ranked monitors also measure VOCs along with meteorological conditions. As explained in the previous chapter, a low-scoring monitor using the Number of Parameters Monitored metric is not in itself a clear indicator of the usefulness of a monitor. Budgetary constraints often necessitate limiting the number of parameters measured at any given monitor.

Table 3-2: Number of Parameters Monitored at Each Meteorological CAMS Site in the San Antonio Region (High values in bold, low values in italics)

Monitor	Number of Parameters	Parameter Score	Rank
CAMS 23	18	19.8	6
CAMS 58	59	64.8	2
CAMS 59	20	22.0	5
CAMS 140	*6*	*6.6*	*14*
CAMS 501	8	8.8	10
CAMS 502	8	8.8	10
CAMS 622	10	11.0	8
CAMS 676	7	7.7	13
CAMS 677	**91**	**100.0**	**1**
CAMS 678	8	8.8	10
CAMS 1038	58	63.7	3
CAMS 1069	9	9.9	9
CAMS 1070	58	63.7	3
CAMS 5004*	14	15.4	7

* Includes ozone as a parameter; ozone site is less than 2 km away

3.1.2 Trends Impacts

The Trends Impacts chart seen in Table 3-3 shows how long each monitor has measured meteorological parameters. The Duration of Operation for each monitor may be different than what is shown in Table 2-3, which gives the duration of operation for each ozone monitor. For example, CAMS 23 began measuring ozone more than six months before it began measuring temperature and resultant wind speed and direction. Monitors with a lower Trends Impacts score are not necessarily less important to the overall meteorological monitoring network. CAMS 1069, although in operation only two years, is required by the EPA as a near-road NO_X monitor. It is important that this monitor is collocated with meteorological equipment so as to get a more accurate portrayal of on-road emissions at that site. If southeasterly winds are measured at that site, then it is not detecting NO_X from the roadway as the monitor is to the southeast side of Interstate 35. Northerly or northeasterly winds would best transport those on-road emissions over the monitoring site. CAMS 1070 is the newest monitor in the entire San Antonio regional monitoring network, but has one of only three Auto-GCs, which measure VOCs. CAMS 140 measures the fewest parameters, giving it the lowest Number of Parameters Monitored score, but has the second-longest history of meteorological observations of any monitor in the region, ranking it second in the Trends Impacts analysis.

Table 3-3: Duration of Operation and Trend Impacts Score for Each Meteorological CAMS Site in the San Antonio Region (High values in bold, low values in italics)

Monitor Number	Duration of Operation (as of 1/1/16)	Trend Impacts Score	Rank
CAMS 23	**33 years, 11 months**	**100.0**	**1**
CAMS 58	17 years, 5 months	51.3	4
CAMS 59	17 years, 8 months	52.0	3
CAMS 140	18 years, 7 months	54.8	2
CAMS 501	13 years, 7 months	39.9	6
CAMS 502	13 years, 6 months	39.8	7
CAMS 622	11 years, 5 months	33.7	9
CAMS 676	9 years, 5 months	27.8	10
CAMS 677	9 years, 3 months	27.2	11
CAMS 678	16 years, 10 months	49.6	5
CAMS 1038	2 years, 5 months	7.2	12
CAMS 1069	2 years	5.8	13
CAMS 1070	*1 year*	*3.1*	*14*
CAMS 5004	12 years, 11 months	38.1	8

3.1.3 Area and Population Served

To perform the Area and Population Served analysis, Thiessen Polygons were again created around each meteorological monitor, as shown in Figure 3-2. There are seven monitors outside the AACOG boundary that serve an area within the AACOG region. Together, these seven monitors serve nearly 1,700 km^2 and 12,386 people. The monitor with the largest area served is CAMS 502 in Fair Oaks Ranch, followed closely behind by CAMS 501 at Elm Creek Elementary in extreme southwest Bexar County. Both of these monitors are on the periphery of the monitoring network, causing them to have a large area of service. Within Bexar County alone, there are eleven meteorological monitors. Out of the three smallest Thiessen polygons, two (CAMS 140 and CAMS 678) correspond to monitors within Bexar County, with CAMS 140 having the smallest area served out of any in the analysis. The meteorological monitor with the highest population served is CAMS 23 with just over 400,000 people. CAMS 1069, the near-road NO_X monitor adjacent to Interstate 35, serves the second-highest number of people at 388,705. Six additional monitors each serve at least 100,000 people. Table 3-4 and Table 3-5 list the population and area served, respectively, along with each site's ranking.

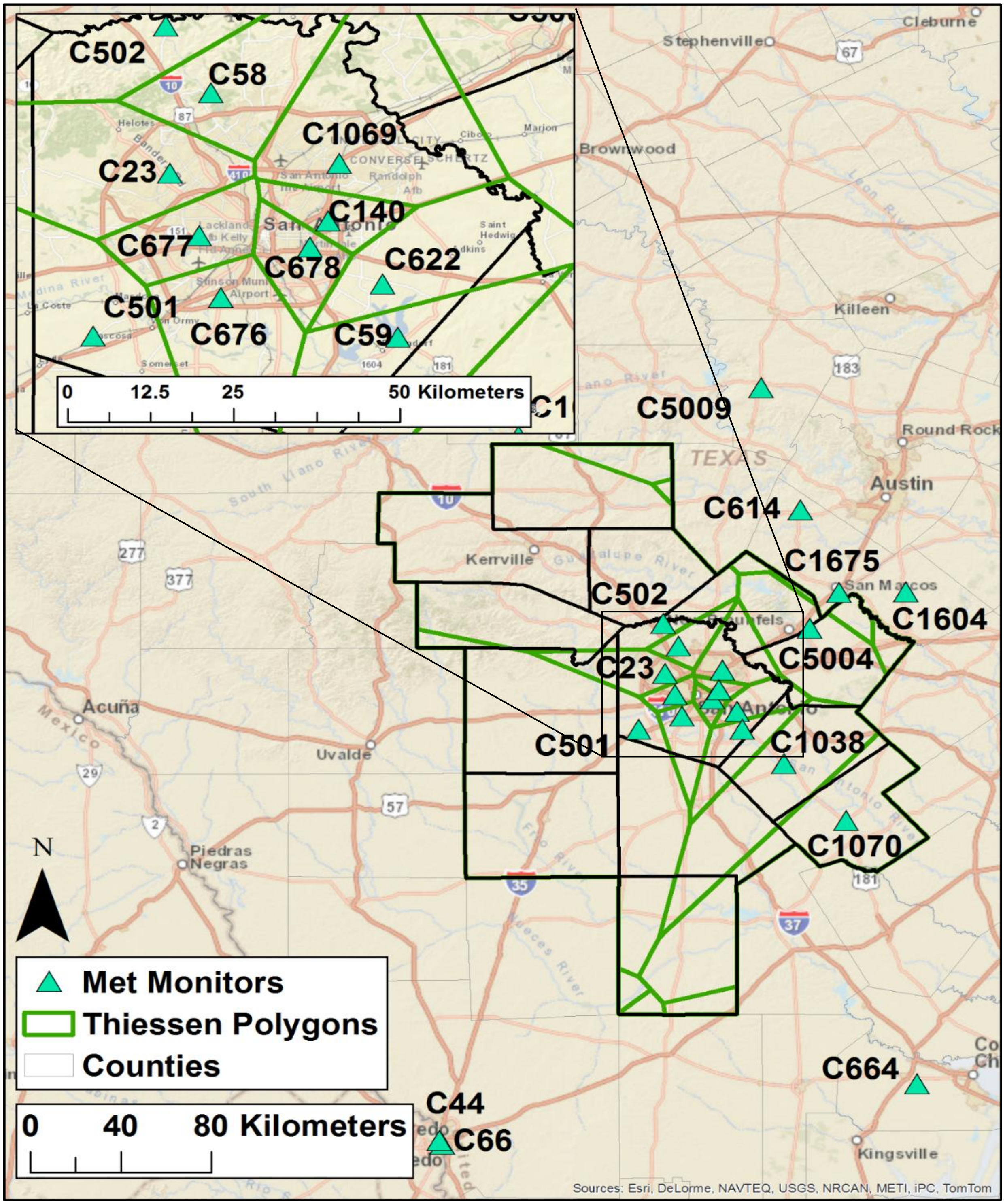


Figure 3-2: Thiessen Polygons Surrounding Area Meteorological Monitors

Table 3-4: Population Served by Meteorological CAMS Sites in and Around the San Antonio Region

Meteorological Monitor Name	Monitor ID	Population Served (2010)	Rank
San Antonio Northwest	C23	402,167	1
Camp Bullis	C58	169,074	4
Calaveras Lake	C59	43,369	11
San Antonio Seale	C140	83,403	10
Elm Creek Elementary	C501	114,886	9
Fair Oaks Ranch	C502	160,362	6
Heritage Middle School	C622	23,131	13
Palo Alto	C676	154,223	7
Old Highway 90	C677	344,876	3
CPS Pecan Valley	C678	162,838	5
Floresville Hospital Boulevard	C1038	27,641	12
San Antonio Interstate 35	C1069	388,705	2
Karnes County Courthouse	C1070	15,655	14
New Braunfels Airport KBAZ	C5004	146,977	8
* Dripping Springs School	C614	2,108	16
* Lockhart	C1604	1,178	17
* CAPCOG San Marcos	C1675	8,167	15
* Burnet County Airport KBMQ	C5009	916	18
* Laredo Vidaurri	C44	0	21
* Laredo Bridge	C66	5	20
* Violet	C664	12	19

* Monitor is located outside of the 13-county AACOG region

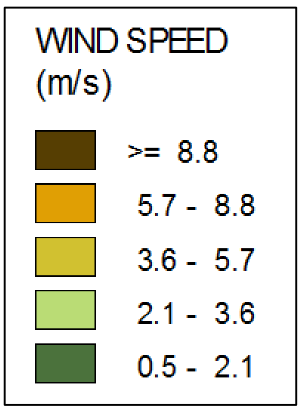
Table 3-5: Area Served by Meteorological CAMS Sites in and Around the San Antonio Region

Meteorological Monitor Name	Monitor ID	Area Served (km^2)	Rank
San Antonio Northwest	C23	753.1	7
Camp Bullis	C58	407.6	12
Calaveras Lake	C59	785.0	6
San Antonio Seale	C140	118.0	21
Elm Creek Elementary	C501	8,864.1	2
Fair Oaks Ranch	C502	9,255.5	1
Heritage Middle School	C622	447.4	11
Palo Alto	C676	537.3	10
Old Highway 90	C677	204.2	15
CPS Pecan Valley	C678	142.5	19
Floresville Hospital Boulevard	C1038	2,975.2	4
San Antonio Interstate 35	C1069	704.7	8
Karnes County Courthouse	C1070	3,745.1	3
New Braunfels Airport KBAZ	C5004	1,968.0	5
* Dripping Springs School	C614	149.5	17
* Lockhart	C1604	200.7	16
* CAPCOG San Marcos	C1675	253.5	14
* Burnet County Airport KBMQ	C5009	552.3	9
* Laredo Vidaurri	C44	148.8	18
* Laredo Bridge	C66	119.6	20
* Violet	C664	265.4	13

* Monitor is located outside of the 13-county AACOG region

3.2 Bottom-Up Analysis

Research from the 2014 Ozone Conceptual Model for the San Antonio Region shows that, on any given ozone season day, over 70% of ozone is transported from outside of the area.[13] In the previous chapter, back trajectories were analyzed to determine the source regions of high ozone on days where the 8-hour average is greater than 70 ppb. The bottom-up analysis of meteorological monitors in the AACOG region utilizes wind rose plots to compare wind characteristics on days where any monitor recorded ozone in excess of 70 ppb. Wind rose plots were created for each of the 14 meteorological monitoring stations for morning (6 a.m. to 8 a.m. local time) and afternoon (12 p.m. to 2 p.m. local time) average wind speed and direction. The purpose of creating these wind rose plots is to assess the degree of uniformity of wind patterns at each of the 14 meteorological stations on high ozone days. The legend for the wind speeds shown in the following wind rose plots is given below.



The Ozone Conceptual Model discusses morning and afternoon wind characteristics on high ozone days as having a shift from NW in the morning to SE in the afternoon at CAMS 58. The wind roses in Figure 3-3 clearly show this reversal of winds and the frequency at which it occurs on high ozone days. Roughly 65% of high ozone days began with average morning winds originating from a general northwesterly direction. More than half of high ozone days had afternoon winds out of the general southeast direction, with very few out of the northwest. Morning wind speeds were generally weaker than those in the afternoon on high ozone days. Morning and afternoon wind characteristics were also investigated for the other thirteen meteorological monitors to determine whether similar wind regimes occur in other areas of the San Antonio Region.

[13]Alamo Area Council of Governments, 2015. "Conceptual Model Ozone Analysis of the San Antonio Region Updates through Year 2014." San Antonio, TX. P. 114. Available online: http://www.aacog.com/DocumentCenter/View/34654. Accessed September 8, 2016.

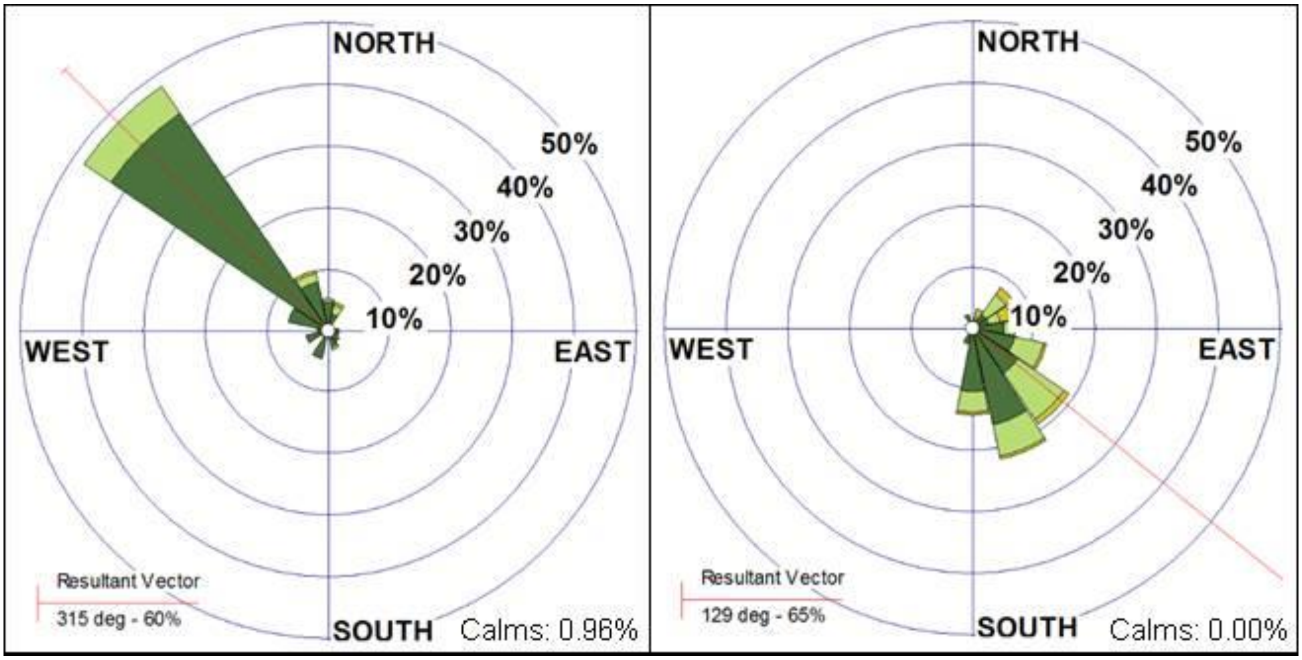


Figure 3-3: Morning (left) and Afternoon (right) Wind Rose at CAMS 58

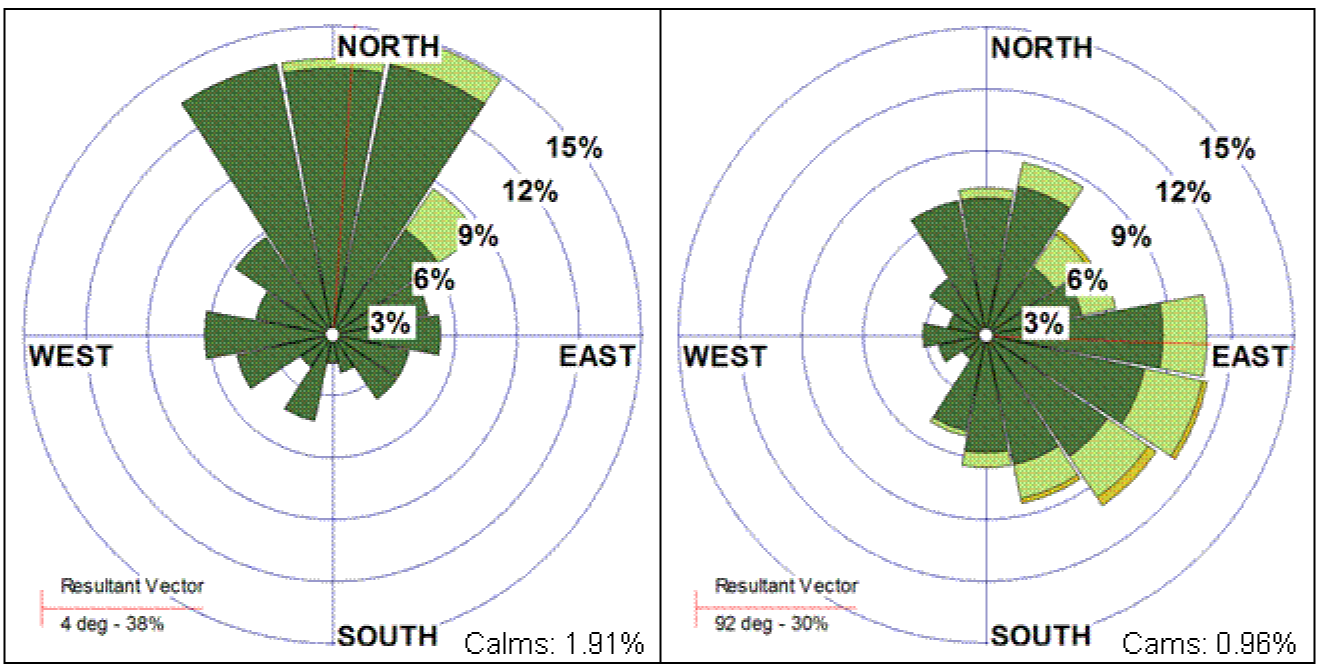


Figure 3-4: Morning (left) and Afternoon (right) Wind Rose at CAMS 23

Wind rose plots from CAMS 23, shown in Figure 3-4, indicate that a similar, albeit less pronounced, wind shift often occurs between morning and afternoon. Nearly 45% of high ozone days had morning winds out of a generally northerly direction, while afternoon wind directions tended to be out of the east and southeast. Wind roses at CAMS 59 show a different morning and afternoon wind regime on high ozone days, where northwesterly winds tend to dominate in the morning and afternoon winds are fairly evenly split between northeast and southeast (Figure 3-5). There is also a larger proportion of wind speeds > 3.6 m/s, especially in the morning hours, compared to what is seen at other monitors.

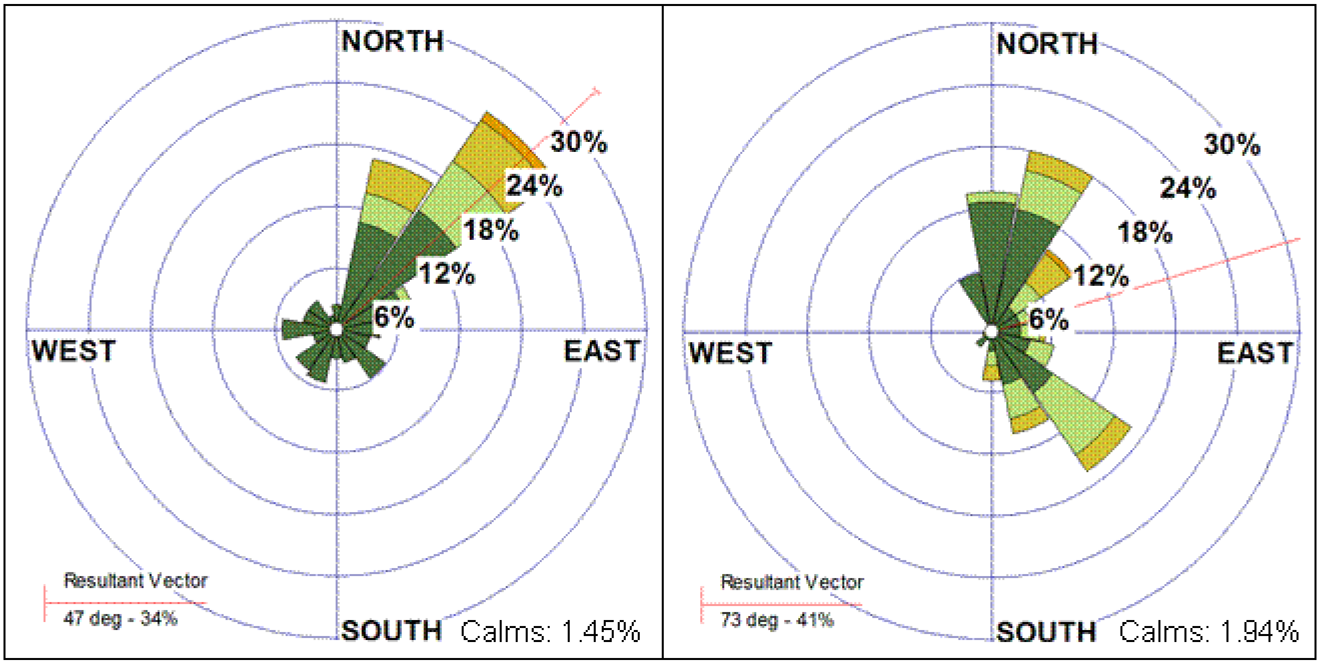


Figure 3-5: Morning (left) and Afternoon (right) Wind Rose at CAMS 59

Figure 3-6 shows that morning and afternoon wind roses at CAMS 140 depict a wind shift from northwest in the morning to east and southeast in the afternoon.

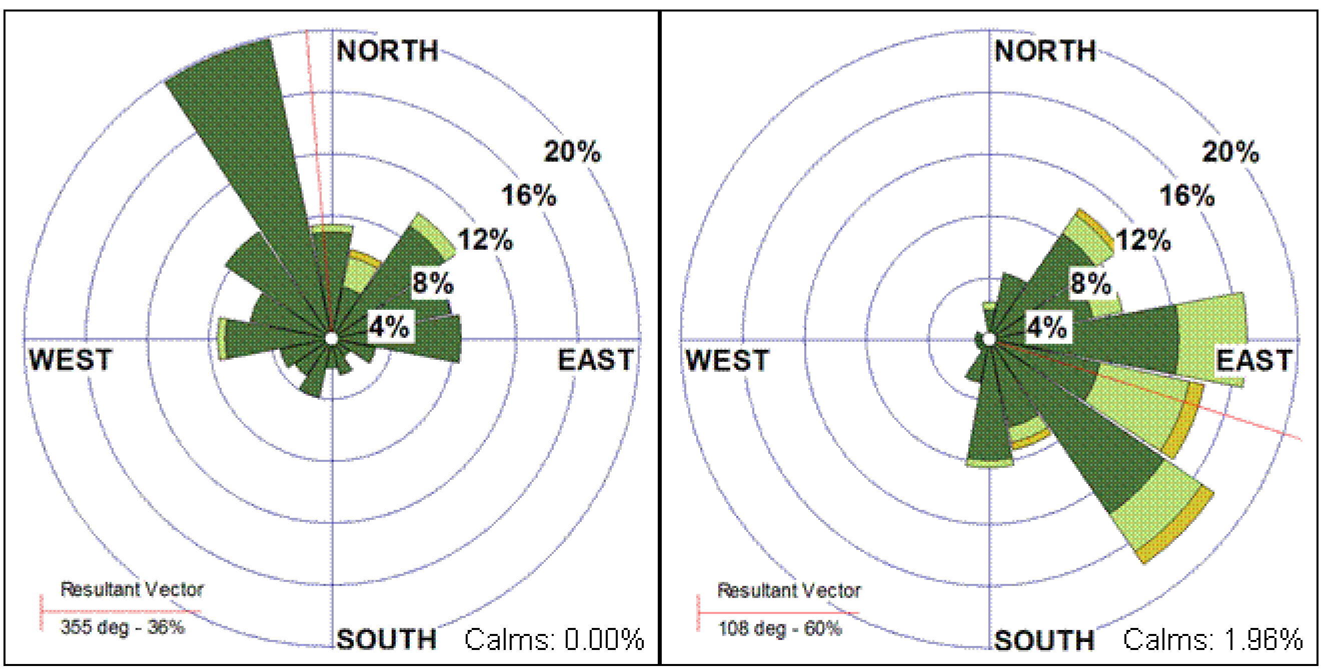


Figure 3-6: Morning (left) and Afternoon (right) Wind Rose at CAMS 140

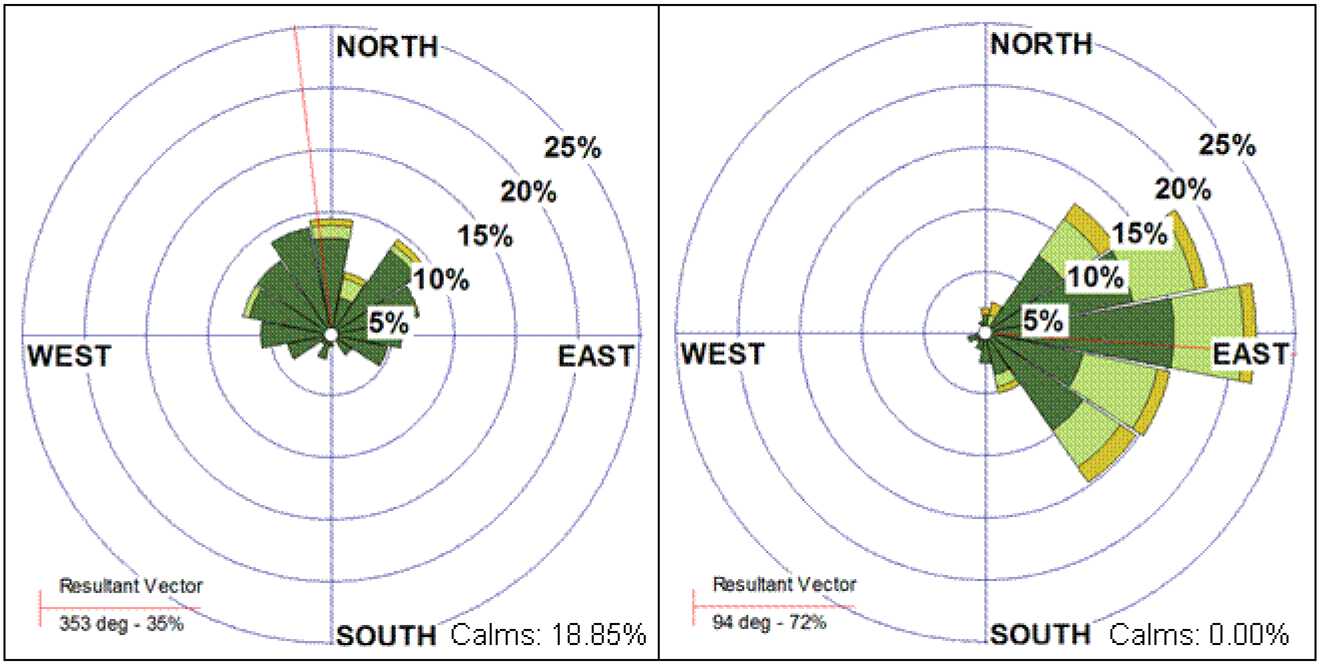


Figure 3-7: Morning (left) and Afternoon (right) Wind Rose at CAMS 501

Morning winds at CAMS 501 (Figure 3-7) do not show a clear dominant direction and are calm or variable over 18% of high ozone days, but afternoon winds tend to come from the east with greater speed. At CAMS 502 (Figure 3-8), the wind shift between morning and afternoon is more pronounced, with most days reporting northwest winds in the morning and south-southeast in the afternoon. The wind profile at CAMS 502 is similar to CAMS 58, although northwest winds in the morning are not as dominant at CAMS 502.

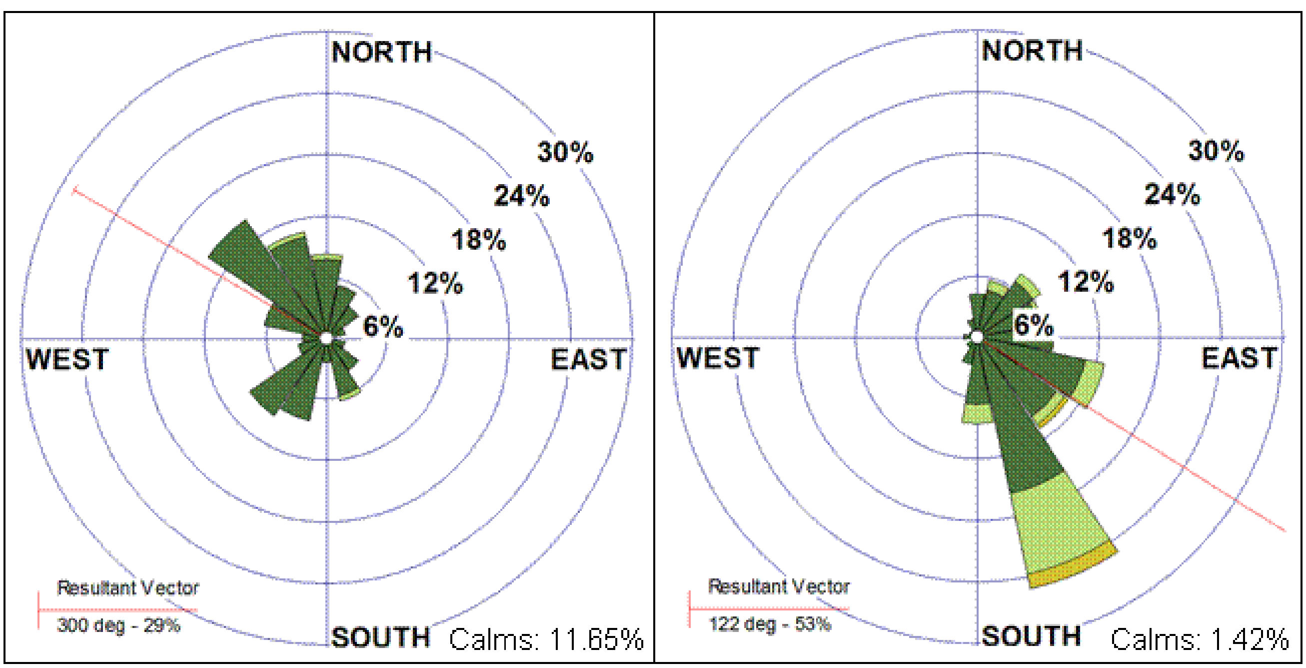


Figure 3-8: Morning (left) and Afternoon (right) Wind Rose at CAMS 502

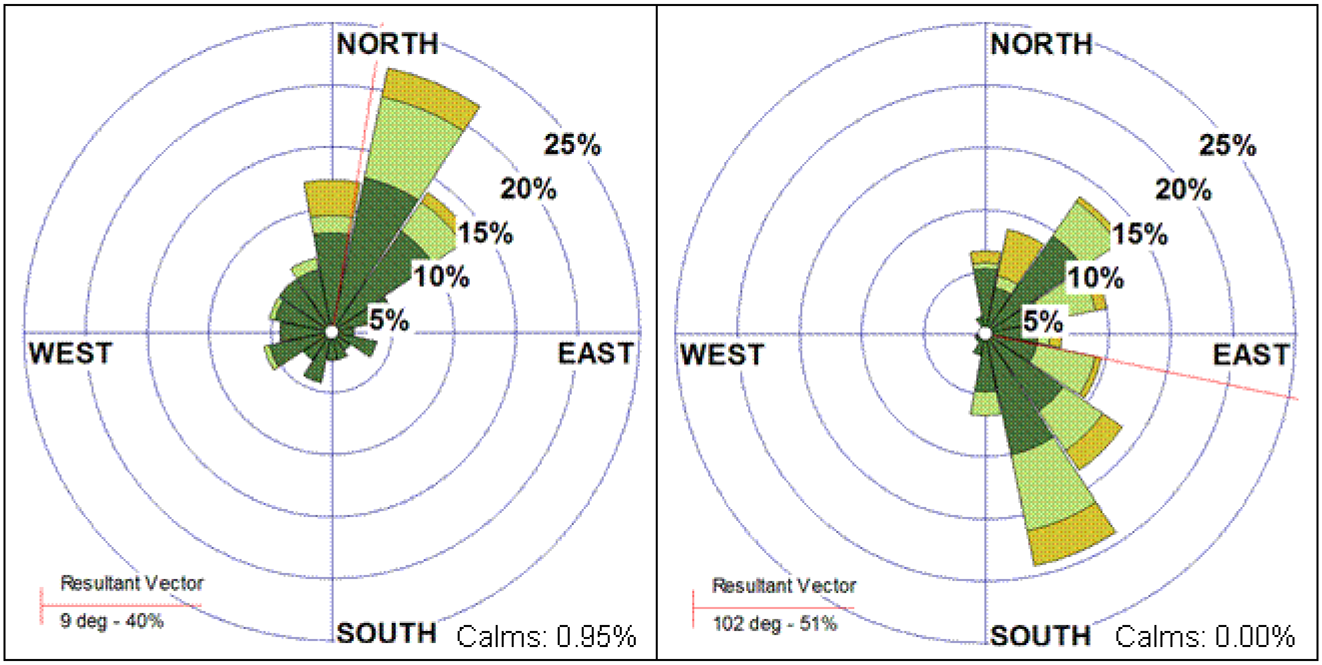


Figure 3-9: Morning (left) and Afternoon (right) Wind Rose at CAMS 622

The wind roses for CAMS 622 (Figure 3-9) are similar to CAMS 59 with generally north to northeast winds often reported in the morning and a fairly even split between northeast and southeast in the afternoon. Morning winds at CAMS 676 (Figure 3-10) are most often out of the northeast as well, with a few more cases of northwest winds than CAMS 622. Southeasterly winds tend to be the dominant wind direction in the afternoon at CAMS 676.

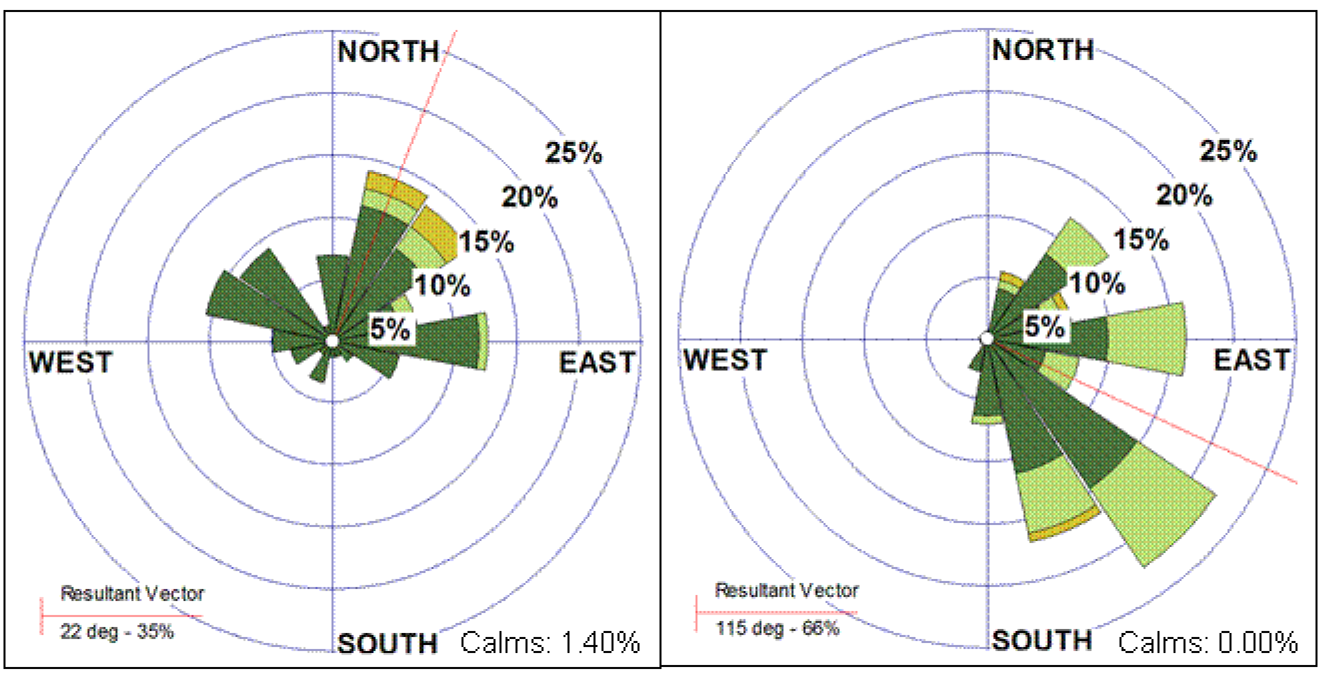


Figure 3-10: Morning (left) and Afternoon (right) Wind Rose at CAMS 676

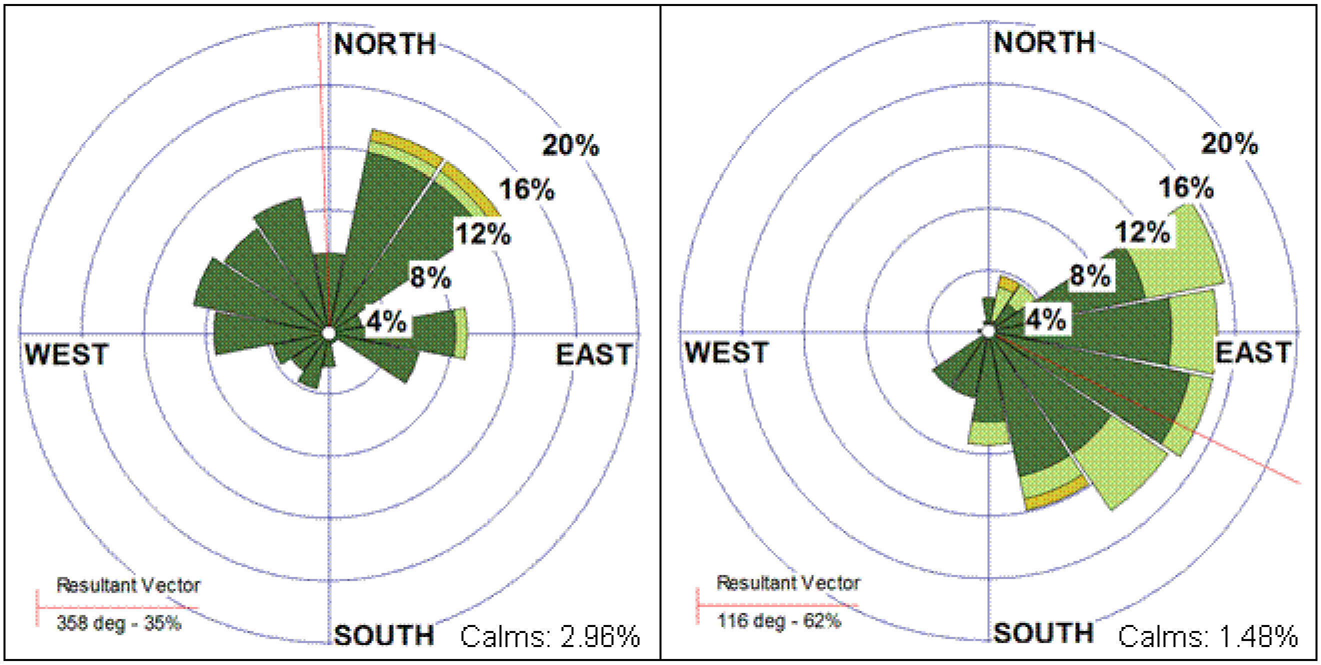


Figure 3-11: Morning (left) and Afternoon (right) Wind Rose at CAMS 677

At CAMS 677 (Figure 3-11), afternoon winds are often out of a generally easterly direction, but morning winds are split between northwest and northeast, making the wind shift less pronounced than other monitors. Winds with a southerly component are rarely observed on high ozone days. CAMS 678 does see a wind shift from northerly to southeasterly on high ozone days, as seen in Figure 3-12.

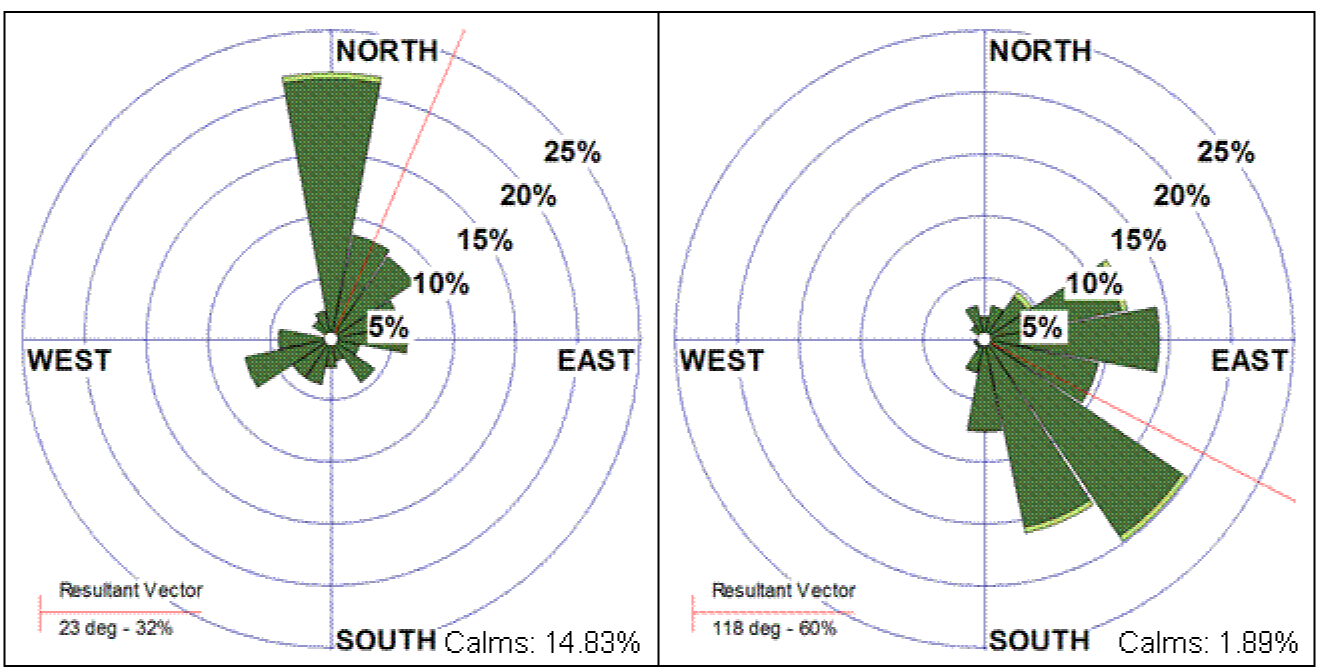


Figure 3-12: Morning (left) and Afternoon (right) Wind Rose at CAMS 678

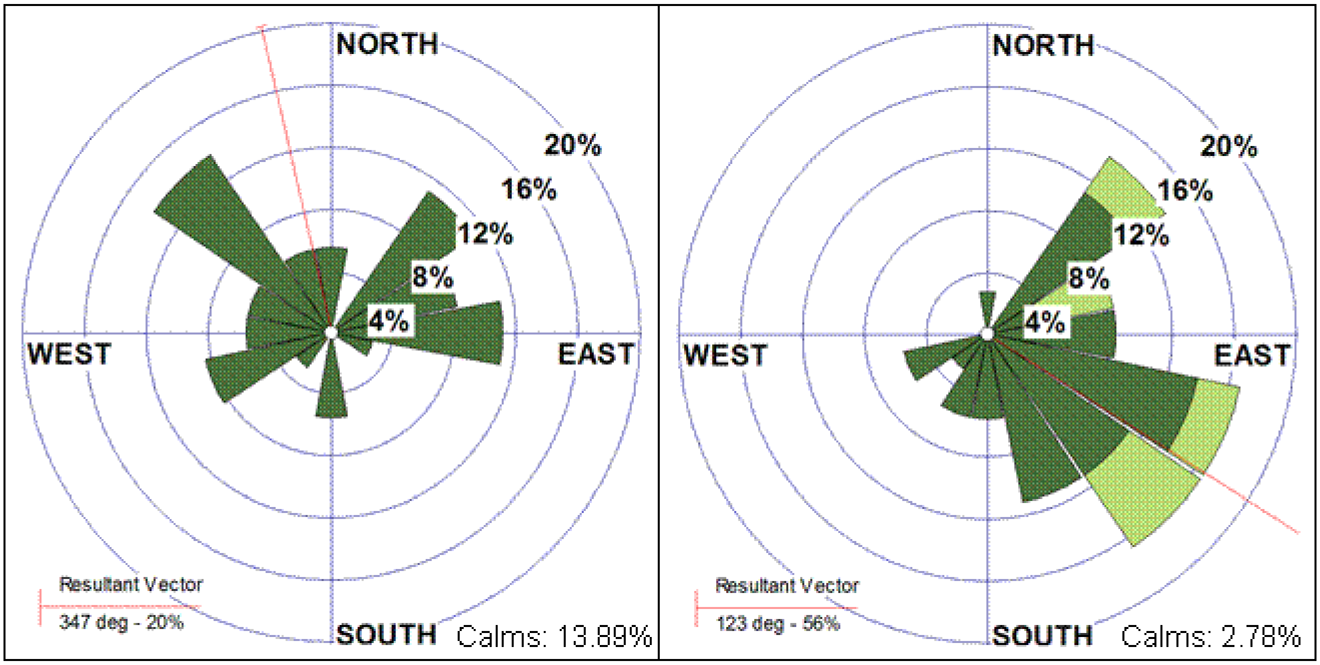


Figure 3-13: Morning (left) and Afternoon (right) Wind Rose at CAMS 1038

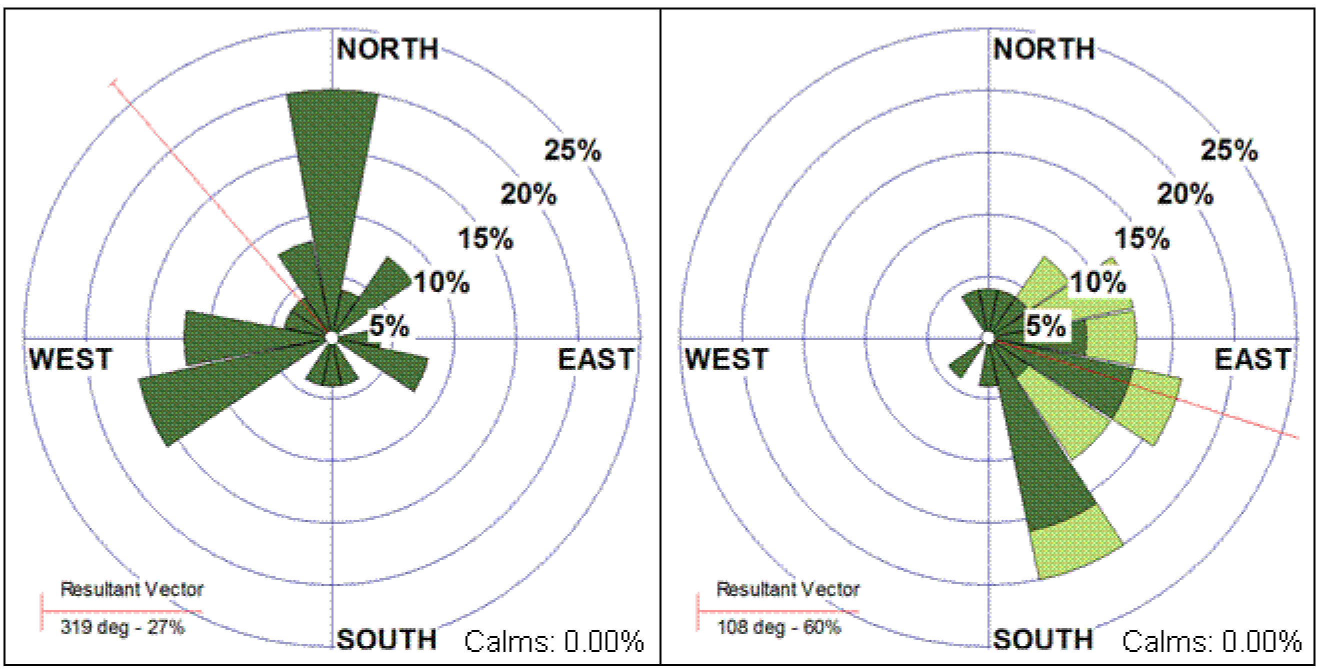


Figure 3-14: Morning (left) and Afternoon (right) Wind Rose at CAMS 1069

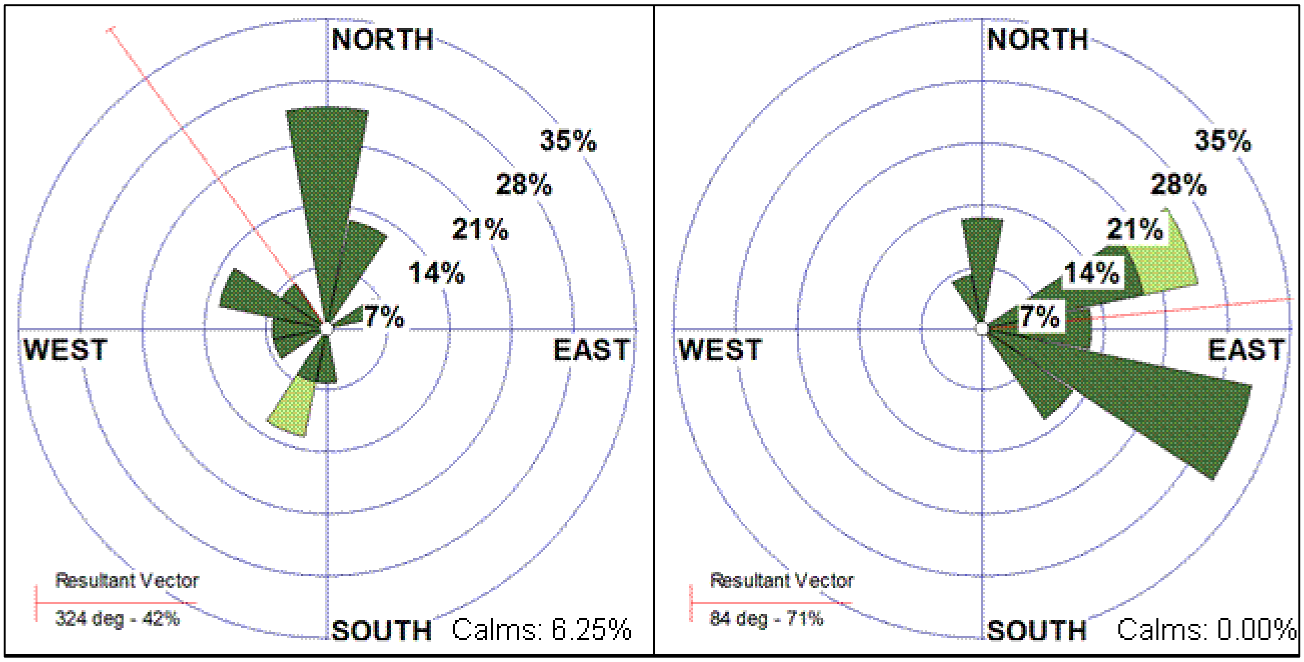


Figure 3-15: Morning (left) and Afternoon (right) Wind Rose at CAMS 1070

The three newest meteorological monitors, CAMS 1038, CAMS 1069, and CAMS 1070, do not have as much history of wind data as other monitors in the region, but there appears to be a wind shift that occurs at these locations on high ozone days as well. Afternoon wind directions are generally southeasterly at all three locations. Morning wind directions are not as uniform, but generally range from the north and west. Calm conditions, where winds are less than 0.5 m/s, occur at CAMS 1038 and CAMS 1070 with greater frequency than CAMS 1069.

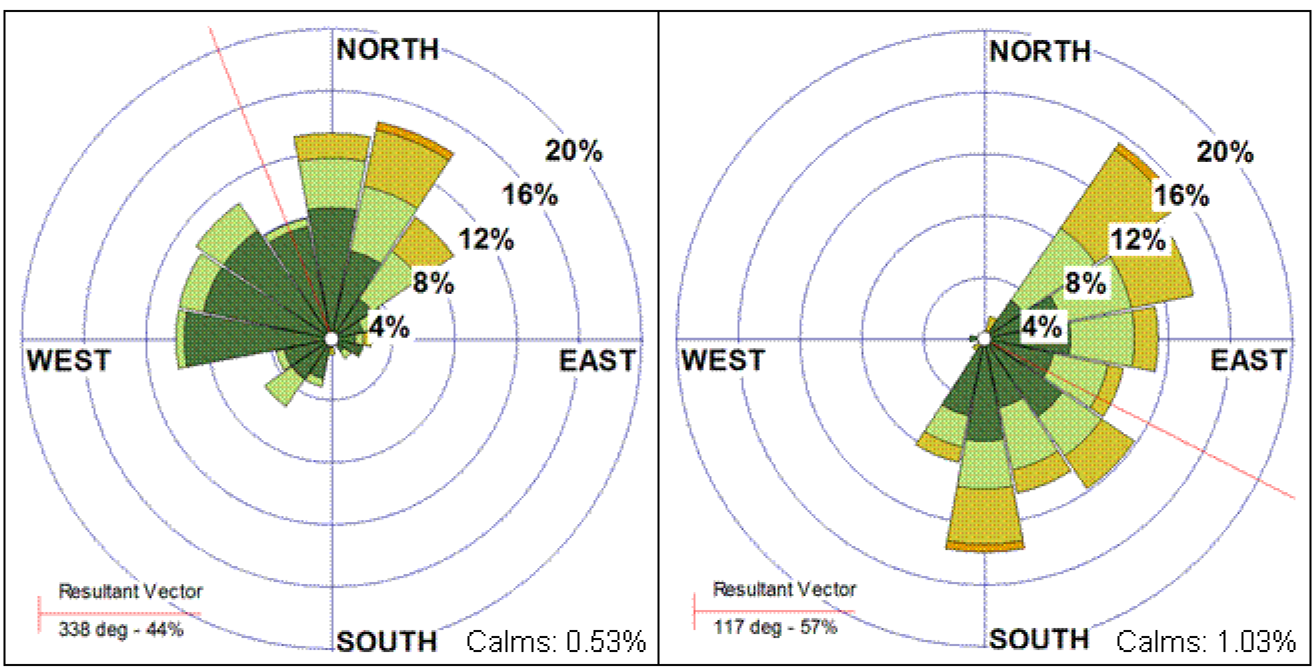


Figure 3-16: Morning (left) and Afternoon (right) Wind Rose at CAMS 5004

At CAMS 5004, the difference between morning and afternoon wind roses is clearly seen in Figure 3-16. Morning winds are most often out of the north and north-northeast, but northwesterly winds can also occur. Afternoon winds are usually stronger, but can come from any direction from northeast, clockwise to south.

Most meteorological monitoring sites in the San Antonio Region experience a wind shift on high ozone days. Some monitors, namely CAMS 58 and CAMS 502, show a northwesterly to southeasterly wind shift. Most others (CAMS 59, CAMS 622, etc.) show a northeasterly to southeasterly wind shift, and in some cases, no wind shift at all. This is commonly observed at CAMS 59, where winds on some high ozone days remain northeasterly throughout the day. It is unclear at this time why CAMS 58 exhibits such a consistent wind shift on high ozone days. No other meteorological monitor shows such a high percentage of cases with winds originating from one of the 16 possible directions shown on the wind rose. It is possible that its location along the Balcones Escarpment and the associated sharp elevation change might be contributing to this relatively consistent wind shift. Additional meteorological monitoring in the vicinity of CAMS 58 and along the Escarpment might be useful in helping explain why this phenomenon occurs.

3.3 Profiler

The previous section focuses on the horizontal surface movement of air across meteorological monitoring sites in the San Antonio Region. A radar wind profiler (RWP) is an instrument that uses radar pulses to assess winds several hundred meters up in the atmosphere. A radio acoustic sounding system (RASS) uses sound waves pointed vertically, in conjunction with the RWP, to determine the temperature profile based on the compression of air as the sound wave moves through the atmosphere.[14] In 2005, a 915-MHz RWP and (RASS) were deployed at the National Weather Service in New Braunfels, where CAMS 5004 is located. The purpose of these two instruments was to assess mixing height characteristics on high ozone days. The mixing height represents the “cap” on vertical air movement, and changes throughout the day as temperatures rise and subsequently fall. Results from this 2005 study, found in the 2014 Ozone Conceptual Model for San Antonio, show that there is a larger diurnal change in mixing height on high ozone days compared to low ozone days.[15]

The area around the New Braunfels NWS station is relatively flat, while other meteorological monitors are situated deeper in the Texas Hill Country or along the Balcones Escarpment, like CAMS 58. It might be of interest to assess vertical wind and temperature profiles in other parts of the region, especially where elevation changes are a factor. The cost to rent and operate a RWP and RASS is too great for AACOG to undertake on its own, so it is not being seriously considered at this time. In the future, if joint funding opportunities arise, AACOG may decide to revisit the idea of renting a RWP and RASS and deploying at another location in the area.

[14] University of Wyoming. “Radio Acoustic Sounding System.” Available online: http://www.atmos.uwyo.edu/~geerts/cwx/notes/chap15/rass.html. Accessed September 12, 2016.

[15] Alamo Area Council of Governments, 2015. “Conceptual Model Ozone Analysis of the San Antonio Region Updates through Year 2014.” San Antonio, TX. P. 61-63. Available online: http://www.aacog.com/DocumentCenter/View/34654. Accessed September 8, 2016.

4 OXIDES OF NITROGEN MONITORING NETWORK

There are six air monitors, shown in Figure 4-1, in the 13-county AACOG region that measure NO_X concentrations. Three (CAMS 23, CAMS 58, and CAMS 59) are collocated with ozone monitors. CAMS 59 has the longest continuous record of any NO_X monitor currently in operation in the region. CAMS 23 began monitoring NO_X in October 2012 when CAMS 58 originally ceased NO_X monitoring. On August 26, 2014, NO_X monitoring recommenced at CAMS 58, operated by Technical Monitoring Services Incorporated (TMSI). CAMS 1038 in Wilson County was established in July 2013 to measure NO_X concentrations on the edge and downwind of the Eagle Ford Shale. In 2010, the EPA promulgated new NO_2 monitoring requirements, mandating one near-road monitor for any core-based statistical area (CBSA) with a population over 500,000.[16] To satisfy this requirement, CAMS 1069 was established along Interstate 35 near the Interstate 410 interchange in January 2014. This segment of Interstate 35 northeast of the urban core has some of the highest Annual Average Daily Traffic counts in the San Antonio Region.[17] In December 2014, CAMS 1070 was established in Karnes County to measure NO_X concentrations within one of the most heavily developed parts of the Eagle Ford Shale.

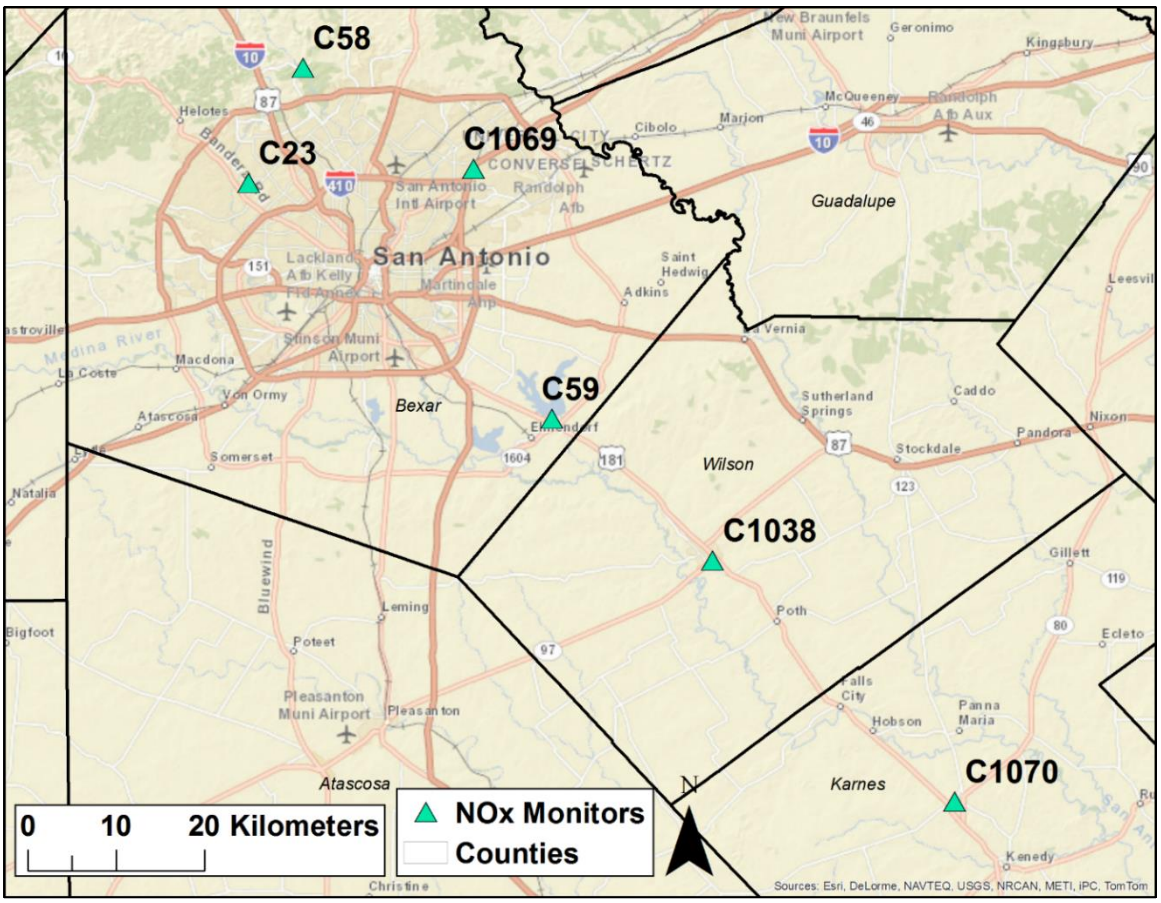


Figure 4-1: NO_X Monitors in the San Antonio Region

[16] US Environmental Protection Agency, June 2012. "Near-Road NO_2 Monitoring Technical Assistance Document." Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. Available online: https://www3.epa.gov/ttnamti1/files/nearroad/NearRoadTAD.pdf. Accessed August 2, 2016.

[17] Texas Department of Transportation, 2015. "2014 San Antonio District Traffic Map." Austin, Texas. Available online: http://ftp.dot.state.tx.us/pub/txdot-info/tpp/traffic_counts/2014/sat-base.pdf. Accessed August 2, 2016.

Table 4-1: List of NO_X Monitors in the San Antonio Region, Locations, Data Measured, and Date/Agency of Operation

Designation / Site Name	Location Description	Data Measured	First date of operation, Currently maintained by
CAMS 23 San Antonio Northwest	San Antonio, Bexar County	NO_X, Ozone, Meteorology, $PM_{2.5}$	October 18, 2012 TCEQ and San Antonio Metro Health District
CAMS 58 Camp Bullis	San Antonio, Bexar County	Auto-GC, Ozone, NO_X, Meteorology	August 10, 1998* Orsat and TMSI
CAMS 59 Calaveras Lake	San Antonio, Bexar County	SO_2, NO_X, Ozone, Meteorology, $PM_{2.5}$	May 13, 1998 San Antonio Metro Health District and Dios-Dado
CAMS 1038 Floresville Hospital Blvd	Floresville, Wilson County	Auto-GC, NO_X, Meteorology	July 17, 2013 Orsat and UTCEER
CAMS 1069 San Antonio IH-35	San Antonio, Bexar County	NO_X, Meteorology	January 8, 2014 TCEQ
CAMS 1070 Karnes County Courthouse	Karnes City, Karnes County	Auto-GC, NO_X, Meteorology	December 17, 2014 Orsat

* CAMS 58 did not record NO_X between October 2012 and August 2014

4.1 Site-by-Site Analysis

The site-by-site analysis for NO_X monitoring uses the same techniques found in the meteorological monitoring section. A Monitor-to-Monitor correlation was not conducted for NO_X monitors because there are so few monitors and such a small period of record for some of them. Because there are only six NO_X monitors in the San Antonio Region, the following techniques in this section are primarily for informational purposes, rather than for revealing any redundancies in the network.

4.1.1 Number of Parameters Monitored

Three of the six NO_X monitors in the region continuously measure VOCs. These monitors are CAMS 58 at Camp Bullis, which also records ozone, CAMS 1038 in Floresville, and CAMS 1070 in Karnes City. These monitors have the highest score due to the dozens of individual VOC species that are measured. The monitor with the lowest score, CAMS 1069, only measures NO_X (nitric oxide and nitrogen dioxide, NO and NO_2) and meteorological parameters. The Number of Parameters Monitored analysis, shown in Table 4-2, would place the least importance on this monitor with respect to the overall NO_X monitoring network. However, this monitor is federally mandated as a near-road NO_X monitor. Its sole purpose is to record NO_X adjacent to one of the busiest sections of roadway in an urbanized area. CAMS 23 and CAMS 59 measure the same parameters, except CAMS 59 also measures sulfur dioxide (SO_2) and Total Suspended Particulates. Based on this analysis, and considering other factors like regulations, there is no NO_X monitor that is deemed unnecessary or redundant.

Table 4-2: Number of Parameters Monitored at Each CAMS Site in the San Antonio Region (High values in bold, low values in italics)

Monitor	Number of Parameters	Parameter Score	Rank
CAMS 23	18	30.5	5
CAMS 58	**59**	**100.0**	**1**
CAMS 59	20	33.9	4
CAMS 1038	58	98.3	2
CAMS 1069	*9*	*15.3*	*6*
CAMS 1070	58	98.3	2

4.1.2 Trends Analysis

As mentioned earlier, CAMS 59 at Calaveras Lake has the longest continuous history of recording NO_X out of any of the San Antonio Area monitors. CAMS 58, despite beginning NO_X monitoring the same year as CAMS 59, did not record NO_X between October 2012 and August 2014 and thus, ranks second in the Trends Analysis. The three lowest-ranked monitors are not necessarily less useful because of their relatively short duration of operation. As previously mentioned, CAMS 1038 and CAMS 1070 measure NO_X within the Eagle Ford Shale, which is often upwind of San Antonio. CAMS 1038 is just on the downwind edge of the most heavily-developed part of the Shale, while CAMS 1070 is situated within the densest area of wells, as seen in Figure 5-1. Each NO_X monitor in the San Antonio Region serves an important purpose and thus, none are recommended for deletion from the network.

Table 4-3: Duration of Operation and Trend Impacts Score for Each CAMS Site in the San Antonio Region (High values in bold, low values in italics)

Monitor Number	Duration of Operation (as of 1/1/16)	Trend Impacts Score	Rank
CAMS 23	3 years, 2 months	18.2	3
CAMS 58	15 years, 7 months*	88.1	2
CAMS 59	**17 years, 8 months**	**100.0**	**1**
CAMS 1038	2 years, 5 months	13.9	4
CAMS 1069	2 years	11.2	5
CAMS 1070	*1 year*	*5.9*	*6*

* Does not include the period where there was no NO_X monitoring

4.1.3 Area and Population Served

Thiessen polygons were created around each NO_X monitor in the San Antonio Region, as well as monitors in adjacent areas whose Thiessen polygons might extend into the region. With only six NO_X monitors in the San Antonio Region, each is expected to have a rather large area served. Figure 4-2 shows the relatively linear arrangement of NO_X monitors across the region.

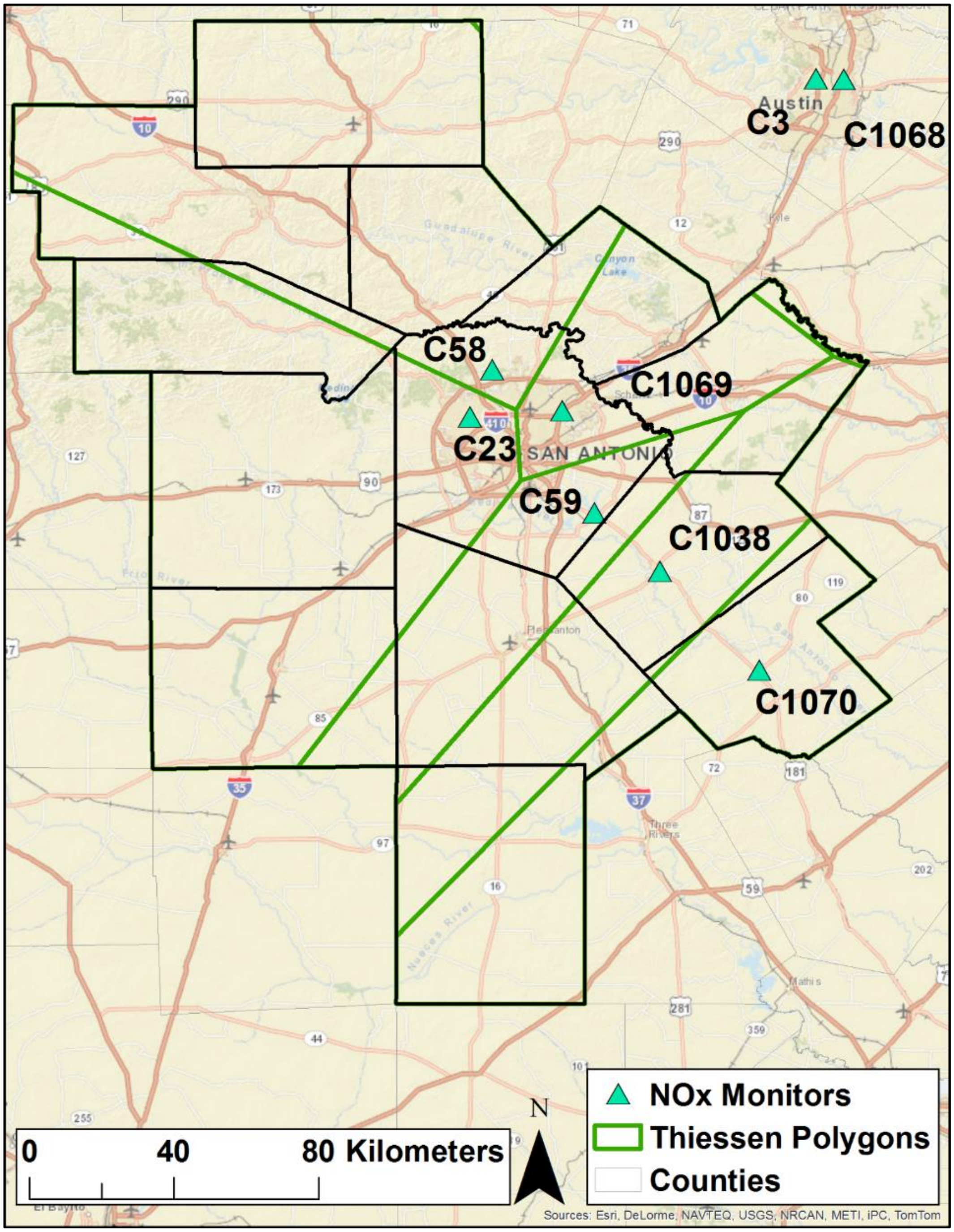


Figure 4-2: Thiessen Polygons Surrounding Area NO_X Monitors

The two monitors on the northwestern periphery of the NO_X monitoring network, CAMS 23 and CAMS 58, cover the largest area served. The area served by CAMS 23 covers most of the western half of the San Antonio urbanized area and thus, has the highest population served. Despite having one of the smallest areas served in the region, the monitor with the second largest population served is near-road NO_X monitor CAMS 1069, whose area of service includes the fast-growing Interstate 35 corridor between San Antonio and New Braunfels. The two Austin-area NO_X monitors (CAMS 3 and CAMS 1068) whose area of service extends into the AACOG area serve 4,392 people in extreme northeastern Guadalupe and Gillespie Counties.

Table 4-4: Population Served by CAMS Sites in and around the San Antonio Region

NO_X Monitor Name	Monitor ID	Population Served (2010)	Rank
San Antonio Northwest	C23	975,287	1
Camp Bullis	C58	316,314	3
Calaveras Lake	C59	160,769	4
Floresville Hospital Boulevard	C1038	34,852	5
San Antonio Interstate 35	C1069	742,407	2
Karnes County Courthouse	C1070	15,672	6
* Austin Northwest	C3	4,266	7
* Austin North Interstate 35	C1068	126	8

* Monitor is located outside of the 13-county AACOG region

Table 4-5: Area Served by CAMS Sites in and around the San Antonio Region

NO_X Monitor Name	Monitor ID	Area Served (km^2)	Rank
San Antonio Northwest	C23	9,679.5	1
Camp Bullis	C58	8,247.6	2
Calaveras Lake	C59	3,207.8	5
Floresville Hospital Boulevard	C1038	4,349.3	3
San Antonio Interstate 35	C1069	2,670.9	6
Karnes County Courthouse	C1070	4,344.4	4
* Austin Northwest	C3	82.2	7
* Austin North Interstate 35	C1068	15.8	8

* Monitor is located outside of the 13-county AACOG region

4.2 Bottom-Up Analysis

The bottom-up analysis technique for the NO_X monitoring network is similar to that of ozone, where HYSPLIT wind trajectories are utilized. In this case, however, forward trajectories are modeled to show where NO_X emissions from major point sources are commonly transported. For this analysis, the top three largest point sources of NO_X were used as the origin point for the forward trajectories. The days chosen for analysis were those between 2013 and 2015 when any monitor in the San Antonio Region recorded an 8-Hour ozone of at least 70 ppb.

4.2.1 Forward Trajectories

The top three largest emitters of NO_X in the San Antonio – New Braunfels MSA are shown in Table 4-6. The largest NO_X emissions come from the Calaveras coal-fired power plant southeast of San Antonio. It is estimated to emit over two-and-a-half times more NO_X in a year than the second-largest NO_X emitter.

Table 4-6: Top Three NO_X Emitters in the San Antonio – New Braunfels MSA (2014)[18]

Operating Entity	Facility or Site	NO_X (tons per year)
City Public Service	Calaveras Plant	6856.6
Alamo Cement Company	1604 Plant	2486.3
San Miguel Electric Cooperative, Inc.	San Miguel Plant	2354.0

The use of forward wind trajectories from large point sources of NO_X will be useful in determining possible locations of new NO_X monitors. If forward trajectories are shown to commonly pass over the same area, it might be beneficial to have a NO_X monitor at that location. Figure 4-3 shows the density of the forward trajectory paths originating from the CPS Calaveras Power Plant. The darker the blue color, the more trajectories that traverse that area. The lightest blue color represents only one trajectory. The map shows that air parcels tend to travel mostly from the point source northeast into Guadalupe County most often. It is also common for air to flow toward the north and southwest from the point source.

[18] Texas Commission on Environmental Quality, 2014. "2014 Point Source Emissions Inventory." Available online: https://www.tceq.texas.gov/assets/public/implementation/air/ie/pseisums/2014statesum.xlsx. Accessed October 7, 2016.

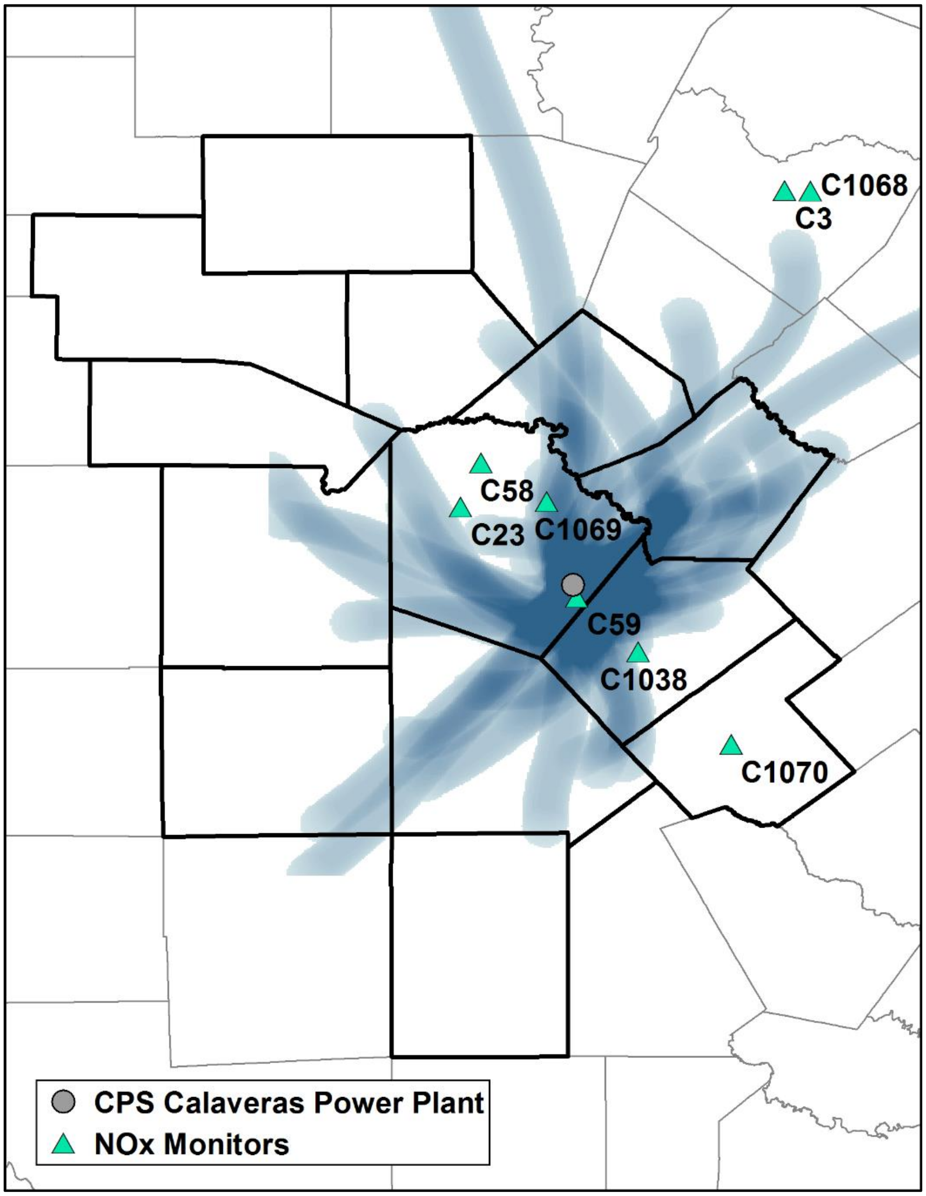


Figure 4-3: Line Density of Forward Trajectories Originating from the CPS Calaveras Power Plant

Forward trajectories were then calculated originating at Alamo Cement's 1604 Plant. A line density map was created using those forward trajectories and can be seen in Figure 4-4. Not surprisingly, the highest line density area extends northeast away from the point source. The area of forward trajectory densities closely resembles those of the Calaveras Plant, although there is less concentration of forward trajectories extending to the southwest.

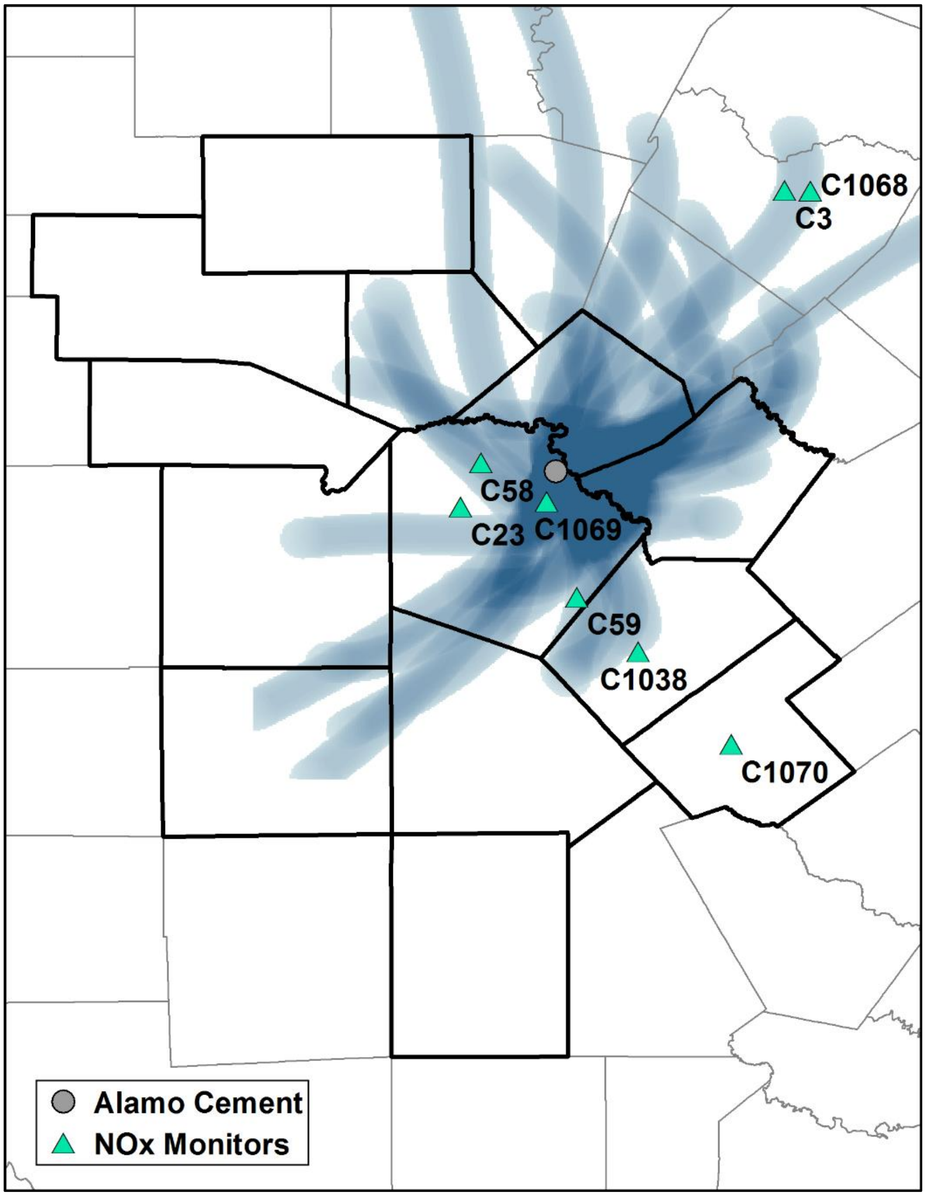


Figure 4-4: Line Density of Forward Trajectories Originating from the Alamo Cement 1604 Plant

A final set of forward trajectories was calculated originating from the San Miguel Power Plant in southern Atascosa County (Figure 4-5). These forward trajectories are a bit different from the previous two in that the heaviest concentration of forward trajectory paths is more evenly distributed around the point source. If there is a dominant wind flow, it appears to be toward the west and north.

To summarize, the dominant wind flow from the two largest point sources of NO_X, the Calaveras Power Plant and Alamo Cement's 1604 Plant, are primarily toward the northeast into Comal and Guadalupe Counties. Without accounting for vertical flow of emissions which might miss being detected by downwind monitors, it might be worth collocating a potential new NO_X monitor with one of the existing ozone monitors in those counties. Another option would be to locate the NO_X monitor in northwestern Atascosa County, where forward trajectories from the Alamo Cement plant and the San Miguel Power Plant are often found. The next section will focus on the totality of NO_X emissions in the San Antonio Region to determine optimal locations for a potential new NO_X monitor.

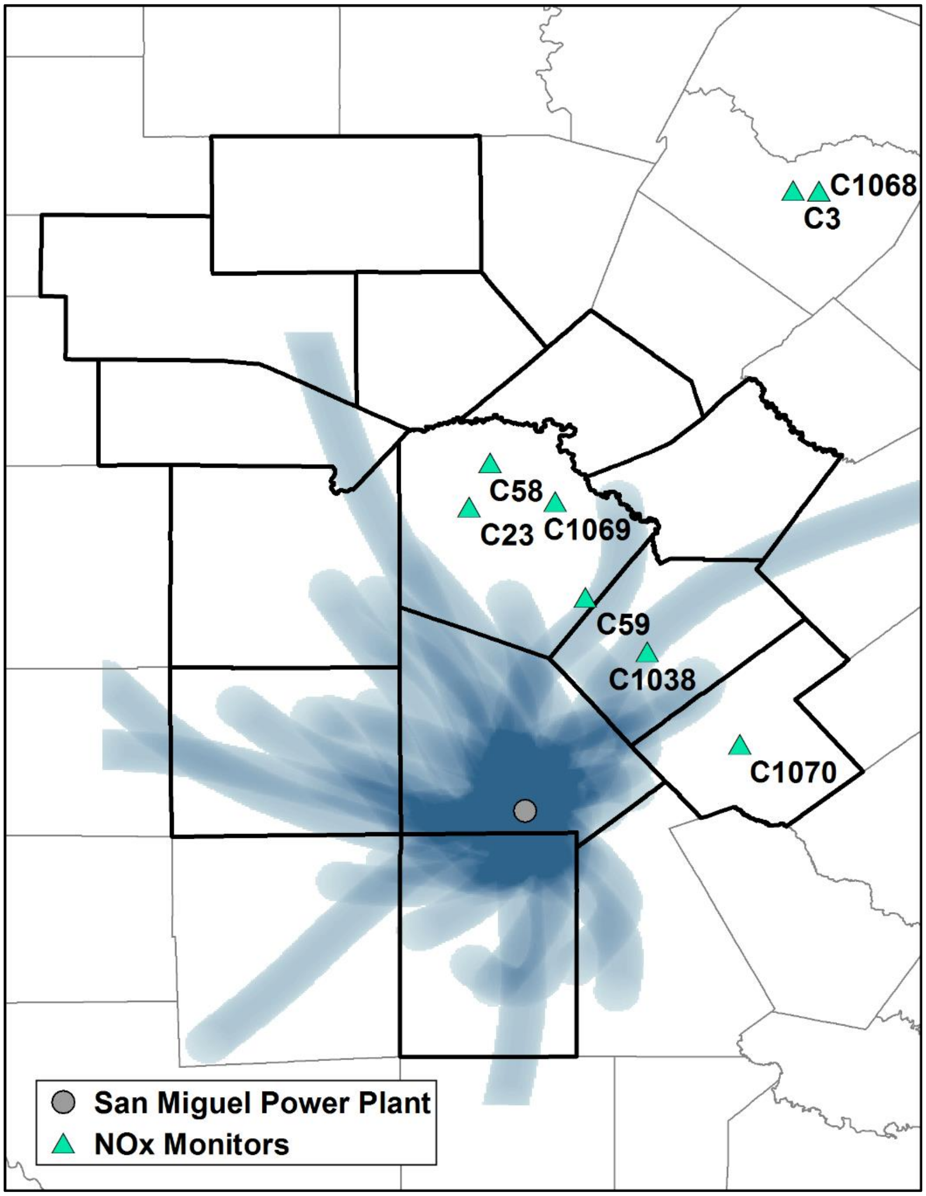


Figure 4-5: Line Density of Forward Trajectories Originating from the San Miguel Power Plant

4.2.2 Emissions Inventory

This analysis technique uses emissions inventory data to determine where the greatest concentrations of pollutants are located. For the purposes of an ozone monitoring network assessment, oxides of nitrogen (NO_X) and volatile organic compounds (VOCs) were chosen as the pollutants of concern.

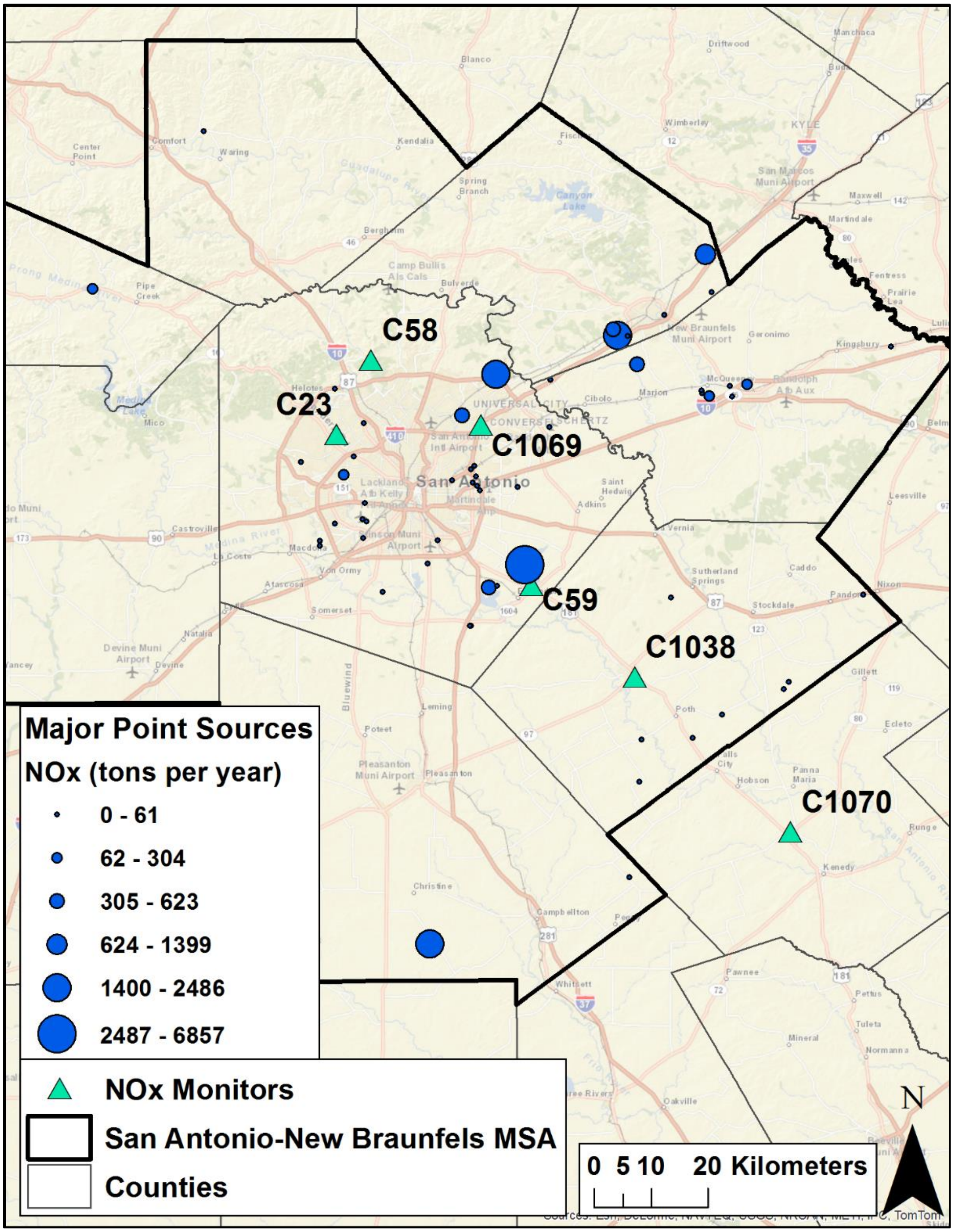


Figure 4-6: Major Point Sources of NO_X in the San Antonio-New Braunfels MSA

Figure 4-6 only includes those “major” point sources as defined by TCEQ that are located within the 8-county San Antonio – New Braunfels Metropolitan Statistical Area (MSA). Most point sources within the MSA are located in Bexar, Comal, Guadalupe, and Wilson Counties. Numerous smaller point sources are scattered about these four counties, but of the larger point sources, most tend to be located along the Interstate 35 corridor northeast of the city of San Antonio. The largest of these are cement and other mineral processing facilities.

Point sources represent a fraction of the total NO_X emissions in the San Antonio Region. Figure 4-7 shows the total NO_X emissions on a county-by-county basis, measured in tons per day. The total NO_X

emissions include the aforementioned point sources, area sources, on-road and off-road sources, and non-road sources. The 13-county AACOG region is shown below in a heavier black outline and surrounding counties are included in the map to account for transport of NO_X into the region. Counties that are darker in color have greater NO_X emissions. The counties along the fast-growing Interstate 35 corridor between Temple and San Antonio can be clearly seen as a line of darker-colored counties extending to the northeast of Bexar County. On those high ozone days where back trajectories come into San Antonio from the northeast, the NO_X emissions from these counties are carried into the region and contribute to high ozone. In Table 4-7, the value of tons per day of NO_X is provided for every county in the AACOG region, as well as any county immediately adjacent to the AACOG boundary. This includes portions of the Austin – Round Rock MSA to the northeast and the Eagle Ford Shale play to the south and east of San Antonio. Of the six counties shown above that have NO_X emissions in excess of 10 tons per day, four are within the San Antonio – New Braunfels MSA.

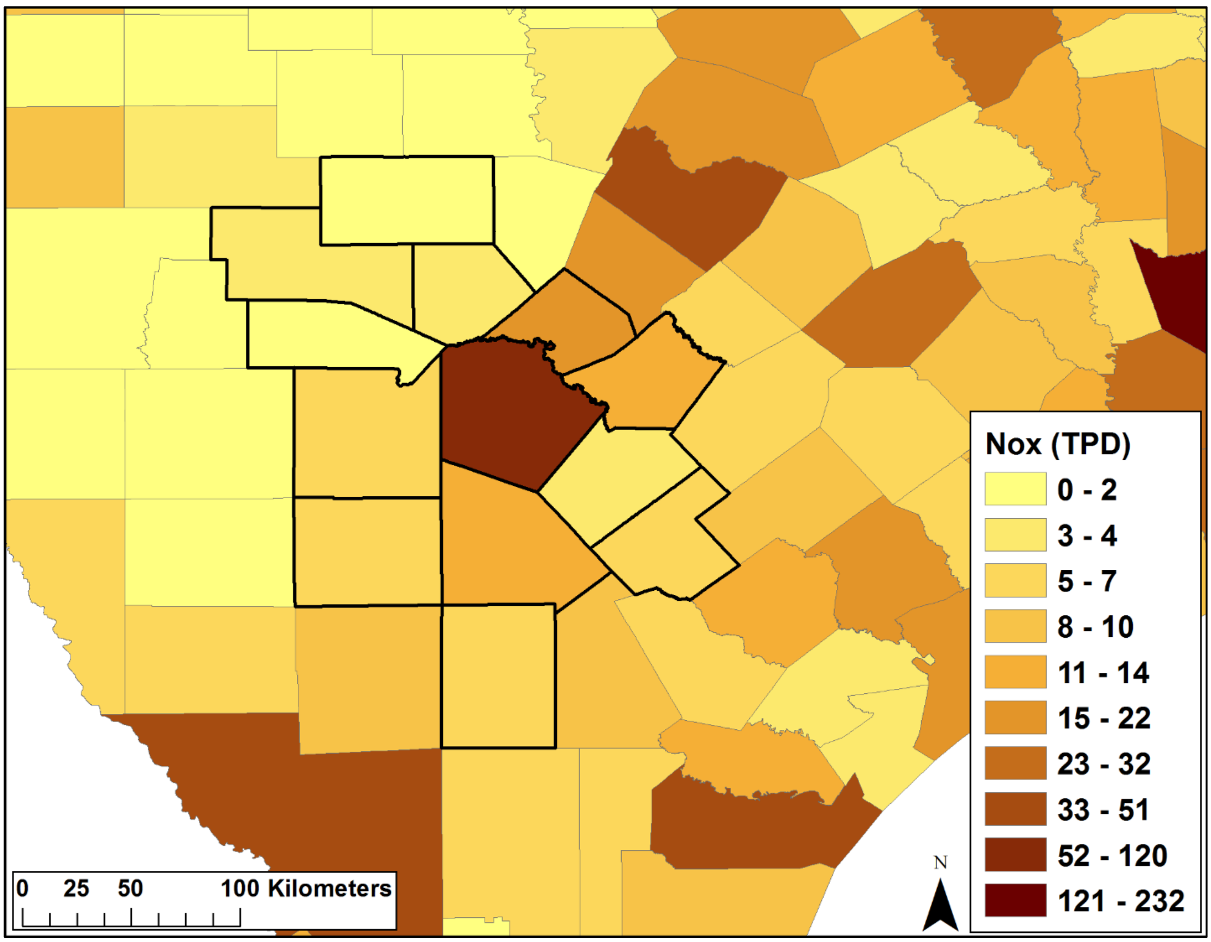


Figure 4-7: Total NO_X Emissions by County, 2012

Table 4-7: Total NO_X Emissions by County in and Surrounding the San Antonio Region

County	NO_X (Tons per Day)
Atascosa	13.22
Bandera	1.75
Bee	4.44
Bexar	105.06
Blanco	1.41
Caldwell	5.11
Comal	17.52
DeWitt	9.48
Duval	4.80
Edwards	1.26
Frio	4.21
Gillespie	1.79
Goliad	10.97
Gonzales	6.09
Guadalupe	11.93

County	NO_X (Tons per Day)
Hays	15.89
Karnes	6.16
Kendall	2.89
Kerr	3.02
Kimble	2.56
Kinney	0.86
Live Oak	8.89
Llano	1.47
Mason	0.41
McMullen	4.41
Medina	4.69
Real	0.42
Uvalde	2.14
Wilson	3.21
Zavala	1.61

At this time there are no plans to begin NO_X monitoring at any new sites in the near future, although there is a NO_X analyzer available for use that is being stored at the CAMS 505 site in Garden Ridge. Should the decision be made to deploy this monitor, a likely location would be on the northeast fringe of the AACOG region, either in Comal or Guadalupe. A NO_X monitor in this area would be ideally suited to record incoming NO_X emissions from the heavily-traveled Interstate 35 corridor during northeasterly wind flow, and also to record NO_X emissions from any of the several cement processing plants that are located in this area under other wind flow regimes. Another likely location for a new NO_X monitor might be in northwestern Atascosa County, where emissions from both the CPS Calaveras Power Plant and the San Miguel Power Plant might be transported, based on forward trajectories.

5 VOLATILE ORGANIC COMPOUNDS (VOC) MONITORING NETWORK

There are four VOC monitors in the AACOG region, which can be seen in Figure 5-2. Three of these, CAMS 58 at Camp Bullis, CAMS 677 at Old Highway 90, and CAMS 1038 in Floresville are located in the MSA, while CAMS 1070 is located in Karnes City outside of the MSA. CAMS 677 does not continuously record VOC concentrations; rather, canister samples are taken every six days, measuring 84 different species. The monitor is positioned such that it records VOCs emitted from automobiles along Highway 90, as well as several large point sources of VOCs on the southeast side of San Antonio. For nearly seven years, this was the only location that monitored VOCs at all. The other three monitors continuously record VOCs using an Automatic Gas Chromatograph (Auto-GC). The first of these, at CAMS 1038, was established in July 2013 to monitor emissions from the Eagle Ford Shale region. This monitor is situated on the western edge of the heaviest extraction activity. In December 2014, CAMS 1070 began operation, in the middle of the activity in the Eagle Ford. In June 2016, an Auto-GC was established at Camp Bullis CAMS 58. The linear spatial nature of the VOC monitors are useful in investigating how VOC concentrations change across the region and what roles major VOC sources, such as Eagle Ford emissions and on-road activity, have in influencing those concentrations.

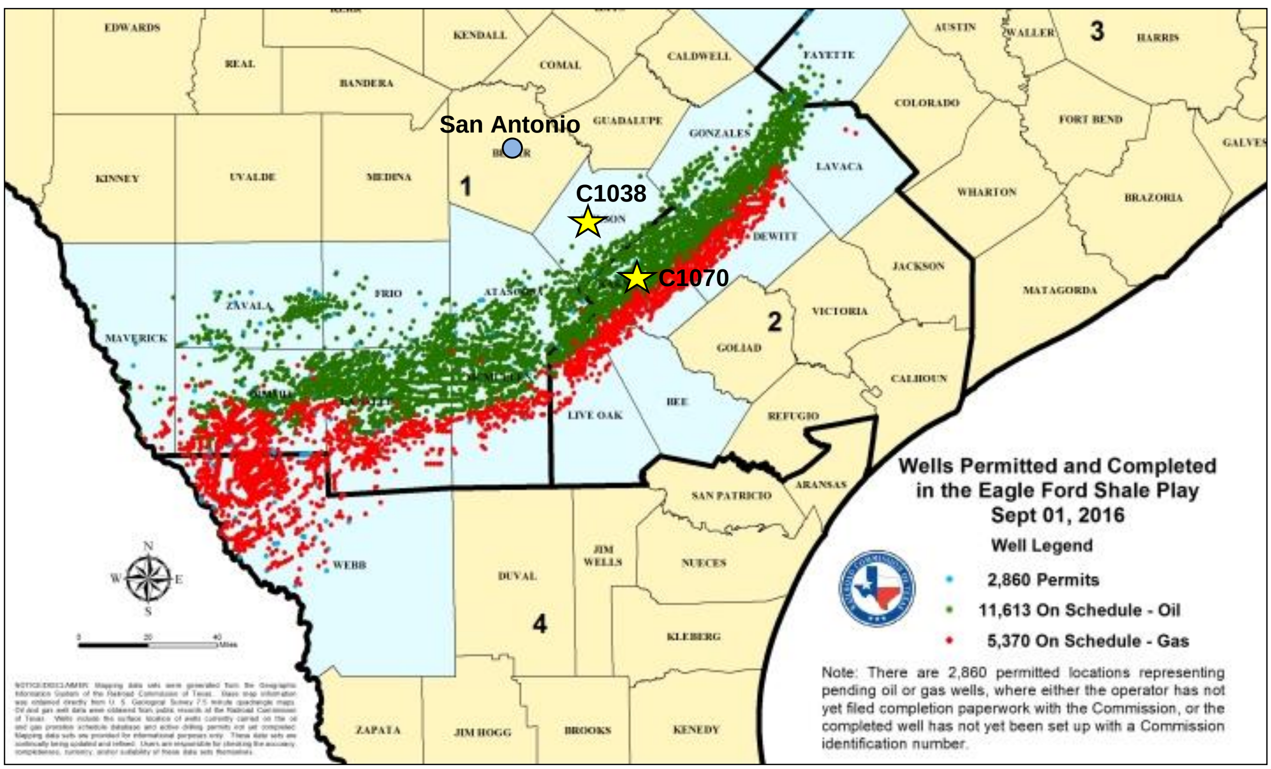


Figure 5-1: Wells Permitted and Completed in the Eagle Ford Shale Play, September 1, 2016, Texas Railroad Commission[19]

The location of the wells associated with Eagle Ford activity relative to the City of San Antonio, CAMS 1038, and CAMS 1070, can be seen in Figure 5-1. CAMS 1070 in Karnes City is clearly seen among some of the heaviest concentrations of oil and gas wells. Under a southeasterly wind flow regime, CAMS 1038 in Floresville is located downwind of the heaviest concentration of oil and gas wells.

[19] http://www.rrc.state.tx.us/media/35250/eaglefordshaleplay2016-09-lg.jpg

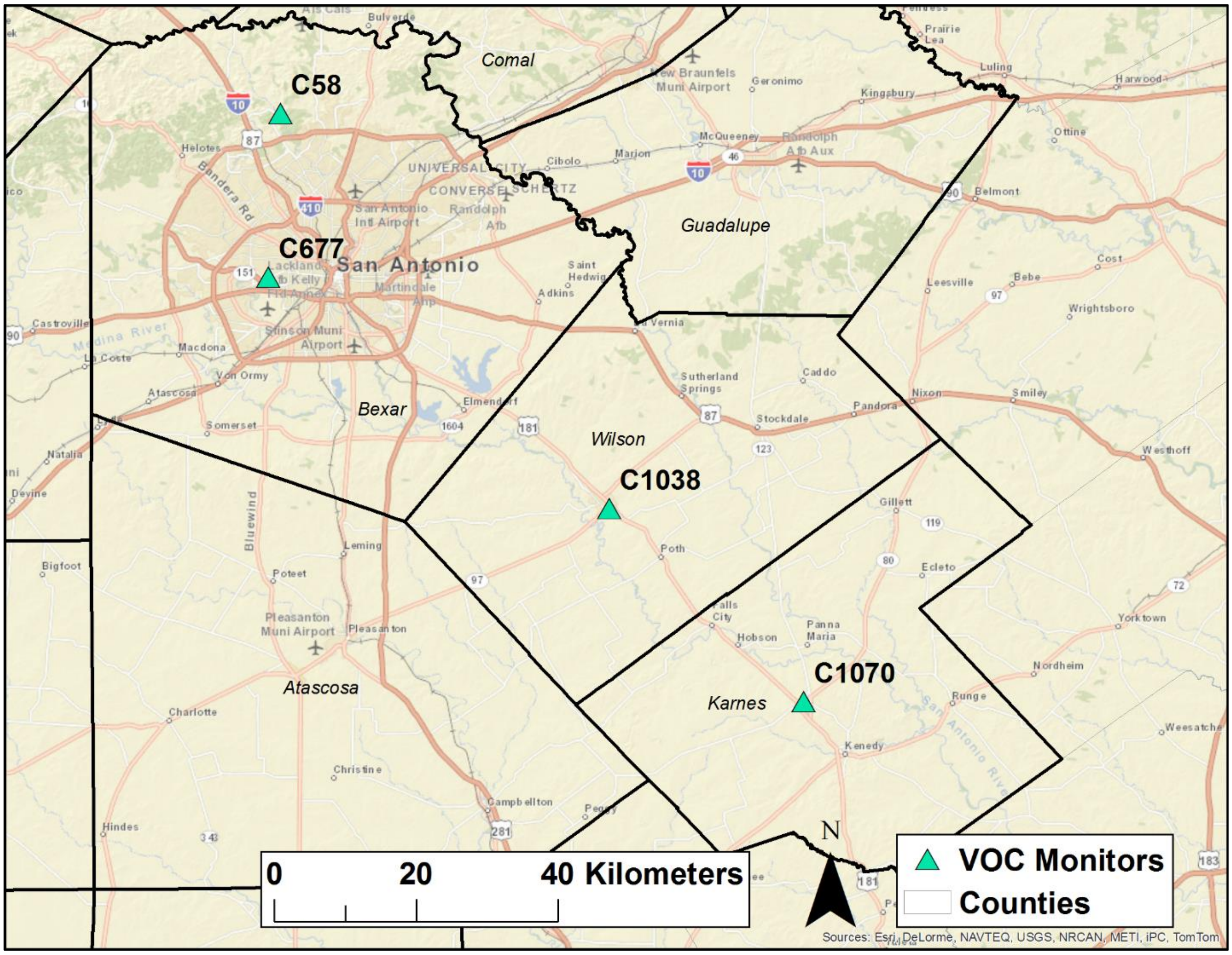


Figure 5-2: VOC Monitors in the San Antonio Region

Table 5-1 provides the start date of VOC monitoring at each CAMS site. As previously mentioned, the canister sampling at CAMS 677 was the first long-term VOC monitoring conducted in the San Antonio Region. Since 2013, Orsat Air Monitoring has deployed three continuous VOC monitors.

Table 5-1: List of VOC Monitors in the San Antonio Region, Locations, Data Measured, and Date/Agency of Operation

Designation / Site Name	Location Description	Data Measured	First date of operation, Currently maintained by
CAMS 58 Camp Bullis	San Antonio, Bexar County	Auto-GC, Ozone, NO_X, Meteorology	June 1, 2016 Orsat and TMSI
CAMS 677 Old Highway 90	San Antonio, Bexar County	Air Toxics, $PM_{2.5}$, Meteorology	October 9, 2006 San Antonio Metro Health District and TCEQ
CAMS 1038 Floresville Hospital Blvd	Floresville, Wilson County	Auto-GC, NO_X, Meteorology	July 17, 2013 Orsat and UTCEER
CAMS 1070 Karnes County Courthouse	Karnes City, Karnes County	Auto-GC, NO_X, Meteorology	December 17, 2014 Orsat

5.1 Site-by-Site Analysis

The site-by-site analysis for the VOC monitoring network will briefly discuss the area and population served by each monitor. There will be no trends analysis or number of parameters monitored assessment because there are only four monitors to analyze, and each monitor has a number of qualities that make them valuable to the overall network. These will be discussed at the end of the section.

5.1.1 Area and Population Served

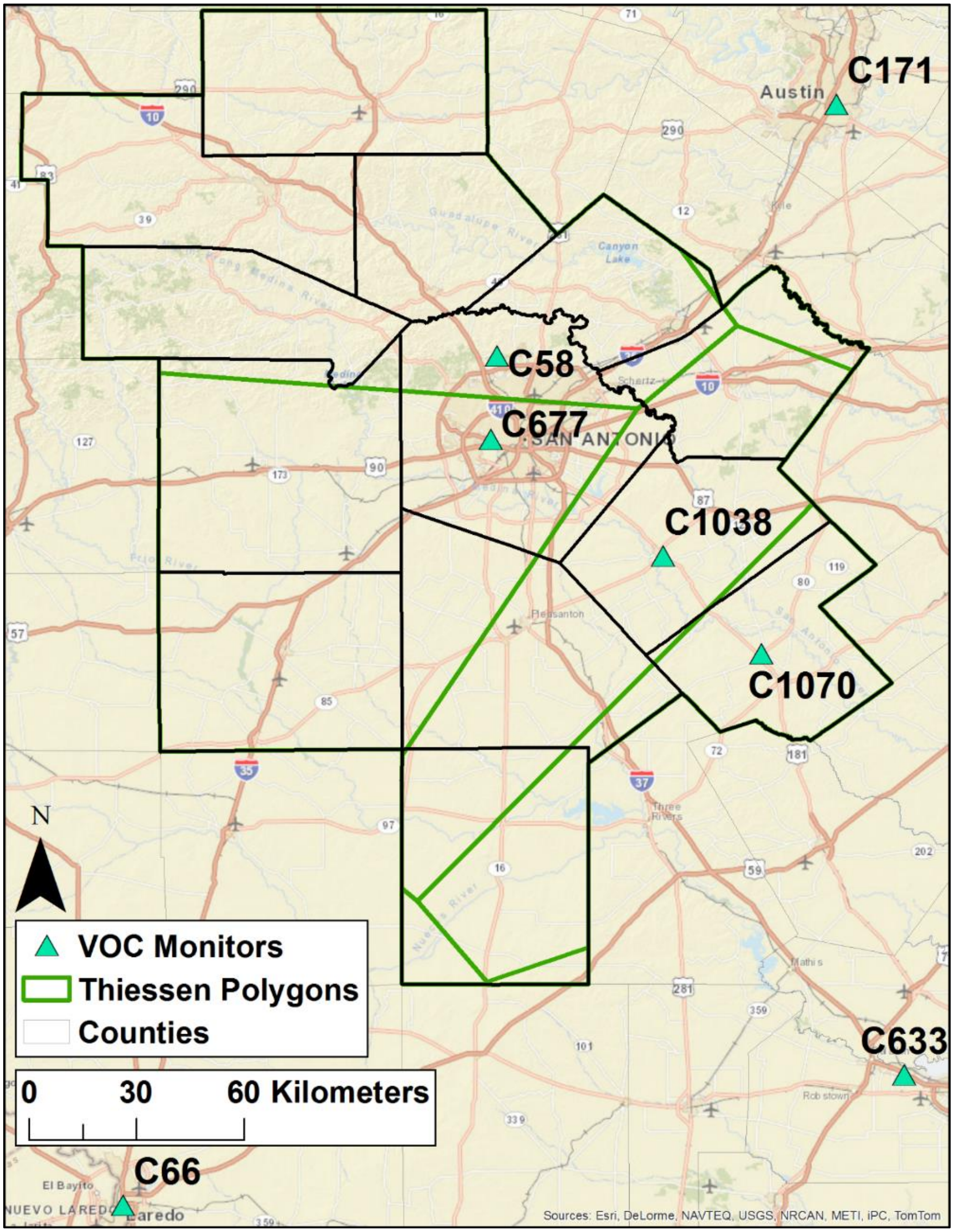


Figure 5-3: Thiessen Polygons Surrounding Area VOC Monitors

The area served of each VOC monitor in and adjacent to the San Antonio Region is shown in Figure 5-3. There are three VOC monitors that have a service area that extends into the AACOG area: one is in Austin, one is in Laredo, and the other is in Corpus Christi. Only one, CAMS 633 in Corpus Christi, is equipped with an Auto-GC. CAMS 66 in Laredo and CAMS 171 in Austin perform canister samples of VOCs every six days. These three monitors account for 849.1 km^2 and serve 9,175 people in the AACOG region.

Of the VOC monitors within the San Antonio Region, the one with the largest area served is CAMS 58 at Camp Bullis. It covers over 3500 km^2 more than the next-largest area served, CAMS 677. Although CAMS 58 serves a larger area, much of it is rural, and only the top third of Bexar County is covered by this monitor. CAMS 677 covers much of the rest of Bexar County and has the largest population served with well over a million people. The list of monitors and the area they serve is found in Table 5-3. The population served is in Table 5-2.

Table 5-2: Population Served by CAMS Sites in and around the San Antonio Region

VOC Monitor Name	Monitor ID	Population Served (2010)	Rank
Camp Bullis	C58	858,594	2
Old Highway 90	C677	1,234,511	1
Floresville Hospital Blvd.	C1038	131,757	3
Karnes County Courthouse	C1070	15,656	4
Laredo Bridge	C66	5	7
Austin Webberville Rd.	C171	9,159	5
Solar Estates	C633	11	6

Table 5-3: Area Served by CAMS Sites in and around the San Antonio Region

VOC Monitor Name	Monitor ID	Area Served (km^2)	Rank
Camp Bullis	C58	12,585.3	1
Old Highway 90	C677	8,975.7	2
Floresville Hospital Blvd.	C1038	6,263.5	3
Karnes County Courthouse	C1070	3,923.8	4
Laredo Bridge	C66	298.1	6
Austin Webberville Rd.	C171	414.1	5
Solar Estates	C633	136.9	7

The area and population served analysis shows the Auto-GC at CAMS 1070 as ranking last in the San Antonio Region, suggesting that it is not as important as the other three. With only four VOC monitors deployed throughout the entire 13-county AACOG region, there is no need to decommission any. The Auto-GC at CAMS 1070, as mentioned earlier, is situated in the most heavily-developed part of the Eagle Ford Shale. The observations taken here may help to verify emissions inventories of oil and gas production sites in this region. It also might shed some light on the degree of transport of these emissions in conjunction with the other Auto-GC at CAMS 1038 in Floresville. The canister sampling at CAMS 677, although not continuous like the other three, still provides a valuable period of record spanning over ten years. By contrast, the Auto-GC at CAMS 58 has very little historical record, but its collocation with NO_X and ozone monitoring will be quite valuable in assessing the ozone forming regime (NO_X or VOC limited) in that area.

5.2 Bottom-Up Analysis

The bottom-up analysis for VOC monitors does not contain a forward trajectory assessment due to the similarity in trajectory densities seen at different point sources in the NO_X monitor chapter. Additionally, ozone in the San Antonio Region forms under a NO_X-limited regime, meaning changes in NO_X concentrations have a greater effect on ozone formation than changes in VOCs.

5.2.1 Emissions Inventory

The map of major point sources of VOCs in Figure 5-4 shows a wider geographic distribution than that for NO_X. Many larger point sources of VOCs (73 tons per year or greater) are situated on an axis spreading from northeast of the city down through the southwest side of town, while many large point sources of NO_X were concentrated northeast of San Antonio with some isolated large point sources southeast of town and one far removed to the south of the city. Also of note is the line of point sources on the southeastern edge of Wilson County south and east of CAMS 1038. This represents the edge of the Eagle Ford Shale region.

A broader look at VOC emissions in Figure 5-5 shows the greater concentration of those emissions in the counties that contain oil and gas activity. Bexar County has the largest VOC emissions of any in the AACOG region and adjacent counties. Karnes County has the second largest VOC emissions and is in the center of the heaviest Eagle Ford oil and gas activity. The exact amount of VOC emissions for AACOG counties and those adjacent to the AACOG area can be seen in Table 5-4.

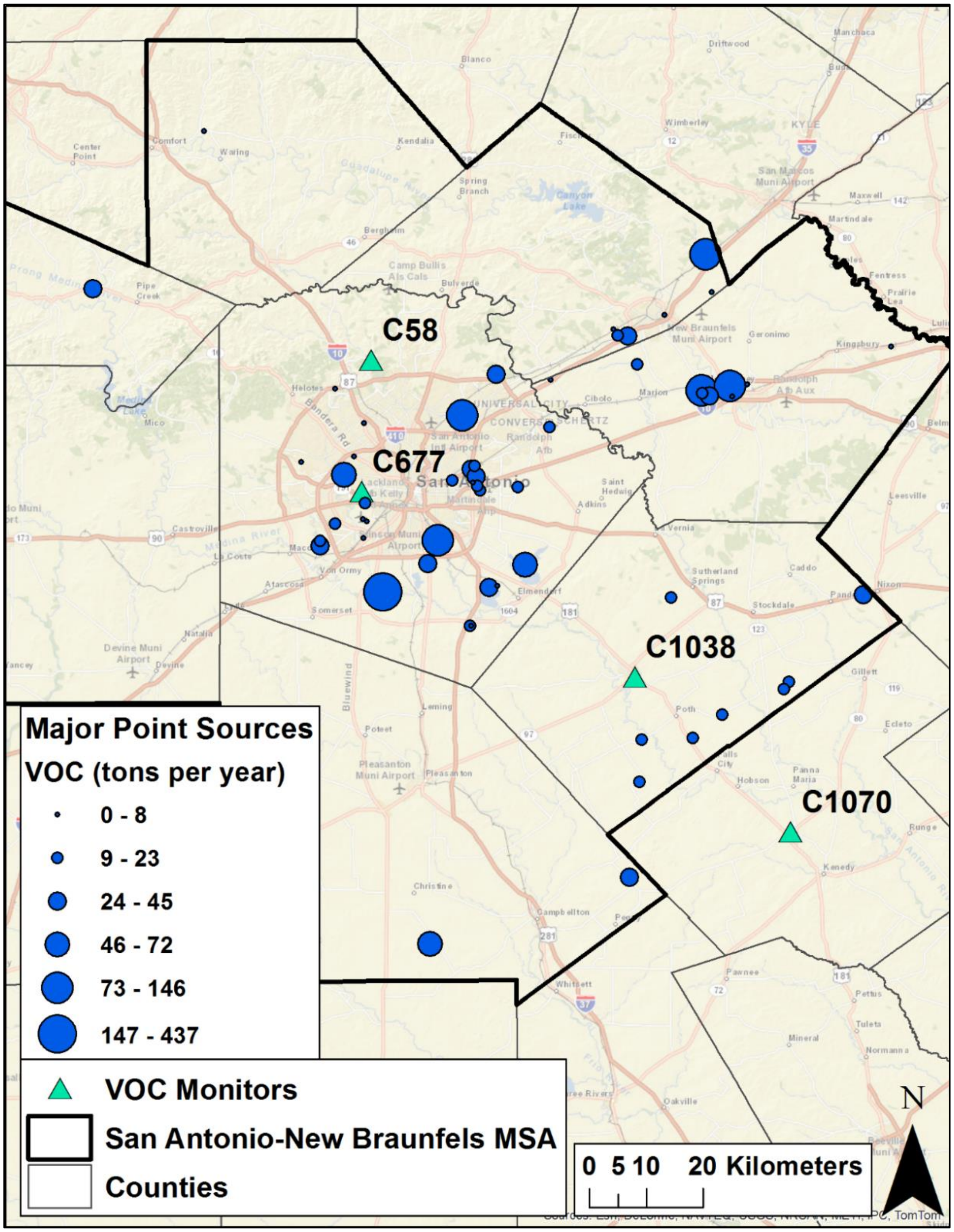


Figure 5-4: Major Point Sources of VOCs in the San Antonio-New Braunfels MSA

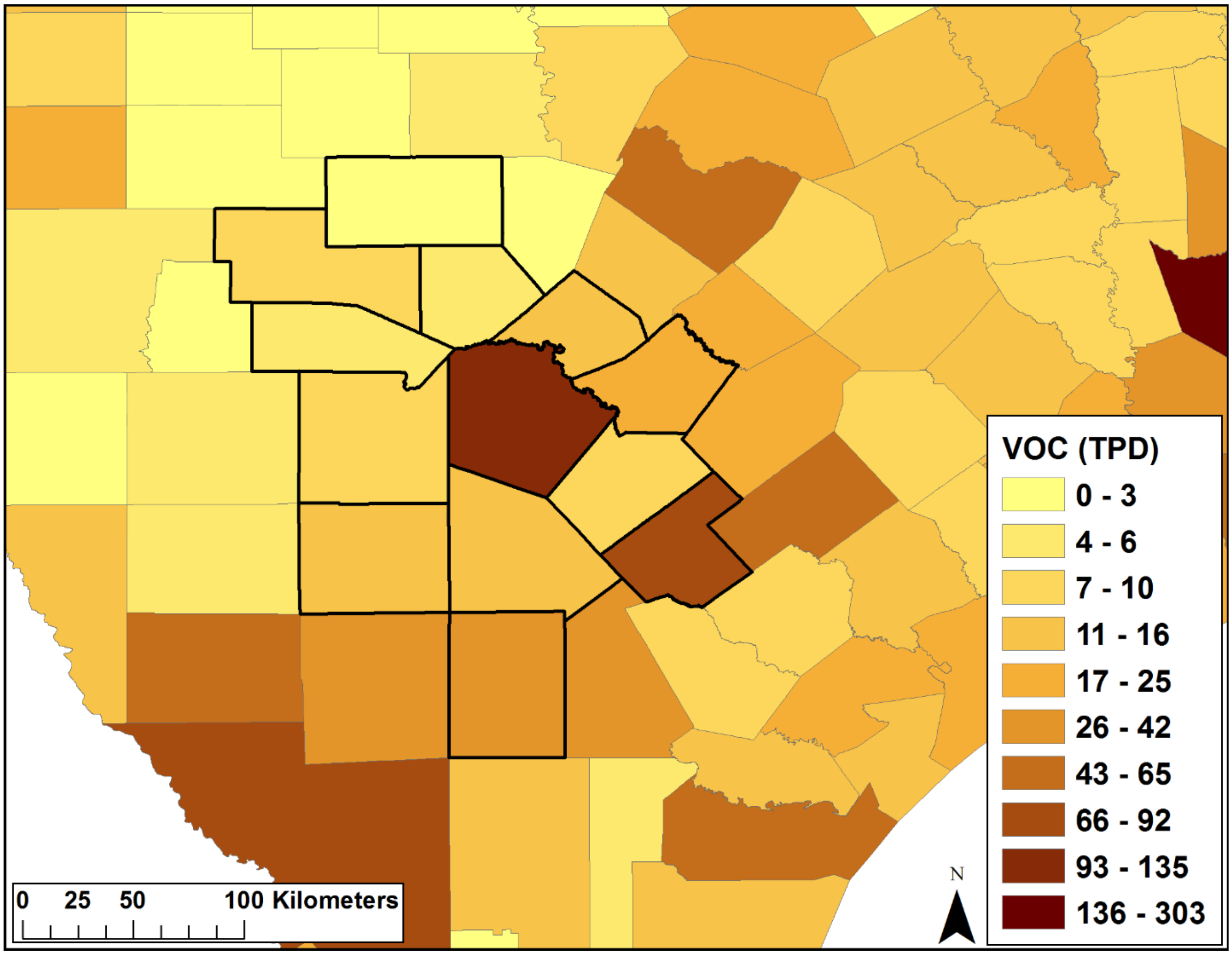


Figure 5-5: Total VOC Emissions by County, 2012

Table 5-4: Total VOC Emissions by County in and Surrounding the San Antonio Region

County	VOC (Tons per Day)	County	VOC (Tons per Day)
Atascosa	16.06	**Hays**	10.55
Bandera	3.92	**Karnes**	67.50
Bee	8.54	**Kendall**	4.48
Bexar	113.20	**Kerr**	6.86
Blanco	2.24	**Kimble**	1.82
Caldwell	19.33	**Kinney**	0.98
Comal	11.15	**Live Oak**	28.07
DeWitt	57.38	**Llano**	4.00
Duval	10.55	**Mason**	1.46
Edwards	3.64	**McMullen**	28.31
Frio	10.86	**Medina**	9.33
Gillespie	2.99	**Real**	1.39
Goliad	7.08	**Uvalde**	4.64
Gonzales	24.50	**Wilson**	10.23
Guadalupe	22.38	**Zavala**	5.03

Due to budget constraints, there are no plans to begin VOC monitoring anywhere in the AACOG region through the year 2017. Over the years, there have been mobile monitoring and temporary monitoring projects in the Eagle Ford Shale area in 2014 and in Somerset in 1998. At this time, the VOC monitoring network is deemed sufficient.

6 RESULTS AND RECOMMENDATIONS

The results from the Network Design Analysis will be used to determine the need for additional monitoring of ozone, meteorology, NO_X, and VOCs, as well as investigate which monitors, if any, are redundant and may be relocated or removed from the network altogether. The following are AACOGs recommendations for changes to the regional monitoring network.

6.1 Existing Monitoring Network

The quantitative methods used in this analysis suggest that, among ozone monitors, there appears to be some redundancy in the network to the east and south of San Antonio. The summary of site-by-site analysis scores is shown in Table 6-1, with their rankings shown in Table 6-2. CAMS 506 in Seguin consistently ranks as one of the least useful ozone monitors in the entire network and the least useful of the monitors owned by AACOG. It doesn't record any other parameters besides ozone, it has one of the lowest three-year averages, and is the newest among AACOG-owned sites. In addition, that monitor is highly correlated with CAMS 504 in New Braunfels, and these two monitors have the lowest average removal bias of any AACOG monitor. However, the evidence for keeping these two monitors in the network outweighs the rankings given in the site-by-site analysis. First, CAMS 506 commonly measures incoming air quality, before the influence of local emissions sources. This explains why it has the lowest three-year average for ozone. Second, this monitor serves a large area in the eastern portion of the AACOG region. If it were to be removed, a large section of the AACOG region would be underserved. Finally, although the average removal bias for CAMS 506 is relatively low, there are two days in which it has the second-highest removal bias, making it highly necessary for the interpolation of regional ozone on some days. Another monitor that had characteristics of redundancy according to EPA guidance was CAMS 622. However, since this monitor is owned by CPS, it is not being considered for removal from the network at this time. According to the summary of site-by-site analysis methods, CAMS 502 at Fair Oaks Ranch is the most useful of the non-regulatory ozone monitors. As was mentioned earlier in the report, the site conditions at that location do not meet basic criteria defined by the EPA, and as a result, the monitor must be relocated. It is the goal of AACOG to relocate the CAMS 502 monitor to a more suitable location as close as possible to its existing location.

Table 6-1: Site-by-Site Analysis Score Summary for Ozone Monitors (High values in bold, low values in italics)

Monitor	SITE-BY-SITE ANALYSIS SCORES							
	Number of Parameters	Trend Impact	Measured Conc.	Population Served	Area Served	All Days Correl. Score	>70 ppb Correl. Score	Average Score
C23	30.5	**100.0**	69.2	**100.0**	9.2	15.2	75.7	**57.1**
C58	**100.0**	50.4	**100.0**	29.9	3.0	18.2	78.6	54.3
C59	33.9	51.1	7.7	14.5	55.7	16.4	68.4	35.4
C501	13.6	39.3	30.8	28.0	**100.0**	18.1	78.2	44.0
C502	13.6	39.2	46.2	22.9	90.3	**22.2**	**83.2**	45.4
C503	*1.7*	38.7	46.2	11.2	11.1	18.8	78.7	29.5
C504	23.7	38.7	7.7	12.9	6.5	14.9	69.3	24.8
C505	*1.7*	37.0	30.8	37.0	8.5	15.9	76.6	29.6
C506	*1.7*	37.0	*0.0*	7.8	19.7	15.1	68.5	*21.4*
C622	16.9	*33.1*	38.5	*4.8*	*4.4*	16.1	70.8	26.4
C678	13.6	48.7	38.5	87.6	5.3	*13.8*	*67.3*	39.3

Table 6-2: Site-by-Site Analysis Rankings Summary for Ozone Monitors (High values in bold, low values in italics)

Monitor	SITE-BY-SITE ANALYSIS RANKINGS							
	Number of Parameters	**Trend Impact**	**Measured Conc.**	**Population Served**	**Area Served**	**All Days Correl. Score**	**>70 ppb Correl. Score**	**Average Score**
C23	3	**1**	2	**1**	6	8	6	**1**
C58	**1**	3	**1**	4	*11*	3	3	2
C59	2	2	9	7	3	5	10	6
C501	6	5	7	5	**1**	4	4	4
C502	6	6	3	6	2	**1**	**1**	3
C503	*9*	7	3	9	5	2	2	8
C504	4	7	9	8	8	10	8	10
C505	*9*	9	7	3	7	7	5	7
C506	*9*	9	*11*	10	4	9	9	*11*
C622	5	*11*	5	*11*	10	6	7	9
C678	6	4	5	2	9	*11*	*11*	5

6.2 Potential Locations of New Monitors

The bottom-up analysis techniques explained in Section 2.2 help determine locations for new ozone monitors. The back trajectory analysis tends to reveal ideal locations for ozone monitors designed to sample incoming ozone into the San Antonio Region. Photochemical modeling results are useful in determining where monitors should go to record higher levels of ozone, downwind of most precursor emissions sources. The back trajectory analysis for ozone monitors suggests that there is a monitoring gap due south of San Antonio where incoming ozone levels may not be adequately captured. Results from photochemical modeling of both the June 2006 and June 2012 episodes often show a broad plume of elevated ozone levels extending southwest into central Medina County and to the west toward Bandera County near Medina Lake.

The extreme northwest corner of Bexar County is another priority for a new ozone monitor based on photochemical modeling results that show up to five ozone exceedances in that area for both the June 2006 and June 2012 modeling episodes. Having a monitor in this area, in conjunction with the aforementioned proposed monitor adjacent to Medina County, will greatly reduce the area served of existing CAMS 501 and CAMS 502. The two proposed ozone monitors in western Bexar County should be useful in interpolating ozone concentrations as they will be situated between the two existing monitors with the highest average removal bias. The third new ozone monitor recommendation is due south of San Antonio in southern Bexar County. The locations of the proposed ozone monitoring sites are shown in Figure 6-1. There are primary recommendations and secondary recommendations. The primary recommendations are the top priority for inclusion into the ozone monitoring network and are explained above. The secondary recommendations are not intended to be immediately used as monitoring sites, but might be considered in the future with additional funding or partnerships with other organizations. As mentioned in Section 1.4, there is enough equipment to begin meteorological monitoring at one ozone site. AACOG proposes this equipment to be deployed at either of the two primary proposed ozone monitoring sites in western Bexar County.

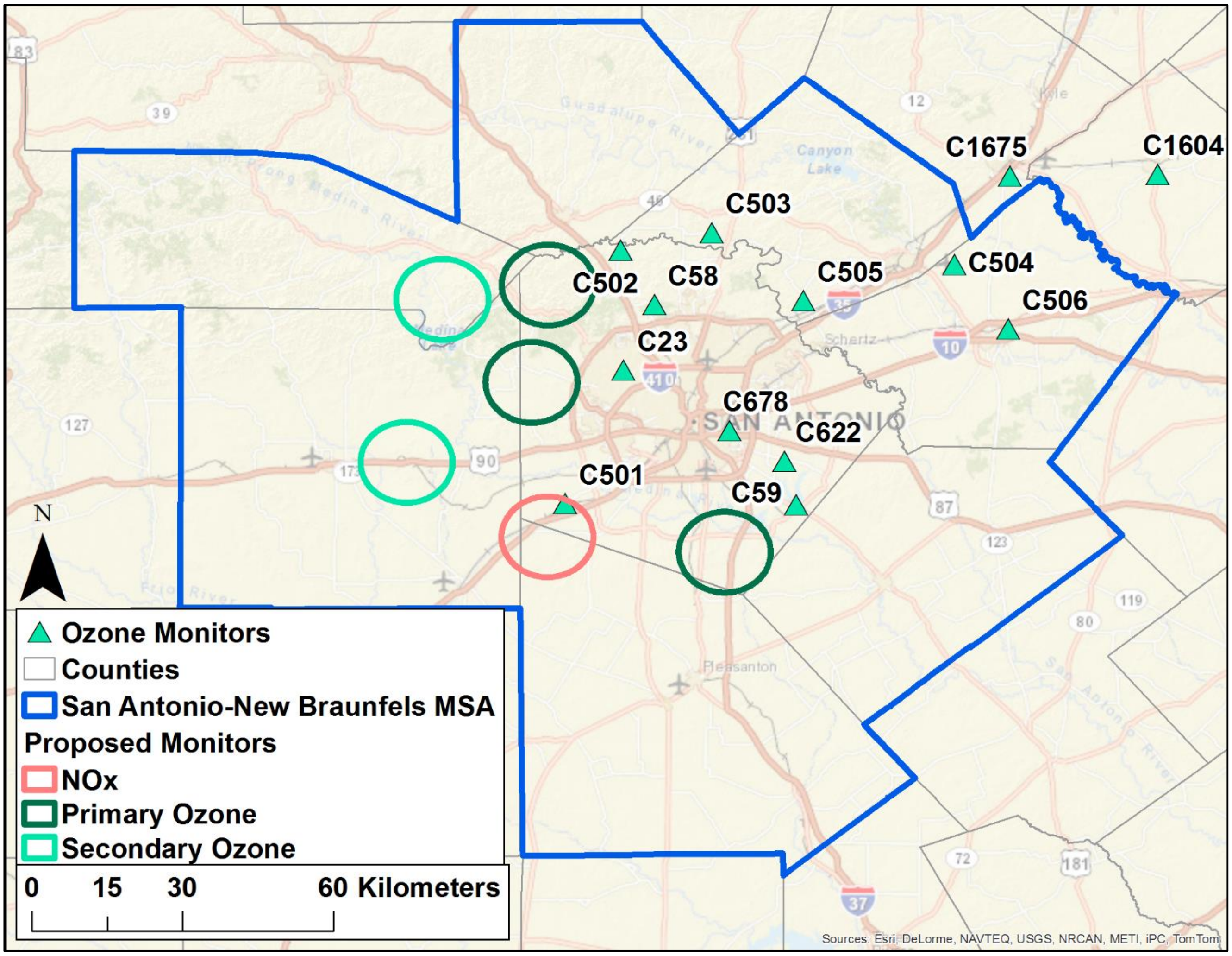


Figure 6-1: Locations of Proposed Ozone Monitors

The recommendation for the NO_X and VOC monitoring networks is to leave them unchanged for the near future due to budget constraints. In the event AACOG does decide to deploy the NO_X monitor currently being stored at the Garden Ridge ozone site, the analyses included in this report will be used to determine the most ideal location. To expand the VOC monitoring network will require a much greater investment of funds in order to purchase an Auto-GC or conduct regular canister sampling. Moreover, with photochemical modeling results indicating a NO_X-limited ozone forming regime, additional VOC monitoring is deemed unnecessary at this time.

7 QUALITY ASSURANCE FINDINGS

An internal quality assurance audit of the Network Design Analysis draft report produced the following findings and recommendations:

- Indicate in the list of ozone monitors (Table 2-1) whether each one is regulatory or non-regulatory,
- Fix the legend and scale bar fonts on maps to make them the same size as the document text,
- Include the rank of each monitor in the site-by-site analysis result tables,
- Include regulatory ozone monitors in Table 2-7 and Table 2-8,
- Provide a summary table of all site-by-site analysis ranks for ozone monitors (Table 6-2),
- Adjust Figure 6-1 to show that a proposed NO_X monitor might be located at CAMS 501,
- Provide clarity in wording. For example, instead of evaluating the “value” of a monitor, we evaluate the “usefulness” of a monitor,
- Provide clarity in sentence structure,
- Use active voice, rather than passive voice,
- Do not use “above” or “below” when referring to tables or figures,
- Maintain consistency in formatting. For example, the items in
-
-
- Table 1-7 were not numbered, while the items in other tables in that section were numbered, and
- Number and provide captions for equations.

All internal staff recommendations were implemented in the draft report. Calculations of parameter score were verified. Some calculations were off by one decimal place due to rounding issues. This was especially true in Table 2-3, where values in the Duration of Operation column were rounded to the nearest month.

The Network Design Analysis draft report was submitted to TCEQ on December 20, 2016. Comments from TCEQ on the draft report were received by AACOG staff on January 27, 2017. There were no comments on the content of the report or the methodology of the analysis, but rather on the formatting of the report. There were three instances where figures and tables themselves were included in the figure or table references in the report. Page breaks were included in figure and table references on two other occasions. These errors caused figures, tables, or page breaks to be inserted in the middle of a paragraph just preceding the figure or table reference.

Other comments from TCEQ included defining the acronyms NO_X and VOC in the abstract and in the executive summary, as well as applying a heading style for figure and table captions. All recommendations from TCEQ have been applied to the final report.