Heart of Texas Council of Governments

July 18, 2014

Ms. Laura Bunte
Ozone Advance
Mail Code C304-01
U.S. EPA, Office of Air Quality Planning and Standards
109 TW Alexander Drive
Research Triangle Park, NC 27711

Dear Ms. Bunte,

Attached, please find the Ozone Advance Action Plan developed by the Heart of Texas Council of Governments Air Quality Advisory Committee (HOTCOG AQAC) for the Waco area and surrounding counties. Since its founding in 2010, the HOTCOG AQAC has made vigorous efforts to identify the causes of high ozone in the HOTCOG counties and to develop measures to reduce local emissions of ozone precursors. The Action Plan outlines our conceptual model of ozone in the HOTCOG counties and the steps we are taking to reduce ozone levels in our area.

We look forward to continuing to work with the EPA and the Texas Commission on Environmental Quality to maintain clean air in the Heart of Texas. If you have further questions, please contact Falen Bohannon, Air Quality Planner for the HOTCOG, at 254-292-1870 or Falen.Bohannon@hot.cog.tx.us . I may also be reached at 254-292-1825 or by email at Russell.Devorsky@hot.cog.tx.us.

Sincerely,

Russell Devorsky
Executive Director
Heart of Texas Council of Governments

Cc: Carrie Paige, EPA Region VI

Heart of Texas Council of Governments Ozone Advance Action Plan

Prepared for:
Falen Bohannon
Heart of Texas Council of Governments
1514 South New Road
Waco, TX, 76711

Prepared by:
Sue Kemball-Cook and Greg Yarwood
ENVIRON International Corporation
773 San Marin Drive, Suite 2115
Novato, California, 94998
www.environcorp.com
P-415-899-0700
F-415-899-0707

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The Heart of Texas Council of Governments (HOTCOG) is participating in the U.S. EPA's Ozone Advance Program on behalf of the region surrounding Waco, TX. HOTCOG represents the six Texas counties of McLennan, Bosque, Hill, Falls, Limestone and Freestone. The ozone design value for the area is 72 ppb, measured in Waco, which attains the current National Ambient Air Quality Standard (NAAQS) for ozone.

Under the Clean Air Act, the EPA is required to review the NAAQS periodically. EPA's next review of the ozone standard is scheduled to be completed in late 2014. Throughout the Obama Administration, the EPA has suggested that it will consider setting a revised standard in the range 60-70 ppb. If this were to occur, the HOTCOG area would be out of compliance based on current data. Because failure to comply with the NAAQS can adversely affect public health and inhibit economic development, ozone air quality planning is critical for the HOTCOG area.

Ozone forms in the atmosphere from emissions of ozone precursors, namely nitrogen oxides (NOx) and volatile organic compounds (VOCs.) High ozone in the HOTCOG area typically occurs on days when local temperatures exceed 90°F, wind speeds are low, and wind directions range between north-northeasterly clockwise through south-southeasterly. These wind directions are favorable for transport of polluted air masses of continental origin into the HOTCOG area. High ozone days in the HOTCOG area are generally characterized by high background ozone levels plus a far smaller contribution from local emissions sources. Although the ozone contribution from local sources is relatively small, ozone reductions are possible via reductions in local ozone precursor emissions.

The HOTCOG area's NOx emission inventory is dominated by emissions from power plants, motor vehicles, and oil and gas exploration and production. The contribution to VOC emissions from biogenic sources such as trees and other vegetation far exceeds the contribution from human activities. The abundance of biogenic VOC ensures that there is always enough VOC available to form ozone so that the amount of ozone formed is determined by the amount of NOx emissions. HOTCOG's analyses of the area NOx and VOC emission inventories, photochemical modeling and comparison of weekday/weekend NOx and ozone are all consistent in showing that ozone formation in the HOTCOG 6-county area is limited by the amount of available NOx. Therefore, local emission control strategies are focused on reducing NOx.

In 2010, the HOTCOG Air Quality Advisory Committee (AQAC) was formed in response to the Waco area's inclusion in the Texas Rider 8 Program for ozone Near Nonattainment Areas. The AQAC includes representatives from local government, industry, the TCEQ, EPA, and private citizens. The AQAC has worked vigorously to study local ozone air quality and to develop voluntary programs that improve air quality while protecting the regional economy. The AQAC is implementing the following measures and programs in order to reduce ozone in the HOTCOG area:

- Engine exhaust catalyst retrofits of gas compressors used in natural gas production
- Retrofit/replacement of municipal fleet heavy-duty diesel engines
- Bicycle parking rack installation with monitoring to document utilization
- Public outreach activities including:
    - Public web site with ozone air quality forecasts, information on ozone and specific actions citizens can take to improve air quality as well as contact information for citizens who would like to become more involved in addressing local air quality issues
    - Facebook page on ozone air quality that provides high ozone day alerts and actions citizens can take to reduce ozone
    - Air quality-themed signage for public buses

As part of its participation in the EPA's Ozone Advance Program, HOTCOG has prepared an Ozone Action Plan. The Action Plan summarizes our understanding of ozone formation in the HOTCOG area and outlines measures being taken to reduce local ozone levels. The schedule for implementation of each measure/program is provided as well as the means of verification of emissions reductions, where applicable.

1.0 INTRODUCTION

The Heart of Texas Council of Governments (HOTCOG) is participating in the U.S. EPA's Ozone Advance Program on behalf of the region surrounding the Waco, TX area. HOTCOG represents the 6-county area consisting of McLennan, Bosque, Hill, Falls, Limestone and Freestone Counties and is an organization of local governments working together voluntarily to solve mutual problems and plan for the future of the area. HOTCOG has over 80 member governments made up of counties, cities, school districts, community colleges, and special districts, and was established in 1966. HOTCOG's responsibilities include:

- Planning for area development,
- Implementing regional plans or recommendations,
- Contracting with members to provide certain services,
- Providing review and comment on proposals seeking federal and state financial assistance,
- Implementing grant services from federal and state programs, and
- Administrative and fiscal agent for the Heart of Texas Workforce Development Board.

More information on HOTCOG may be found at http://www.hotcog.org/default.aspx.

As part of its participation in Ozone Advance, HOTCOG is providing this Ozone Action Plan. The Action Plan gives an overview of ozone air quality and describes the 6-county HOTCOG region (Section 1), summarizes our understanding of ozone formation in the HOTCOG area (Section 2) and outlines measures being taken to reduce 6-county area ozone levels (Sections 3 and 4). In Section 2, we discuss the emission inventory of ozone precursors and summarize analyses of ambient monitoring data and photochemical modeling that informed the selection of emissions control strategies. Stakeholder involvement is discussed in Section 3. Finally, in Section 4, we describe the emissions reductions measures and/or programs that have been and will be implemented in the 6-county area. The schedule for implementation of each measure/program is shown as well as the responsible party and means of verification of emissions reductions, where applicable. Plans described in this Ozone Action Plan are effective through August, 2015.

1.1 Ozone Air Quality: Background

Ozone is the main ingredient in photochemical smog. Ozone affects human lung function, increasing the prevalence and severity of asthma and bronchitis, and damages vegetation. The U.S. EPA sets a National Ambient Air Quality Standard (NAAQS) for ozone in order to protect public health and the environment. The NAAQS is based on health impacts for sensitive groups and there are economic penalties for areas that fail to attain it.

The NAAQS is currently set at 75 parts per billion (ppb). Ozone measurements made at the Waco Mazanec ozone monitoring station determine whether the HOTCOG area is in compliance with the NAAQS. In 2011, the HOTCOG area was designated as being in attainment of the

NAAQS. Based on current data, the Waco monitor is close to the NAAQS (72 ppb) but remains in compliance.

Under the Clean Air Act, the EPA is required to review the NAAQS periodically. EPA's next review of the ozone standard is scheduled to be completed in late 2014. Throughout the Obama Administration, EPA has suggested that it will consider setting a revised standard in the range 60-70 ppb. If this were to occur, the Waco monitor will be out of compliance based on current data. Because failure to comply with the NAAQS can adversely affect public health and inhibit economic development, ozone air quality planning is critical for the HOTCOG area.

Ozone is not emitted directly into the atmosphere, but forms from nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the presence of sunlight. NOx and VOCs are emitted by both natural processes and human activities. Conditions that favor the formation of ground-level ozone are strong sunlight, high temperatures, and high precursor (NOx and VOC) concentrations. High precursor concentrations in the atmosphere occur when emissions are large and/or weather conditions allow precursors to accumulate. When winds are calm and the atmosphere is stable, emitted precursors do not disperse and are available for ozone formation. On the other hand, if the atmosphere is unstable, ozone and precursors can be transported aloft away from the ground, and if winds are brisk, emitted pollutants are transported away from the area so that ozone does not build up.

Ozone is removed from the atmosphere by chemical reactions, photolysis (destruction by sunlight), deposition onto surfaces and uptake by plants. Ozone has a lifetime of several days to weeks at ground level; this lifetime is long enough to allow ozone to be transported thousands of miles. At any given location, therefore, measured ozone is partly due to a contribution from local emissions and partly due to transported ozone, which is often referred to as background ozone. High background ozone exacerbates local ozone problems, but is not a necessary condition for an area to have high ozone. Ozone problems solely from transport can occur, but are rare.

In order to reduce ozone in a given area, the ozone problem must be studied to determine the relative importance of local emissions and transported ozone. Photochemical modeling is used to assess the magnitude of the local and transported contributions. Regional and national emissions control measures such as the Federal vehicle emissions standards aim to reduce the contribution from transported ozone. If local ozone precursor emissions are shown to contribute to ozone levels, then local emissions control measures can be developed. The Ozone Advance Program was developed to assist areas in developing local emissions control strategies designed to reduce ozone.

1.2 Waco and the Heart of Texas Region

The HOTCOG area lies on the central Texas plain between the major metropolitan areas of Dallas-Fort Worth to the north and Austin to the south. A map of the area is shown in Figure 1-1. The six HOTCOG counties together occupy an area of 5,611 sq. miles. The region is relatively flat, with the highest terrain reaching a height of approximately 300-400 meters. Two major interstate highways, I-35 and I-45, pass through the area. These highways connect the Dallas-Fort Worth area with Austin and Houston to the south and are major thoroughfares.

The population in the HOTCOG area is concentrated in the City of Waco. There are smaller towns throughout the area (Figure 2-1), but much of the area in all 6 counties is rural land. U.S. Census data for 2013 (https://www.tsl.state.tx.us/ref/abouttx/popcnty2010-11.html;

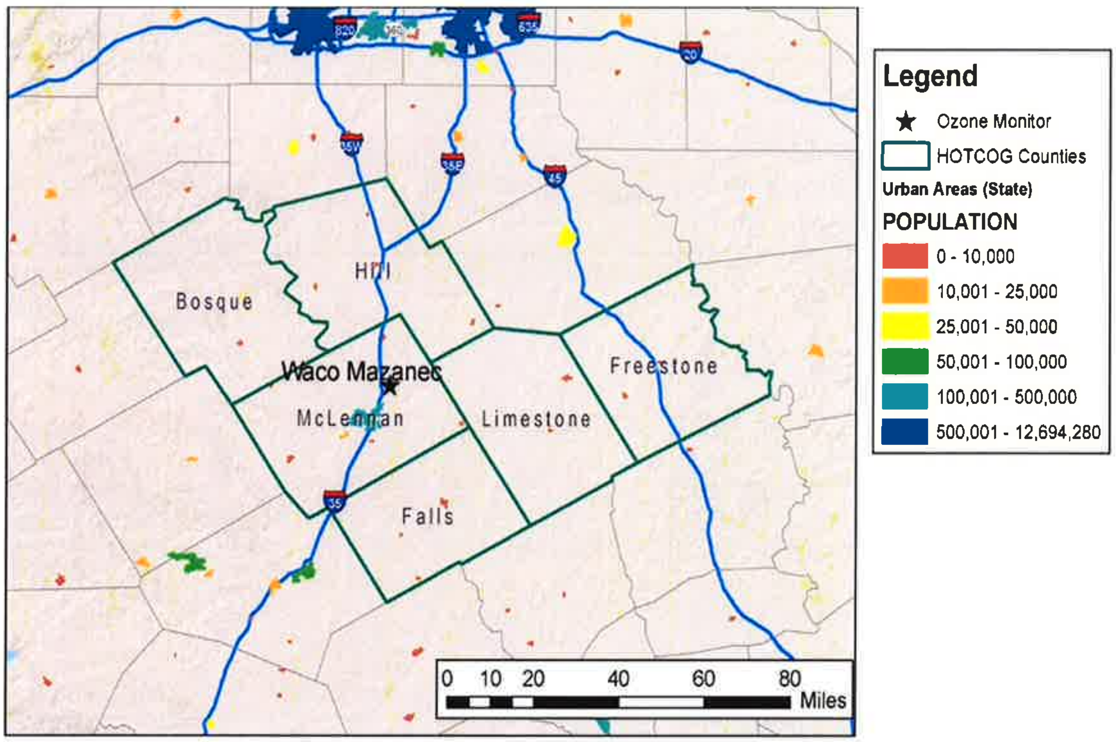


Figure 1-1. Waco Mazanec (CAMS 1037) monitor location. Black star indicates location of the Waco Mazanec ozone monitor. Urban areas are shaded and color indicates population as of 2012. HOTCOG 6-county area is outlined in green.

Figure 1-2) indicate that McLennan County had a population of 241,481 which is 68% of the population of the entire HOTCOG 6-county area (354,624). During the period 2000-2010, all of the HOTCOG counties saw moderate (6-11%) growth in population except for Falls County, which saw a slight decrease in population (-4%) (Figure 1-3).

Figure 1-3 shows that urban areas to the north, south, southeast and southwest of the HOTCOG counties saw significant (>20%) growth in population from 2000 to 2010. The Dallas-Fort Worth, Houston, San Antonio and Austin areas all had two or more counties with >40% growth and these areas are frequently upwind of the HOTCOG area on high ozone days (see Section 2 and McGaughey et al., 2010a; 2012).

The HOTCOG area overlies productive oil and natural gas fields. There are a large number of natural gas wells in Limestone and Freestone County that access conventional natural gas reservoirs, while Hill County marks the southernmost extent of the Barnett Shale natural gas development. There is also oil production in McLennan County, but the number of oil wells is relatively small.

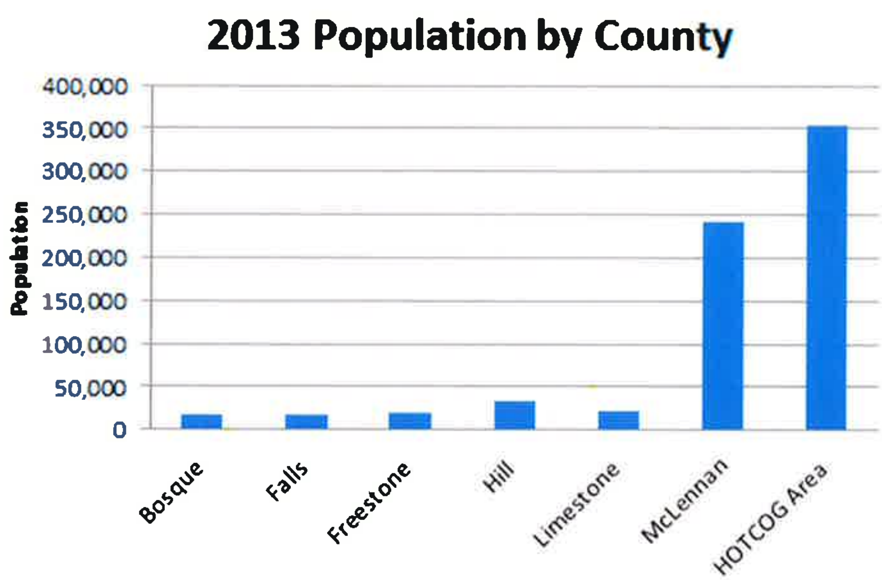


Figure 1-2. Population of HOTCOG Area Counties for 2013 based on U.S. Census data from http://quickfacts.census.gov/qfd/states/48/48309.html.

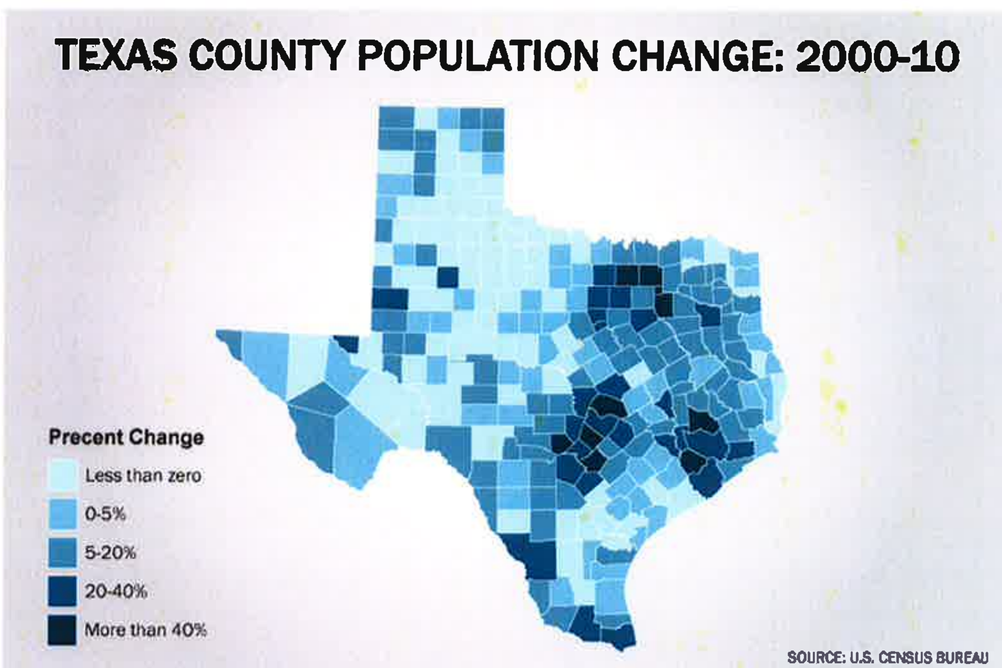


Figure 1-3. Texas population growth from 2000-2010. Figure from Texas Tribune based on U.S. Census data. http://www.texastribune.org/library/data/census-2010/.

2.0 CONCEPTUAL MODEL OF OZONE FORMATION IN THE HOTCOG AREA

The purpose of the Conceptual Model is to provide a basis of understanding of ozone in the Waco region to provide a foundation for all ozone air quality planning activities. EPA guidance on modeled attainment demonstrations and analyses for ozone (EPA, 2007) indicates that one of the first activities to be completed in ozone air quality planning is the formulation of a "conceptual model" that qualitatively describes ozone formation mechanisms and provides a rationale for selection of episodes to be modeled. EPA (2007) specifies that the key components of the conceptual model are analyses of air quality, meteorological and emissions data. Through these analyses, relationships between weather conditions and high ozone events may be established, important emissions sources and trends may be identified, and periods of high ozone suitable for modeling may be selected. Ozone modeling may be used to shed light on the causes of high ozone events as well as the likely effectiveness of proposed control strategies. This section summarizes the conceptual model of ozone formation in the HOTCOG area (McGaughey et al., 2010a; 2012) and describes results of recent analyses of air quality, emissions and meteorological data and trends.

2.1 Attainment Status and Recent Ozone Trends

The Texas Commission on Environmental Quality (TCEQ) operates a Continuous Air Monitoring Stations (CAMS) at the Waco Airport in McLennan County. The location of this station, known as the Waco Mazanec monitor (CAMS 1037) is shown in Figure 2-1. The Waco Mazanec monitor is located northeast of the Waco metropolitan area in McLennan County. At the Waco site, the following measurements are made on a routine basis: meteorological data (winds, temperature, etc.), ozone, oxides of nitrogen, carbon monoxide, sulfur dioxide, and fine particulates ($PM_{2.5}$). These quantities are reported to the TCEQ's automated reporting system on an hourly basis. The Waco Mazanec site began operating in April, 2007, and has always monitored attainment of the NAAQS.

Figure 2-2 shows recent trends in 4th highest daily maximum 8-hour average ozone values (MDA8) and 8-hour ozone design values at the Waco Mazanec monitor. The Waco Mazanec monitor's design value has remained fairly constant since 2007-2009, ranging between 70-72 ppb until the 2011-2013 period, when the design value rose to 74 ppb. The lack of a pronounced downward trend in the HOTCOG area design value taken together with the potential for a more stringent NAAQS in the near future underscore the importance of air quality planning in the HOTCOG area.

Figure 2-3 shows the number of days with MDA8≥75 ppb at the Waco monitor for each year from 2009-2013. 2011 had the largest number of high ozone days as well as the highest value of the 4th high MDA8 (Figure 2-2). The hottest summer ever recorded in Texas ocurred in 2011[1] and hot weather is conducive to ozone formation. The seasonal variation of high ozone days at the Waco monitor is shown in Figure 2-4 and Figure 2-5. The Waco monitor had the largest

[1] http://www.ncdc.noaa.gov/sotc/national/2011/8

number of high ozone days during the August-September period during the years 2009-2013. The monitor also saw high ozone days in June and July, but a smaller number than during the months of August-October. There were no high ozone days recorded in May or October.

The number of high ozone days by day of week for the Waco monitor is shown in Figure 2-6 and Figure 2-7. Figure 2-6 shows the raw count of number of high ozone days for each day of week at each monitor, and Figure 2-7 shows the number of high ozone days by weekend day versus weekday. In Figure 2-7, the number of days in each category is normalized to give equal weight to weekend and weekday days. The total number of weekdays at each monitor is divided by 5 and the total number of weekend days is divided by 2. Figure 2-6 and Figure 2-7 indicate that the Waco monitor has more high ozone days on weekdays than on weekends. This suggests the importance of vehicle emissions in contributing to local ozone, since vehicle activity is generally reaches its peak values during weekday commuting hours.

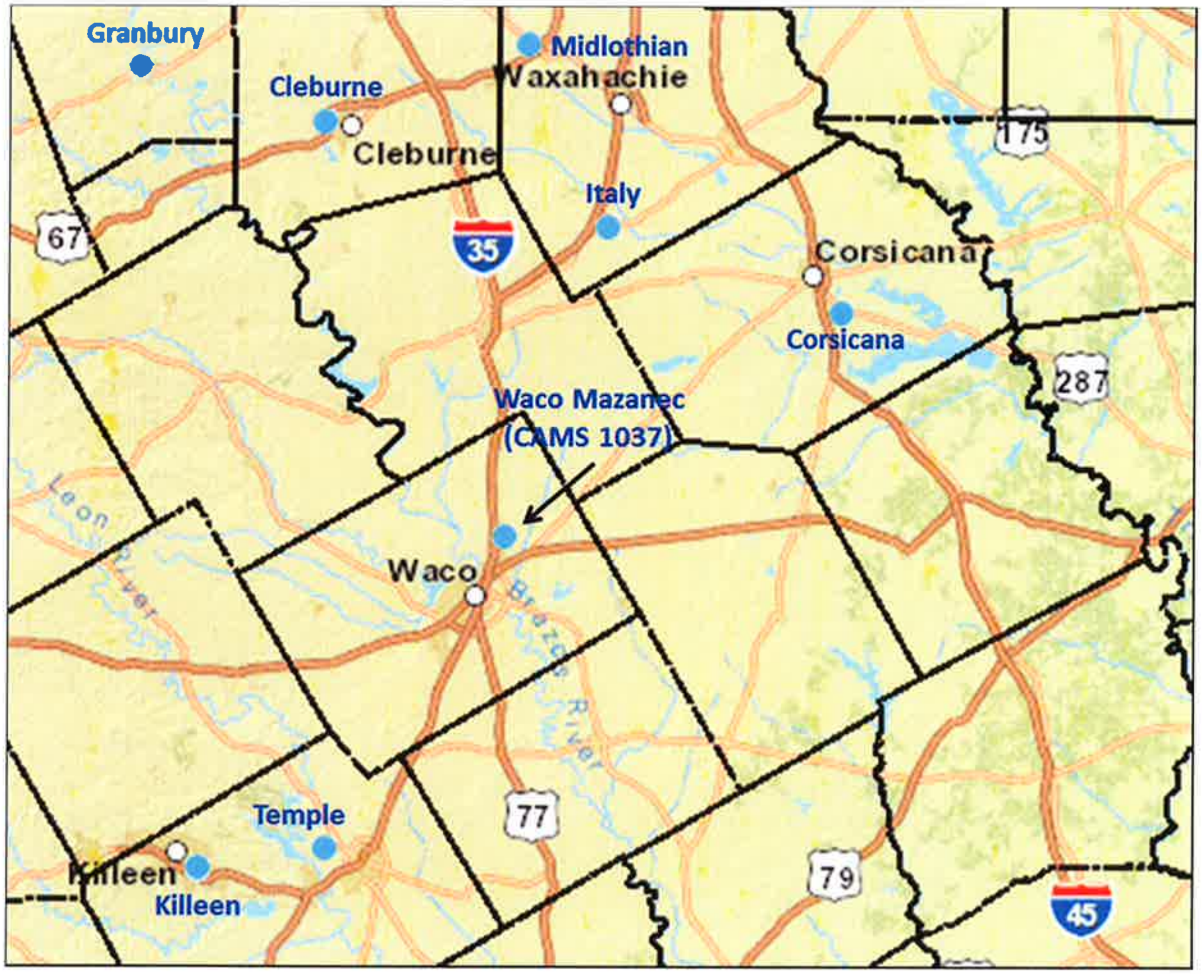
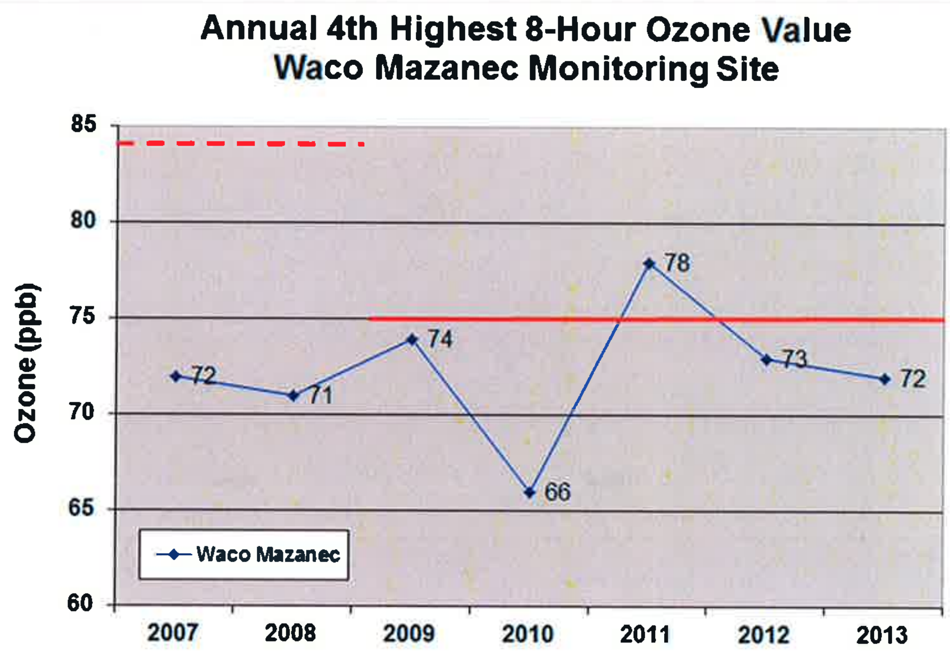


Figure 2-1. Waco Mazanec CAMS monitor location. Adaptation of TCEQ figure from http://gis3.tceq.state.tx.us/geotam/index.html, accessed December 15, 2013. Blue circles indicate the locations of ozone monitors.



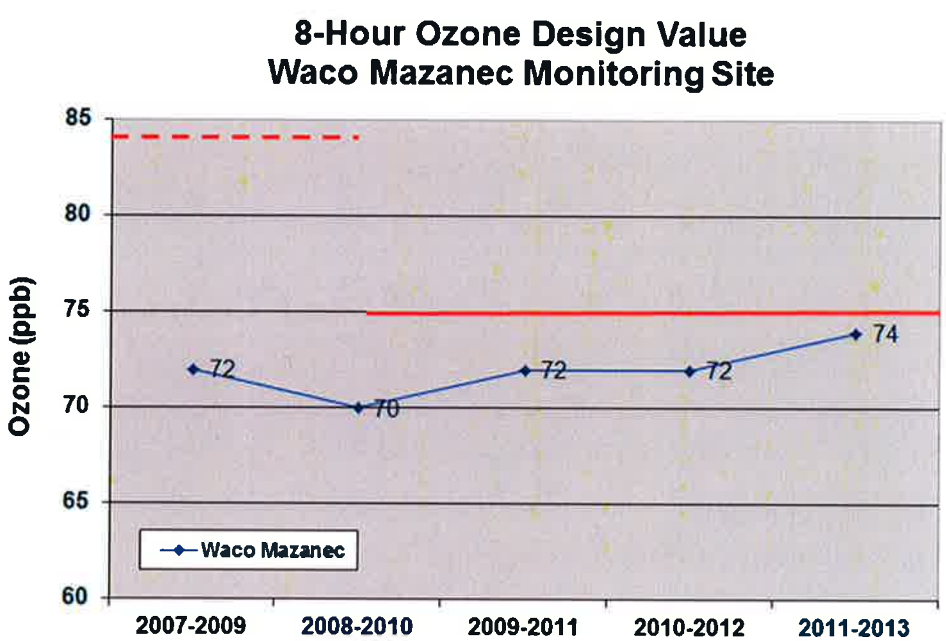


Figure 2-2. Trends in annual 4th highest daily maximum 8-hour ozone values (upper panel) and design values (lower panel) at the Waco Mazanec monitors in McLennan County. The dashed red line indicates the 1996 84 ppb standard and the solid red line shows the 2008 75 ppb ozone standard. All data have been validated by the TCEQ.

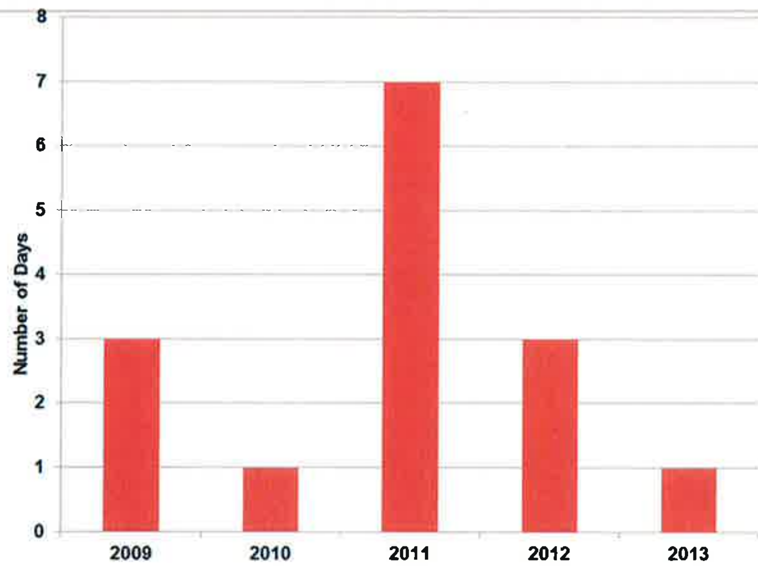


Figure 2-3. Number of days with MDA8≥75 ppb at the Waco (CAMS 1037) monitor.

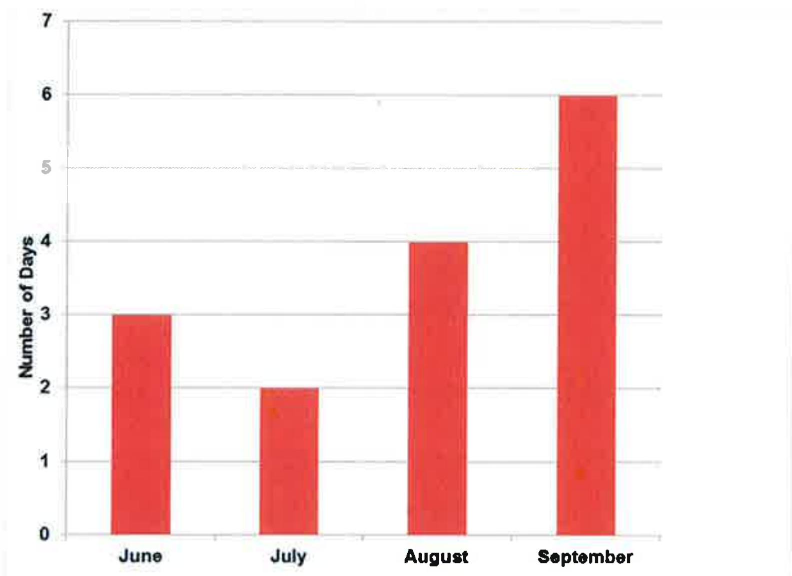


Figure 2-4. Number of days during each month with MDA8≥75 ppb at the Waco monitor during the period 2009-2013.

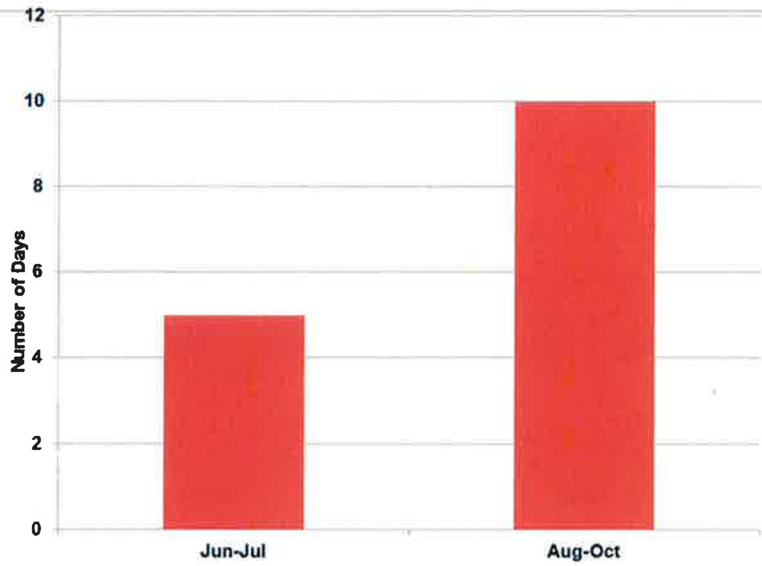


Figure 2-5. Number of days during June-July and August-October periods with MDA8≥75 ppb at the Waco monitor during the period 2009-2013.

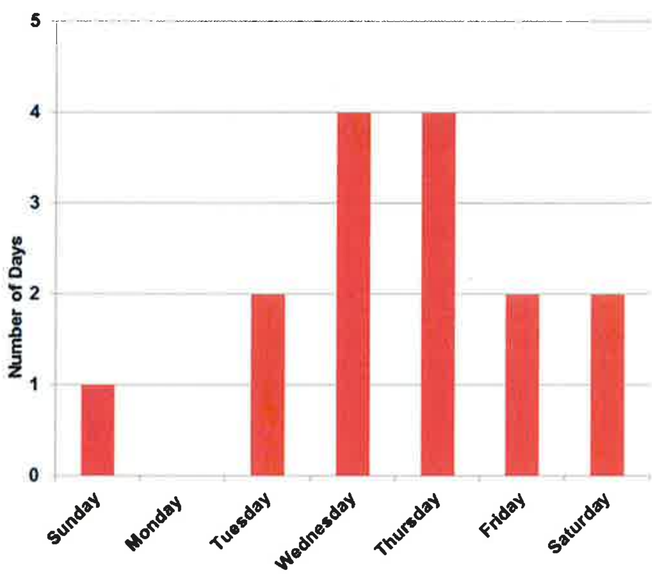


Figure 2-6. Number of high ozone days by day of week at the Waco monitor during the period 2009-2013.

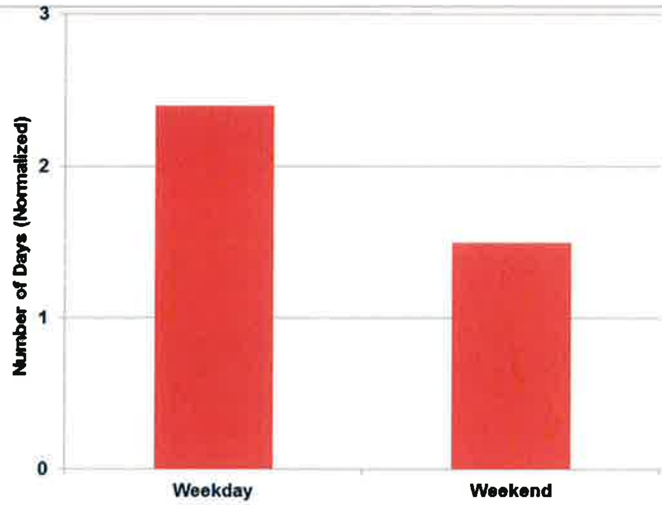


Figure 2-7. Number of high ozone days by day of week at the Waco monitor during the period 2009-2013 normalized by number of days per week in each category.

2.2 Emissions

In this section, we review the emission inventory of ozone precursors for the HOTCOG area. Ozone is not emitted directly, but is formed in the atmosphere from precursor pollutants in the presence of sunlight. The most important ozone precursors are nitrogen oxides (NOx) and volatile organic compounds (VOCs). This analysis shows the source categories that make the most important contributions to the HOTCOG area's ozone precursor emission inventory.

At the time of the analysis, the most recent year for which emissions inventories were available for both anthropogenic and biogenic emissions was 2006. The 2006 emission inventories were developed by the TCEQ for use in ozone modeling by the Texas Near-Nonattainment Areas, and are broken down by emissions source category. The inventories were downloaded from the TCEQ's Rider 8 ozone modeling website at http://www.tceq.texas.gov/airquality/airmod/rider8/rider8Modeling. We also analyzed 2010 and 2012 emissions for some anthropogenic emission source categories in order to identify emissions trends in the 6-county area. First, we review the point source emission inventory, and then we summarize the emission inventories for all sources, including those that are distributed across the 6-county area. Next, we analyze the inventory to determine whether NOx or VOC is the limiting factor in ozone formation in the HOTCOG area. Finally, we examine area-wide emission trends.

2.2.1 Point Source Emission Inventory Comparison

In this section, we summarize the point source emission inventory for the HOTCOG Area. We treat point sources separately from the remainder of the inventory because of their importance in the HOTCOG emission inventory. A detailed description of the point source emission inventory for the 6-county HOTCOG area is given in ENVIRON (2013). Point sources are large, stationary, emissions sources that exceed a specified emissions threshold. Point source emissions are frequently, but not always, released through a stack. In non-attainment areas of Texas, the TCEQ defines a point source to be any industrial, commercial, or institutional sources that emits actual levels of criteria pollutants at or above the following amounts: 10 tons per year (tpy) of VOC; 25 tpy of NOx; or 100 tpy of any of the other criteria pollutants including CO, SO_2, PM10, or lead. In attainment areas of the state, any company that emits a minimum of 100 tpy of any criteria pollutant must submit a point source emissions inventory to the TCEQ. Each point source has a well-defined location (latitude and longitude) as well as ancillary information known as stack parameters that indicate the height at which emissions are released, the temperature of the emitting stack, etc.

The TCEQ's 2006 point source emission inventory for the HOTCOG area was compiled from data from the TCEQ's State of Texas Air Reporting System (STARS) and the EPA's Acid Rain Program Database (ARPDB). The STARS database is administered by the TCEQ. Each year, the TCEQ sends questionnaires to all facilities that meet the reporting requirements of 30 Texas Administrative Code (TAC) §101.10. The TCEQ collects point source emissions data as well as industrial process operating data. For all sources except electric generating units (EGUs), the TCEQ uses this data to compile Ozone Season Day (OSD) emissions. The OSD emission rate represents average daily emissions during the summer, when ambient ozone in Texas is highest.

The EPA requires all utility units serving generators with an output capacity of greater than 25 megawatts and all new utility units to continuously measure and record their emissions of SO_2, NOx, and CO_2, as well as other quantities such as heat input. This is accomplished through in-stack monitoring using a Continuous Emissions Monitor (CEM). All sources must submit hourly emissions data to the EPA's Clean Air Markets Division (CAMD) Acid Rain Program Database (ARPDB) on a quarterly basis. For each Texas electric generating unit (EGU), the TCEQ downloaded the hourly CEM data from the ARPDB and used this hourly data in their emissions modeling. Because VOC and CO emissions are not reported in the ARPDB, the TCEQ calculated hourly emissions for these pollutants by multiplying the STARS OSD VOC-to-NOx and CO-to-NOx emissions ratios by the hourly ARPDB NOx emissions. (TCEQ, 2010).

Although the hourly EGU emissions are used in ozone modeling to provide the most accurate possible simulation of the emission, transport and fate of EGU emissions, OSD average emissions were generated for EGUs from the hourly data for the emissions analysis presented here. For EGU sources in the HOTCOG area, hourly CEM emissions data were extracted from the TCEQ Rider 8 June 2006 episode files and average OSD emissions were calculated over the 33 day episode extending from May 31 to July 2. For non-EGU sources (i.e. all other sources that are not power plant stacks) TCEQ's OSD average emissions estimates for HOTCOG 6-County point sources were used directly.

There are 6 EGUs in the EPA ARPDB within the HOTCOG counties and their ozone season daily emissions are presented in Table 2-1; the location of these facilities is shown in Figure 2-8 and Figure 2-9. Both the Tradinghouse Power Plant and the Lake Creek Steam Electric Station were included in the emission inventories for 2006, but are no longer in operation. As of June 2013, the Sandy Creek EGU, a 925-megawatt coal-fired plant located in southern McLennan County, had begun operating, but emissions for this facility were not yet available at the time of the 2013 study. Table 2-1 indicates that Big Brown and Limestone EGUs together constitute most of the EGU NOx emissions for the 6-county HOTCOG area.

Table 2-1. 2006 emissions for EGUs in the HOTCOG 6-County Area.

Owner	Site	County	NOx [tpd]	VOC [tpd]	SO_2 [tpd]
Bosque Power Co	Bosque County Power Plant	Bosque	0.90	0.00	0.01
Luminant Generation Co	Big Brown	Freestone	19.50	0.43	292.97
Freestone Power Generation	Freestone Power Generation	Freestone	1.54	0.05	0.03
NRG Texas Power	Limestone	Limestone	40.08	0.89	62.22
Luminant Generation Co	Lake Creek	McLennan	1.05	0.02	0.00
Luminant Generation Co	Tradinghouse	McLennan	3.10	0.11	0.01

Sandy Creek facility was not operational until 2013.

Analysis of the 2006 HOTCOG 6-County area emission inventory (ENVIRON, 2013a) shows that these two EGUs with total emissions of ~60 tpd constitute 79% of the 76 tpd total NOx point source inventory for the 6-county area. Figure 2-8 shows that the Waco monitor has a number of small (1 – 3 tpd) NOx emitting point sources within 13 miles to its south and east, and the two largest HOTCOG counties NOx point source emitters (Limestone 40 tpd; Big Brown 20 tpd) are both between 50 – 65 miles to its east. Under typical wind directions on high ozone days (northerly through easterly to southerly) emissions from Limestone or Big Brown power plants may contribute to ozone formation at the Waco monitor, but analysis performed by McGaughey et al. (2010a; 2012) and Parker et al. (2013) indicates that high ozone at the Waco monitor frequently occurs without the presence of SO_2 that is indicative of a coal-fired power plant plume impact. In other words, Limestone and Big Brown have the potential to influence high ozone in Waco but this does not appear to have happened on recent high ozone days.

The VOC point source plot Figure 2-9 indicates that the point source VOC emission inventory is comprised of a number of small sources rather than being dominated by two large sources as is the NOx emission inventory; instead, many point sources have comparable VOC emission rates. It is shown in the next section however, that anthropogenic point VOC emissions are negligible compared to other VOC emission source categories. In particular, biogenic VOC emissions dominate the inventory, and so the location of the point VOC emissions is unlikely to play a significant role in ozone levels at the Waco monitor.

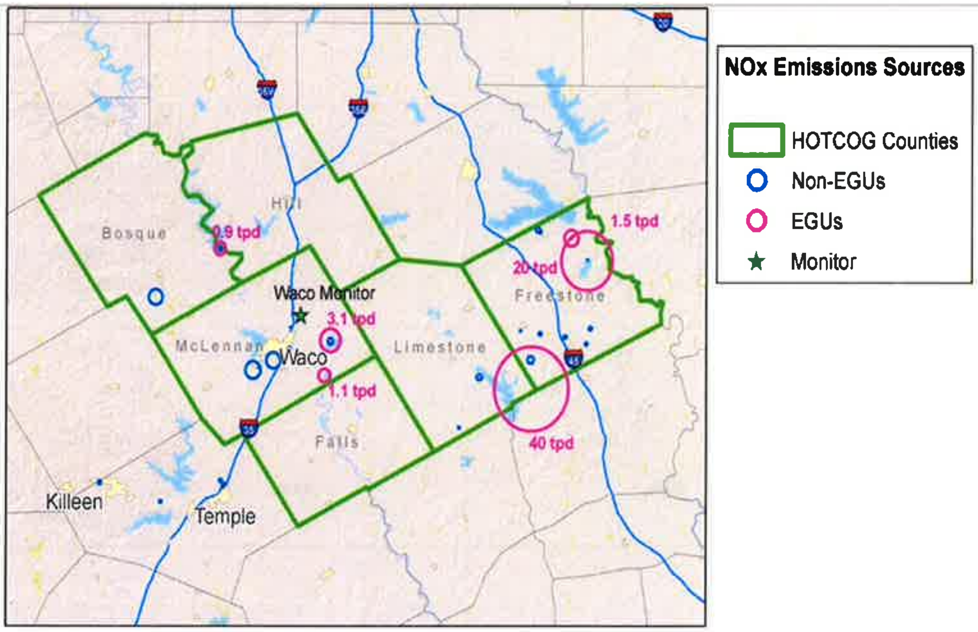


Figure 2-8. 2006 NOx emissions from point sources in the 6-County HOTCOG area and in Bell County. Area of circle is proportional to emissions rate.

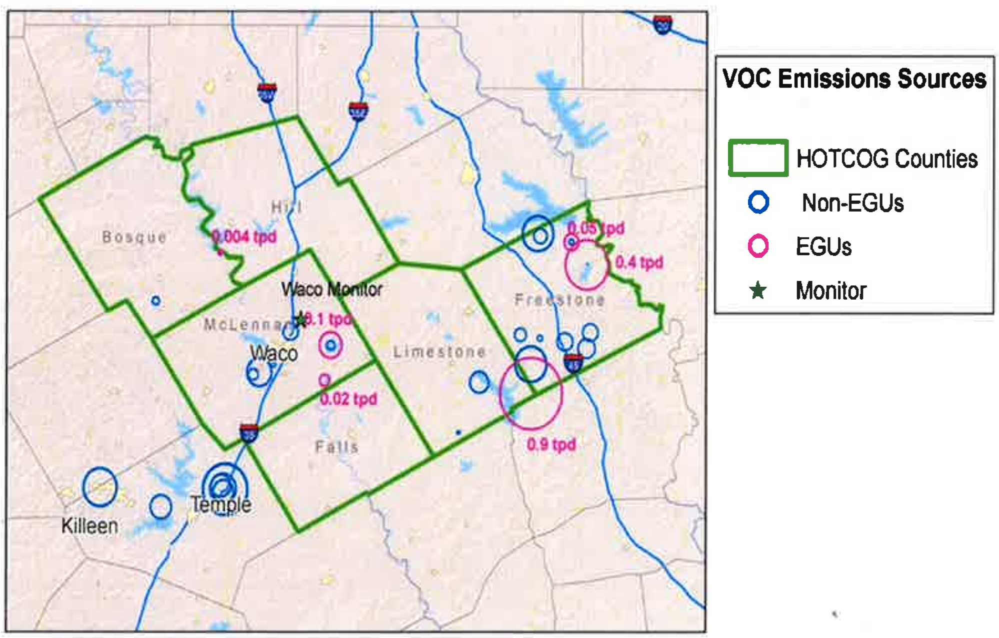


Figure 2-9. 2006 VOC emissions from point sources in the 6-County HOTCOG Area and in Bell County. Area of circle is proportional to emissions rate.

2.2.2 Summary of HOTCOG 6-County Emission Inventories

In this section, we present the NOx and VOC emission inventories for the HOTCOG 6-County area. We consider all emissions source categories. Area, off-road, and on-road, and biogenic emissions for 2006 were extracted from the TCEQ's Rider 8 modeling files at http://www.tceq.texas.gov/airquality/airmod/rider8/rider8Modeling. Because oil and gas emissions dominate the area source inventory in the HOTCOG region, area sources were broken down into oil and gas and non-oil and gas area sources. Non-oil and gas area sources are referred to hereafter as "area sources" and oil and gas area sources are referred to as "oil and gas". The emissions totals represent county-wide emissions for a summer weekday. On-road NOx emissions were computed as the sum of the Motor Vehicle Emissions Simulator (MOVES) output compounds NO, NO_2, and HONO.

2.2.2.1 NOx Emissions

Figure 2-10 shows 2006 ozone season day NOx emissions for the 6 HOTCOG counties by source category. Point sources are the largest contributor to HOTCOG area NOx emissions, accounting for 76 tons per day (tpd) or 46% of the total emissions. As noted in the previous section, EGU emissions comprise most of the point source NOx inventory. Off-road mobile (32 tpd), on-road mobile (47 tpd), and oil and gas sources (24 tpd) constitute most of the remainder of the HOTCOG inventory. NOx emissions come primarily from natural gas production. The 2014 distribution of oil and gas wells in the HOTCOG area is shown in Figure 2-13 and shows far more gas wells than oil wells. Together, point sources and oil and gas sources make up 54% of the 6-county area NOx emission inventory. HOTCOG NOx emissions from non-oil and gas area sources and from biogenics are small relative to emissions from the other categories. McLennan County has higher NOx emissions than the other HOTCOG counties for area, off-road and on-road source categories. This is likely due to the higher populations of McLennan County compared to the other counties taken together with the presence of the I-35 highway in McLennan.

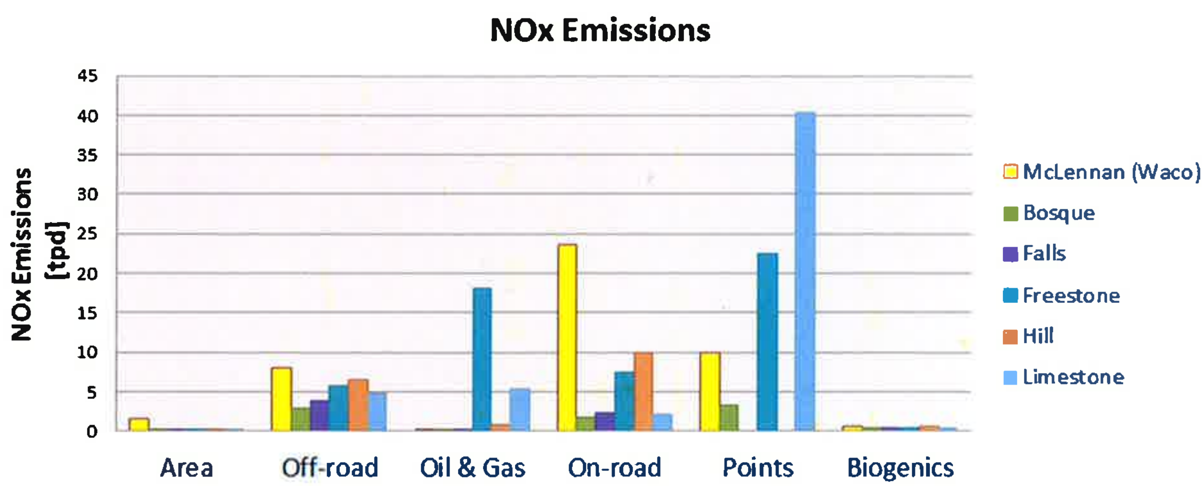


Figure 2-10. 2006 ozone season day NOx emissions by County and by source category.

The oil and gas NOx emission inventory is dominated by a single source category. In Figure 2-11, the contribution from gas compressor engines to the 2006 HOTCOG area NOx emission inventory is shown. Gas compressor engines are used to extract natural gas from a well when reservoir pressures alone are insufficient to bring the gas to the surface. Compressor engines are also used to transmit natural gas along pipelines from the well to gas processing plants and then to consumers. In a mature gas field, such as those found in Freestone and Limestone Counties, the need for compression to produce the gas increases over time as the subsurface gas reservoir is drained and reservoir pressures drop. In Freestone and Limestone Counties, gas compressor engines are the largest component of the oil and gas NOx emission inventory.

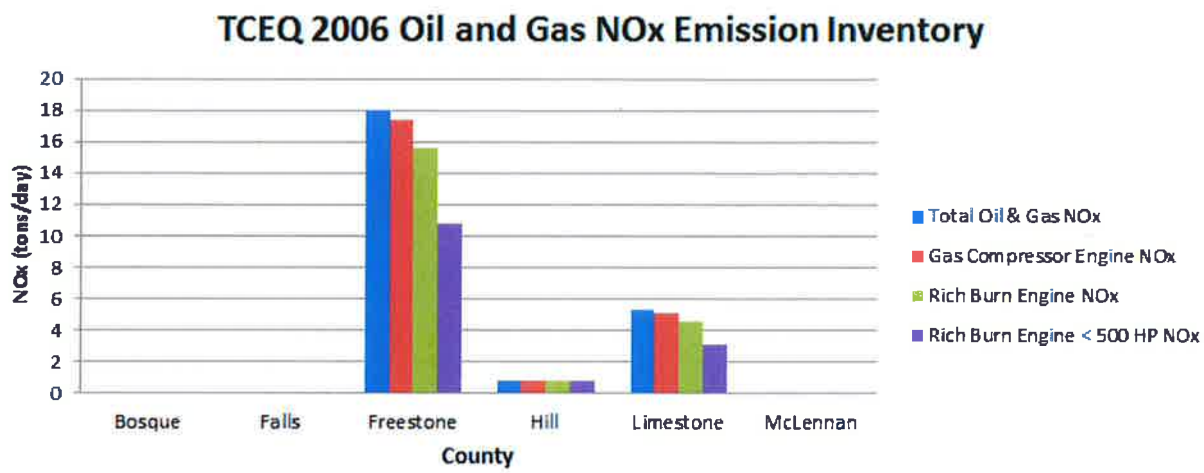


Figure 2-11. Contribution of gas compressor engines to oil and gas NOx in the 2006 TCEQ emission inventory for the HOTCOG area.

Figure 2-12 shows the estimated average natural gas production per gas well in the three HOTCOG counties with significant natural gas production: Hill, Limestone and Freestone. The estimate was derived by dividing the natural gas production in each county for a given year by the number of active gas wells in that county during that year. Figure 2-12 indicates that the natural gas production per well is declining over time in all three counties, which may indicate an increasing need for well-head compression. The potential effect of decreasing per well production on gas compressor NOx emissions is unclear.

In March, 2010, a Texas emissions reduction measure known as the East Texas Combustion Rule went into effect. The East Texas Combustion Rule requires owners and operators of stationary, rich-burn gas-fired, reciprocating internal combustion engines greater than or equal to 240 HP in 33 East Texas counties (including Limestone and Freestone Counties) to meet NOx emission limits and follow specified reporting requirements. The fraction of engines in the 6-county area that have horsepower < 240 HP and are therefore not required to comply with the East Texas Combustion Rule is not known.

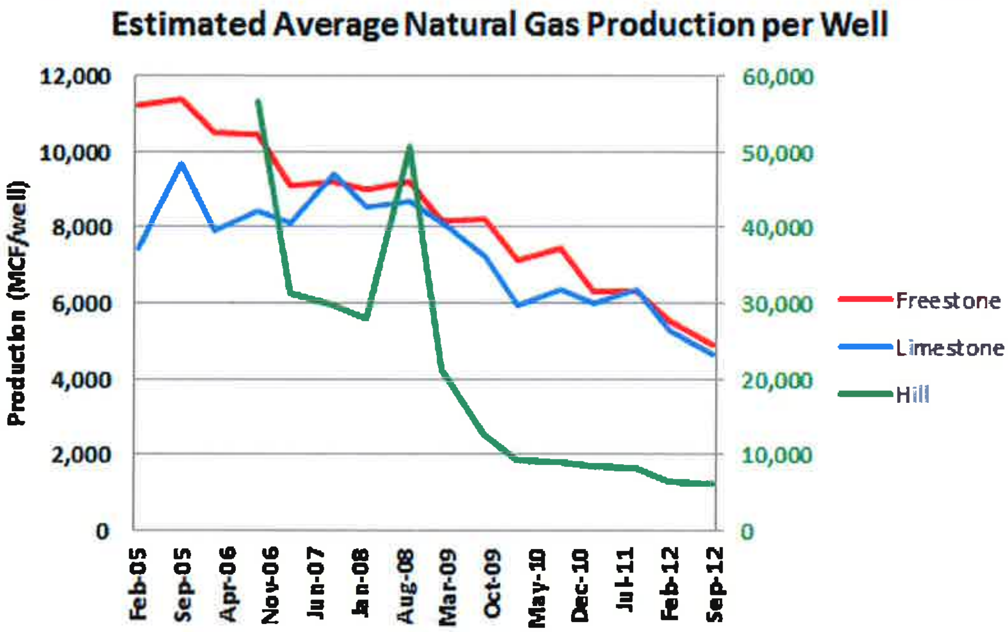


Figure 2-12. Trends in Natural Gas Well Productivity in the HOTCOG Area.

The TCEQ has gathered data on engine distribution for other areas of Texas. The TCEQ Special Inventory for the Barnett Shale collected survey data from oil and gas upstream and midstream facilities in order to determine the location, number, and type of emissions sources associated with oil and gas operations in the Barnett Shale formation during 2009. Hill County is located in the Barnett Shale area and was included in this study. The TCEQ inventory surveys gathered equipment counts for stationary gas fired engines in selected horsepower range bins (0 to 50 HP, 50 to 240 HP and over 240 HP) and by engine type (rich burn versus lean burn). The results of the study show that in the Barnett Shale region as a whole and in Hill County, the majority (about 80 percent of the population) of the gas compressor engines are < 240 HP in size. It also shows the majority of the engines in the <240 HP range are rich burn type engines (about 95 percent).

There is no survey data available to determine what fraction of engines with horsepower<240 HP in Freestone and Limestone Counties are curretnly uncontrolled, but the Barnett Shale survey data suggests that there may be a significant number of gas compressor engines in the 6-county area that could be considered for low-cost, voluntary NOx emission controls implemented at the local level.

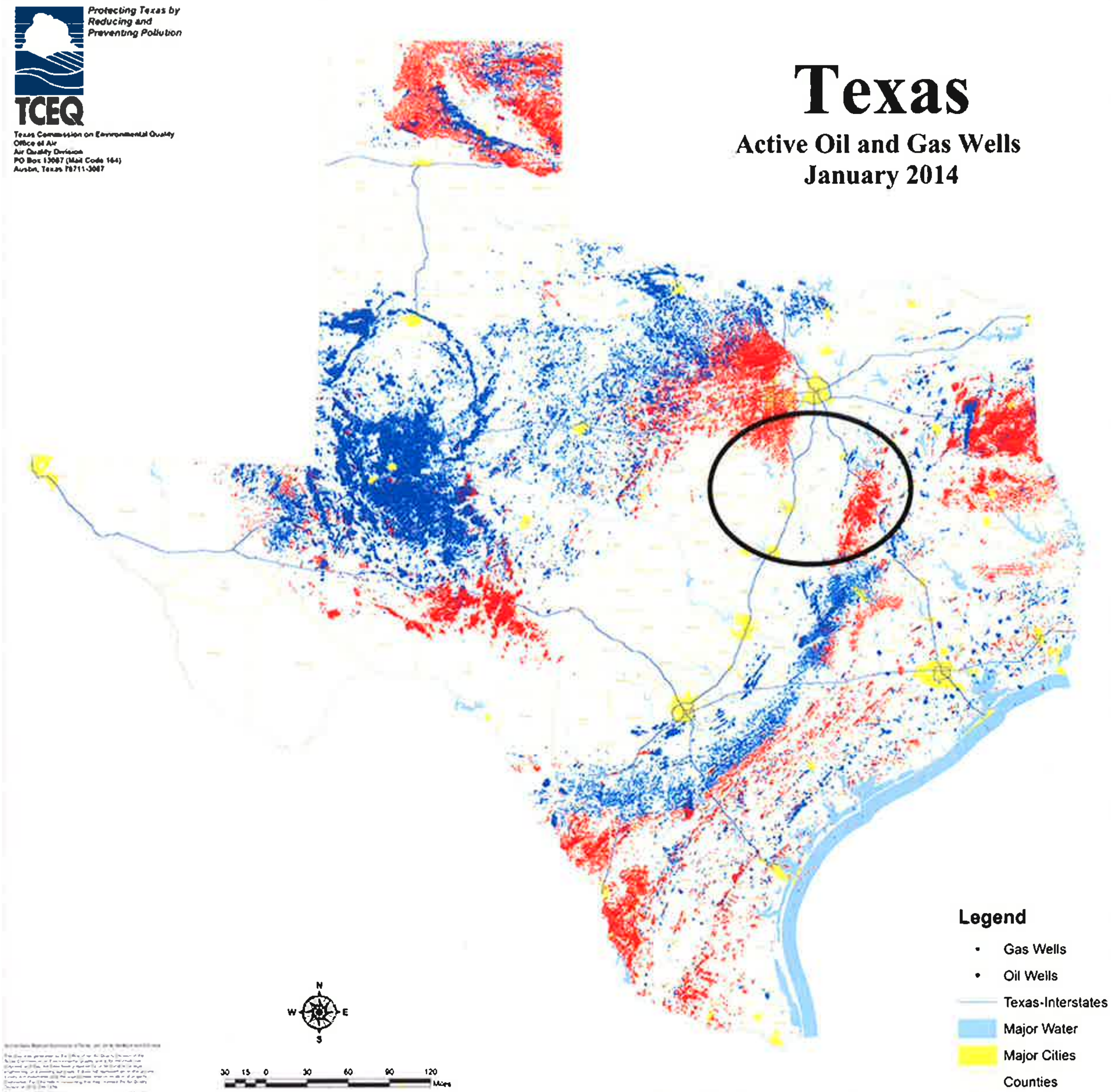


Figure 2-13. Texas oil and gas well locations as of January 2014. TCEQ figure from http://www.tceq.state.tx.us/assets/public/implementation/barnett_shale/bs_images/txOilGasWells.png. Black circle indicates the location of the HOTCOG 6-county area.

2.2.2.2 VOC Emissions

Biogenic emissions sources are naturally-occurring (i.e., not from human activities) such as trees, agricultural crops, or microbial activity in soils or water. The TCEQ Rider 8 biogenic binary CAMx input files were processed to produce June 2006 episode average biogenic emissions totals by county for each county in the HOTCOG area. Each model grid cell was assigned to a county using GIS tools.

HOTCOG area VOC emissions are primarily from biogenic sources, constituting 87% of the total in McLennan County and a higher proportion in the other more rural counties. In order to analyze the anthropogenic VOC emissions in the HOTCOG counties, the biogenic source category is omitted from the VOC bar chart (Figure 2-14) and is examined separately. Figure 2-14 shows ozone season day anthropogenic VOC emissions for the 6 HOTCOG counties by source category. Similar to the NOx emissions, area and mobile source VOC emissions in McLennan Counties are larger than in the other HOTCOG counties; this is likely due to McLennan counties having a larger population than the other counties. As for NOx, the HOTCOG area has a large contribution to the anthropogenic VOC inventory from oil and gas sources.

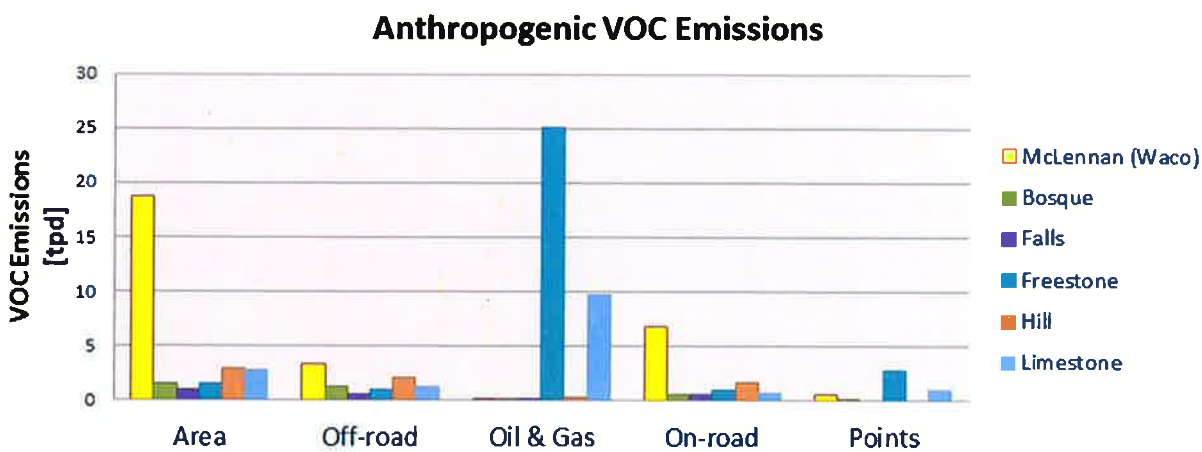


Figure 2-14. Ozone Season Day Anthropogenic VOC Emissions by County and by Source Category.

Figure 2-15 shows ozone season day total anthropogenic and biogenic VOC emissions for the 6-County HOTCOG Area. For each county, the contribution from biogenic emissions far exceeds that of the anthropogenic emissions. Total anthropogenic emissions of VOCs from Freestone County are similar to McLennan County, but they are primarily from the oil and gas sector. As for NOx, the composition of the HOTCOG area VOC emission inventory is strongly influenced by oil and gas. Table 2-2 presents all ozone season day total NOx and VOC emissions by source category and by county.

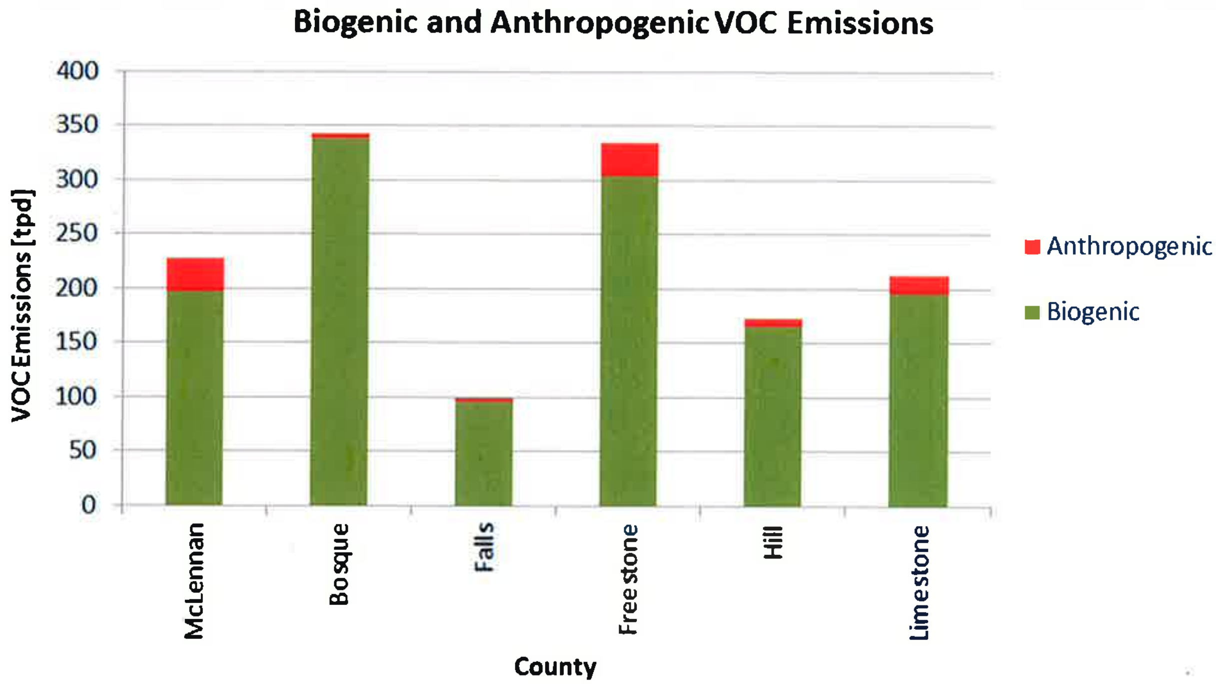


Figure 2-15. Ozone Season Day Total Anthropogenic and Biogenic VOC Emissions by County

Table 2-2. 2006 NOx and VOC emissions by source category for the HOTCOG Counties.

Pollutant	Source Category	McLennan	Bosque	Falls	Freestone	Hill	Limestone
NOx [tpd]	Area	1.65	0.15	0.12	0.12	0.25	0.19
	Off-road	7.99	2.83	3.80	5.80	6.53	4.81
	Oil & Gas	0.06	0.00	0.03	18.02	0.78	5.37
	On-road	23.61	1.69	2.34	7.50	10.00	2.17
	Points	10.01	3.28	0.00	22.55	0.00	40.43
	Biogenics	0.62	0.46	0.50	0.44	0.60	0.48
VOC [tpd]	Area	18.71	1.58	1.04	1.50	3.00	2.78
	Off-road	3.28	1.24	0.53	0.93	2.11	1.29
	Oil & Gas	0.10	0.01	0.06	25.05	0.26	9.70
	On-road	6.76	0.56	0.53	1.00	1.67	0.71
	Points	0.54	0.02	0.00	2.73	0.00	1.06
	Biogenics	198.36	339.50	96.99	304.05	165.90	196.78

2.2.3 Relative Importance of NOx and VOC Emissions in Ozone Formation

In order to develop emission control strategies for the HOTCOG area that will reduce the local contribution to ozone, it is necessary to understand how ozone formation in the area depends on the amount of available NOx and VOC. Ozone formation depends on the amount of NOx and VOC present as well as on the ratio of VOC to NOx, where the ratio is taken in terms of ppbC/ppb. When the VOC/NOx ratio is higher than about 10, ozone formation is limited by the amount of available NOx and reducing NOx tends to decrease peak ozone concentrations. However, if the VOC/NOx ratio is less than about 7, reducing NOx tends to increase ozone levels, and the area is said to be VOC-limited. In this situation, which can occur in urban cores of large cities, ozone is suppressed in the urban area due to titration by large amounts of fresh NO emissions. When NOx emissions are reduced, the suppression of ozone by NO is lessened and ozone increases.

We calculated the VOC/NOx ratio in the June 2006 emission inventories for McLennan County and for the 6-county area as a whole. The VOC/NOx ratios are presented in Table 2-3. For both regions, the VOC/NOx ratio is greater than 10, which indicates that both McLennan County and the HOTCOG 6-county area as a whole are regions where ozone formation is likely to be limited by the amount of available NOx. This finding is consistent with the results of HOTCOG's ozone modeling, which also indicated that ozone formation in the HOTCOG area is NOx-limited (Kemball-Cook et al., 2012).

Table 2-3. VOC/NOx ratios for McLennan County and the HOTCOG 6-County Area.

Counties	VOC/NOx (ppbC/ppb)
McLennan	17.0
HOTCOG	24.7

In developing a conceptual model for ozone formation for an area, it is important to understand the role played by on-road mobile sources. Figure 2-10 shows that on-road sources are a significant source of NOx in the 6-county area. In regions where on-road vehicles play a key role in determining ozone levels, the typical diurnal cycle of ozone and precursors for weekend days may be different from that of weekdays due to differences in driving activity. The main differences are the absence of morning and evening commute periods on weekends and less heavy-duty truck traffic on weekends. NOx differences between weekday and weekend are most pronounced during morning and afternoon commute hours. We might expect that since weekday NOx and VOC emissions from traffic are higher than weekend emissions, ozone would be consistently higher on weekdays than on weekends; the HOTCOG area has more high ozone days on weekdays than on weekends (Figure 2-7).

Diurnal profiles of ozone and NOx for the Waco Mazanec monitor and ozone for the Waco were examined monitor in order to determine whether a weekday/weekend ozone effect is evident. Inspection of average diurnal profiles of NOx and ozone allow us to evaluate whether the monitors exhibit a weekday/weekend difference and to diagnose whether ozone formation is NOx-limited or VOC-limited in the vicinity of the monitor. If the weekday morning NOx peak is higher than the weekend morning NOx peak, then looking at the weekday-weekend difference is approximately equivalent to testing the effect on ozone of reducing NOx emissions. In a NOx-limited area, the peak ozone will be smaller on the weekend day, because the NOx emissions are smaller on the weekend and the total amount of ozone formed each day is limited by the amount of available NOx. Conversely, if the area is VOC-limited, the peak ozone value will be higher on the weekend than on the weekday. A diurnal profile analysis is shown for each year (2009 to 2012) in order to determine whether the limiting pollutant in ozone formation changed during those years.

Average diurnal profiles for ozone and NOx for weekday (WD) and weekend (WE) were created by averaging hourly values of all Wednesday measurements for the WD profiles and all Sunday measurements for the WE profiles for each year from 2009-2012. At the time this analysis was performed, complete data were not yet available for 2013. For each profile, only April-September months were used in the averaging. These correspond to months when high ozone was most likely to occur at the Waco Mazanec monitor.

The magnitudes of peak NOx and ozone in the diurnal average profiles varied from year to year, but every year shows a weekday peak NOx that is higher than the weekend peak NOx and also weekday peak ozone that is higher than weekend peak ozone). Figure 2-16 shows weekday/weekend average diurnal profiles for each year. Each annual average diurnal profile was based on between 24 and 26 individual daily profiles.

At Waco, the weekday morning NOx peak is higher than the weekend morning NOx peaks for all years from 2009-2012. The morning NOx peaks varied from 1.5 ppb to 9.0 ppb; 2009 had the lowest peak and 2011 the highest. The difference between weekday and weekend (WD-WE) morning NOx peaks varied from 0.6 ppb to 4.8 ppb. For all years from 2009-2012, the WD NOx peak is higher than the WE NOx peak, and the WD-WE ozone difference is well-correlated with the magnitude of the WD-WE NOx difference. This suggests that ozone formation is NOx-limited in the vicinity of the Waco monitor.

The analyses of the NOx and VOC emission inventories, ozone modeling and the weekday/weekend NOx and ozone profiles all are consistent in showing that ozone formation in the HOTCOG 6-county area is NOx-limited. Therefore, local emission control strategies should be focused on NOx mitigation.

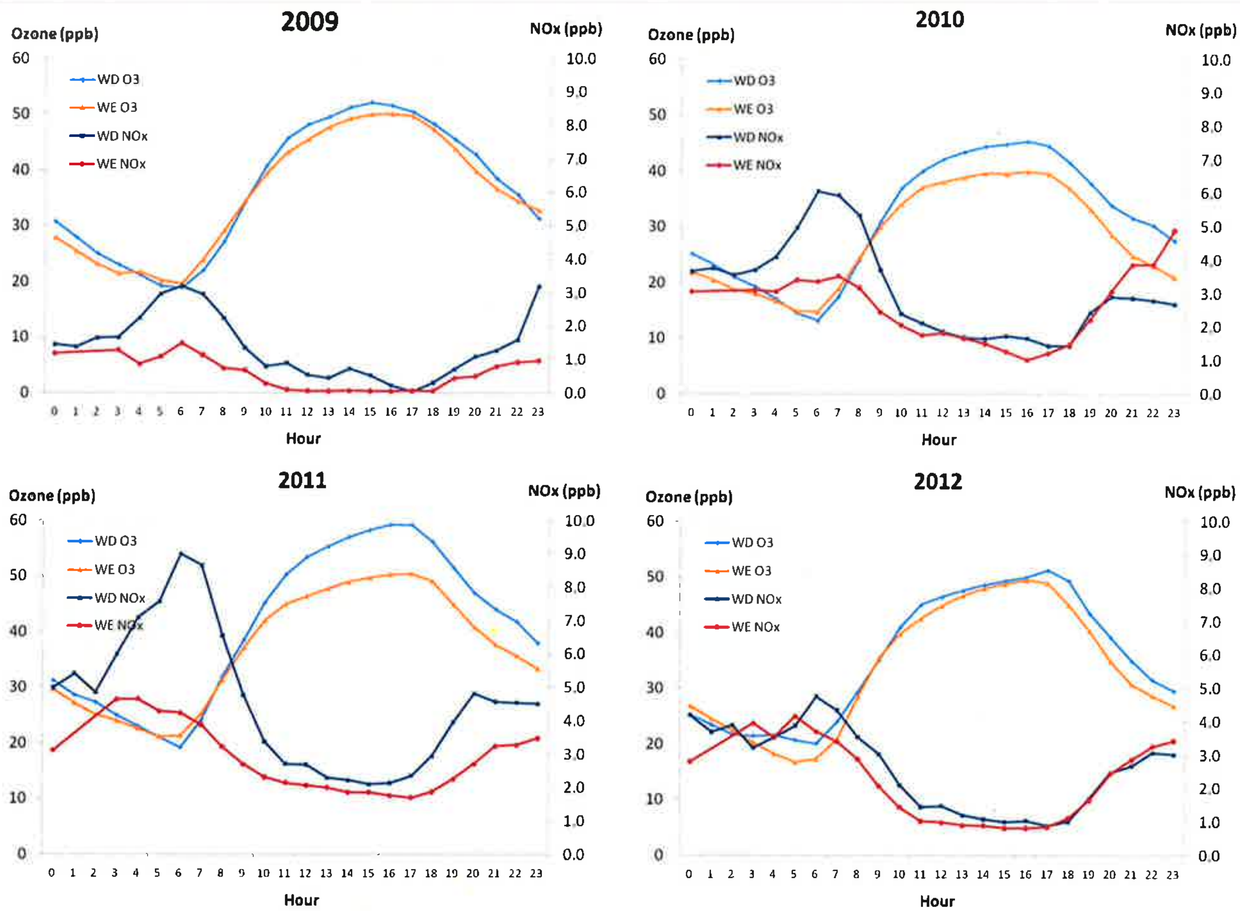


Figure 2-16. NOx and ozone average diurnal profiles for April–September, 2009 – 2012, at the Waco Mazanec monitor. Figure from Parker et al. (2013).

2.2.4 Emissions Trend Analysis

In this section, we show the results of several emission inventory analyses that indicate trends in NOx and VOC emissions in the 6-county area. The TCEQ has developed an anthropogenic emission inventory for June 2012 that is specific to the day of the week. The TCEQ inventory uses 2012 summer quarter hourly average emissions for power plants that report day-specific hourly emissions to EPA's ARPDB. For Texas point sources that do not report to the ARPDB, emissions were extracted from the TCEQ's STARS data base. Emissions for point sources outside of Texas were taken from the EPA's 2008 National Emission Inventory (NEI). The on-road portion of the inventory was developed using the Motor Vehicle Emission Simulator emissions model (MOVES; www.epa.gov/otaq/models/moves/). The EPA NONROAD model (www.epa.gov/otaq/nonrdmdl.htm) was the basis for developing much of the non-road inventory.

Figure 2-17 and Figure 2-18 compare the 2006 and 2012 6-county HOTCOG area anthropogenic NOx and VOC emissions by source category. Going from 2006 to 2012, there is an overall decrease in NOx emissions in the 6-county area from 182 tpd to 137 tpd. Point source NOx emissions decreased by 13 tpd and on-road mobile emissions decreased by 20 tpd. Smaller declines occurred for oil and gas (3 tpd) and non-road mobile sources (9 tpd), while area source NOx emissions remained constant. The relative proportion of each source category to the total NOx emission inventory does not change significantly from 2006 to 2012. Point source and on-road mobile source NOx are the two largest source categories in both 2006 and 2012.

Total anthropogenic VOC emissions declined from 84 tpd in 2006 to 62 tpd in 2012. Note that anthropogenic VOC emissions are small relative to biogenic VOC emissions. In 2006, biogenic VOC emissions totaled 1261 tpd compared to the anthropogenic VOC inventory of 85 tpd. Biogenic emissions were not available for 2012, but are expected to be similar to 2006 and therefore far larger than the 2012 anthropogenic VOC emission inventory. Oil and gas VOC emissions decreased by a factor of two. Area source VOC emissions increased from 24 to 27 tpd while point source VOC emissions increased by approximately 1 tpd.

Fleet turnover to cleaner burning engines is responsible for the decrease in on-road and non-road mobile emissions, given the overall increase in population during this period. The Tradinghouse and Lake Creek EGUs operated in 2006 but not in 2012 (ENVIRON, 2013a). The reasons for the decreases in oil and gas emissions is not clear, since the number of both oil and gas wells in the 6-county area has grown from 2006 to 2012 (http://www.rrc.state.tx.us/data/wells/wellcount/gaswellct_092013.pdf). Documentation of TCEQ oil and gas emissions estimation methods was not available at the time this document was written.

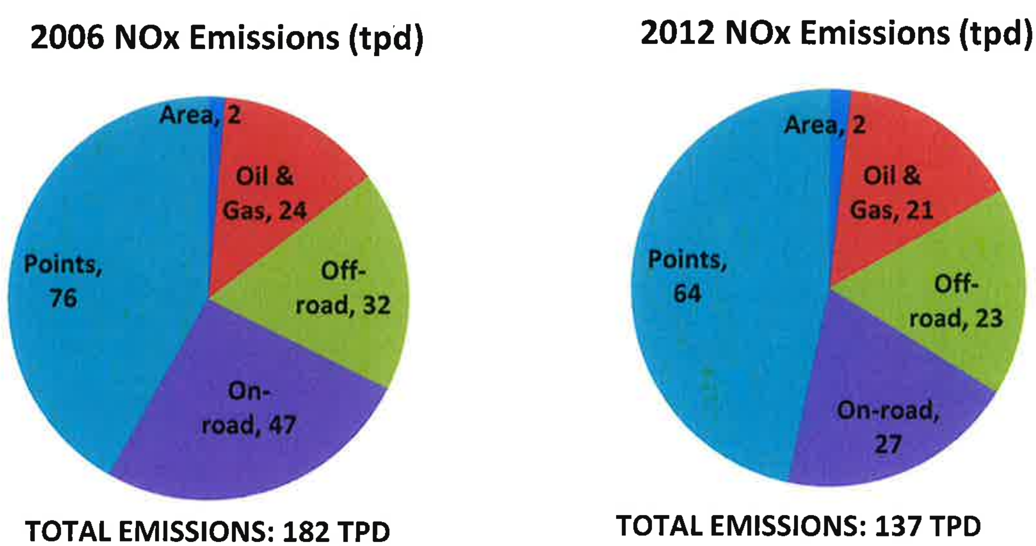


Figure 2-17. TCEQ HOTCOG 6-county area NOx emissions comparison for 2006 (left panel) and 2012 (right panel).

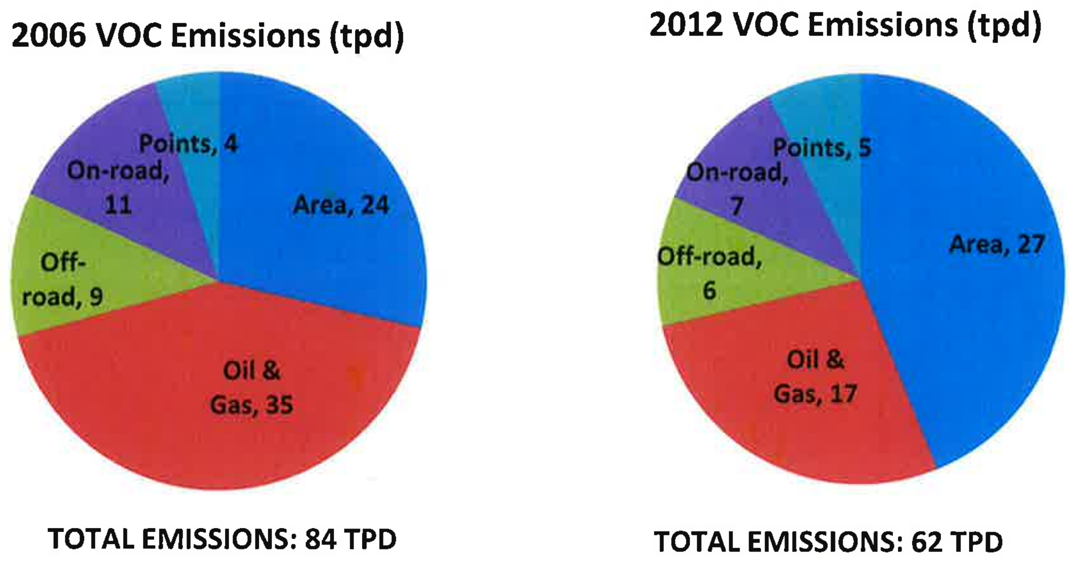


Figure 2-18. TCEQ HOTCOG 6-county area VOC emissions comparison for 2006 (left panel) and 2012 (right panel).

Emission inventories for 2006, 2008, and 2010 were used to analyze recent trends in HOTCOG county point source emissions. The TCEQ base case ozone modeling inventory was used for 2006. The EPA National Emission Inventory (NEI) is published by the EPA on a triennial basis and includes point source emissions compiled from state, local, and tribal agencies, supplemented with data from the EPA[2]. 2008 emissions were taken from the EPA 2008 NEI. 2010 emissions are facility totals from the TCEQ's STARS database. Figure 2-19 shows trends in ozone precursor emissions in the 6-county area. Point source emissions decrease from 2006 to 2008 and again from 2008 to 2010 for all three pollutants. In summary, available emission inventories for the 6-county HOTCOG area show significant reductions in local ozone precursor emissions during the 2006-2012 period.

[2] http://www.epa.gov/ttnchie1/net/2008inventory.html

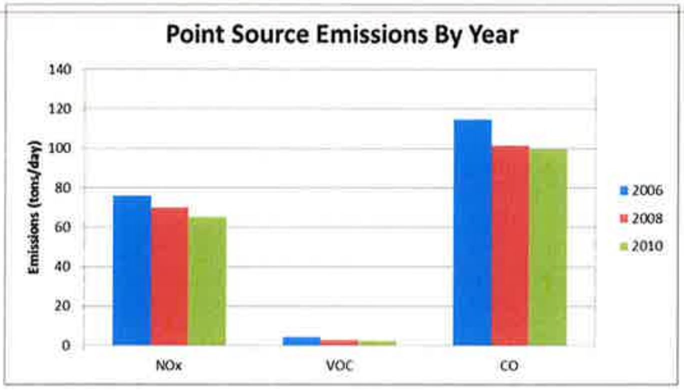


Figure 2-19. HOTCOG area total ozone season day point source emissions for 2006, 2008, and 2010.

2.3 Meteorology

High ozone at the Waco monitor typically occurs on days when local temperatures are high (average daily maximum temperature of 97°F), wind speeds are low and wind directions range between north-northeasterly clockwise through south-southeasterly (McGaughey et al., 2010; 2012). Wind rose plots that characterize near-surface wind speed and direction at the Waco Mazanec monitor over the 2009-2012 period are shown in Figure 2-20. In a wind rose diagram, the orientation and length of spokes indicate the frequency with which a given wind direction occurs. The spokes show the direction from which wind blows toward the monitor, and the colored bands indicate the percentage of time the winds fall in a given speed range. Two sets of wind rose diagrams are shown, corresponding to: (1) no MDA8 threshold (all days), and (2) days with MDA8 ≥ 75 ppb. In addition, the wind data are divided into morning (6 am – 11 am) hours and afternoon (12 noon – 5 pm) hours in order to investigate whether wind shifts between morning and afternoon are present on high ozone days. For each threshold, the morning and afternoon plots are based on the same set of days, and the MDA8 ≥ 75 ppb threshold plots are based on fewer days than the no threshold plots. The number of input data points is the same for the morning and afternoon wind rose plots for each monitor and threshold (unless some wind data are missing). Because there are fewer days with very high ozone (MDA8≥75 ppb) there are far fewer days of data represented in the MDA8≥ 75 ppb plots than in the no threshold plots.

The no threshold plots for morning and afternoon (left panels of Figure 2-20) show that winds are most frequently from the south. Less frequently, winds are from the north. Only very rarely are winds from the east or west. Wind speeds are typically faster than 7 knots. Because the all days plots are strongly weighted toward days with MDA8<75 ppb, this indicates that low ozone days at the Waco monitor are characterized by relatively strong southerly winds. The strong southerly winds prevent buildup of ozone and precursors over the area, and bring clean Gulf air into central Texas. The afternoon wind pattern for no threshold days is similar to the morning wind pattern. By contrast, on high ozone days (right panels of Figure 2-20), morning winds can be from any direction and winds speeds are typically slower than 7 knots. The afternoon wind for high ozone days is typically from southeast (~54%) or northeast (~30%), with average wind speed from southeast predominantly 4-7 knots and typical wind speeds from northeast at least 7 knots but less than 11 knots. This suggests that two distinct emission source regions affect the Waco monitor.

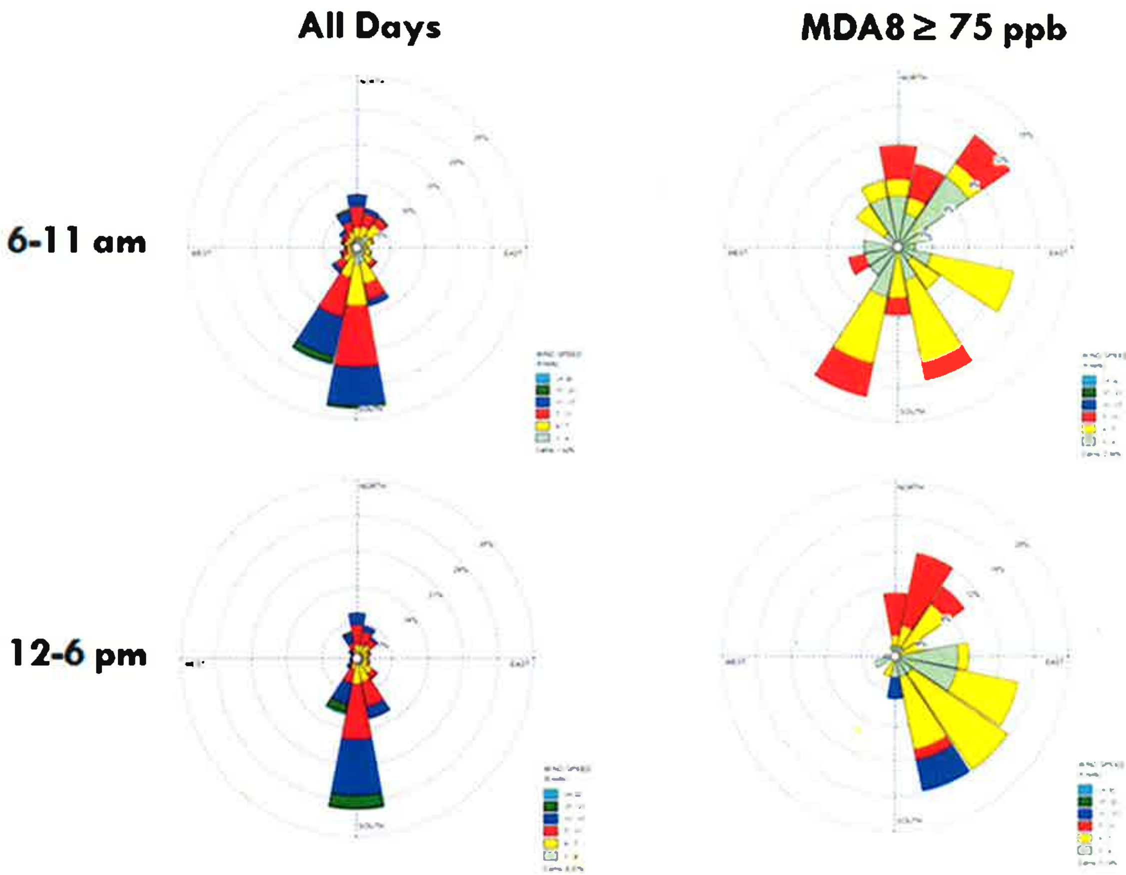


Figure 2-20. Waco wind roses for morning (upper panels) and afternoon (lower panels) on all days (left panels) and days with MDA8≥75 ppb (right panels).

Conditions conducive to the transport, formation, and accumulation of ozone are primarily dependent on the prevailing large-scale weather patterns. The continental-scale atmospheric circulation features during high ozone episodes at the Waco monitor for 2007-2012 were investigated using a case study approach. A surface ridge of high pressure often extended south from the Central Plains or southwest from the eastern U.S. into Texas. The ridge was typically associated with clear skies, warm temperatures, and light wind speeds at the surface. High pressure was sometimes over Texas at upper levels as well; however, northerly or zonal (i.e., east/west) flow aloft was more common. Most high ozone episodes had high ozone concentrations at monitoring locations throughout the eastern half of Texas, demonstrating the regional nature of high ozone events.

Long-range back-trajectories initiated within the daytime mixed layer suggested that the inflow of continental air into Texas at one or more layers above the surface was a necessary condition for high ozone concentrations at the Waco monitor. Figure 2-21 shows inter-state back-trajectory maps based on five-day HYSPLIT model (Draxler and Rolph, 2013) back-trajectories initiated at a height of 1 km above ground level (AGL) at 1700 CST. The five-day trajectory duration was selected to capture long-range transport not only within Texas, but also from distant areas, such as the central and southeastern U.S. The back-trajectory initialization height of 1 km AGL was used since this height approximates the middle of the afternoon mixed layer on high ozone days in the HOTCOG area (McGaughey at al., 2010a).

The back-trajectories for the 17 high ozone days at the Waco monitor are shown in Figure 2-21. The vast majority of back-trajectories indicate flow into Texas from continental regions located to the north and northeast of eastern Texas; only two back-trajectory indicated flow that originated from over the Gulf of Mexico. This is consistent with the Waco monitor wind rose analysis shown in Figure 2-20. The most common non-Texas geographic areas located in the upwind regions prior to high ozone days at the Waco monitor include northwestern Louisiana, Arkansas, eastern Oklahoma, and Missouri. Within Texas, the back-trajectory paths encompass a wide range of Texas areas located to the north, east, and southeast of the HOTCOG area.

The continental airmass transported into Texas likely contained elevated background concentrations of ozone and its precursor compounds associated with both biogenic and anthropogenic emissions. Upwind areas within Texas mostly included eastern portions of Texas east of a north-south line between DFW and Victoria; common upwind non-Texas areas were the Mississippi River Valley and geographic areas to the west such as Louisiana, Arkansas, eastern Oklahoma, and Missouri and portions of surrounding states.

The majority of high ozone episodes were initiated by the passage of a cold front through the HOTCOG area. Some cold fronts were accompanied by strong gusty winds and the transport of noticeably cooler air into Texas, while other cold fronts primarily represented a diffuse and ill-defined transition zone between drier continental air to the north and moister, maritime air to the south. For these latter systems, increased solar radiation and drier air were associated with increases in the daytime maximum temperatures compared to pre-frontal conditions. For a subset of episodes, the cold front stalled just to the south of the HOTCOG area so that high ozone concentrations were limited to northern Texas regions.

For some high ozone episodes, the southward movement of the surface ridge of high pressure into Texas was associated with long-range transport of continental air into the HOTCOG area from locations located well north of Texas. Other high ozone episodes were initiated when a surface high pressure ridge over eastern portions of the US expanded southwestward into Texas. For this latter scenario, the high pressure ridge was sometimes associated with a cold front that had moved south into or through the eastern U.S. during previous days and was associated with long-range transport from the northeast. A few high ozone days had inland-moving tropical low pressure systems in the western Gulf of Mexico that may have enhanced northeasterly or easterly winds in the lower atmosphere over eastern Texas.

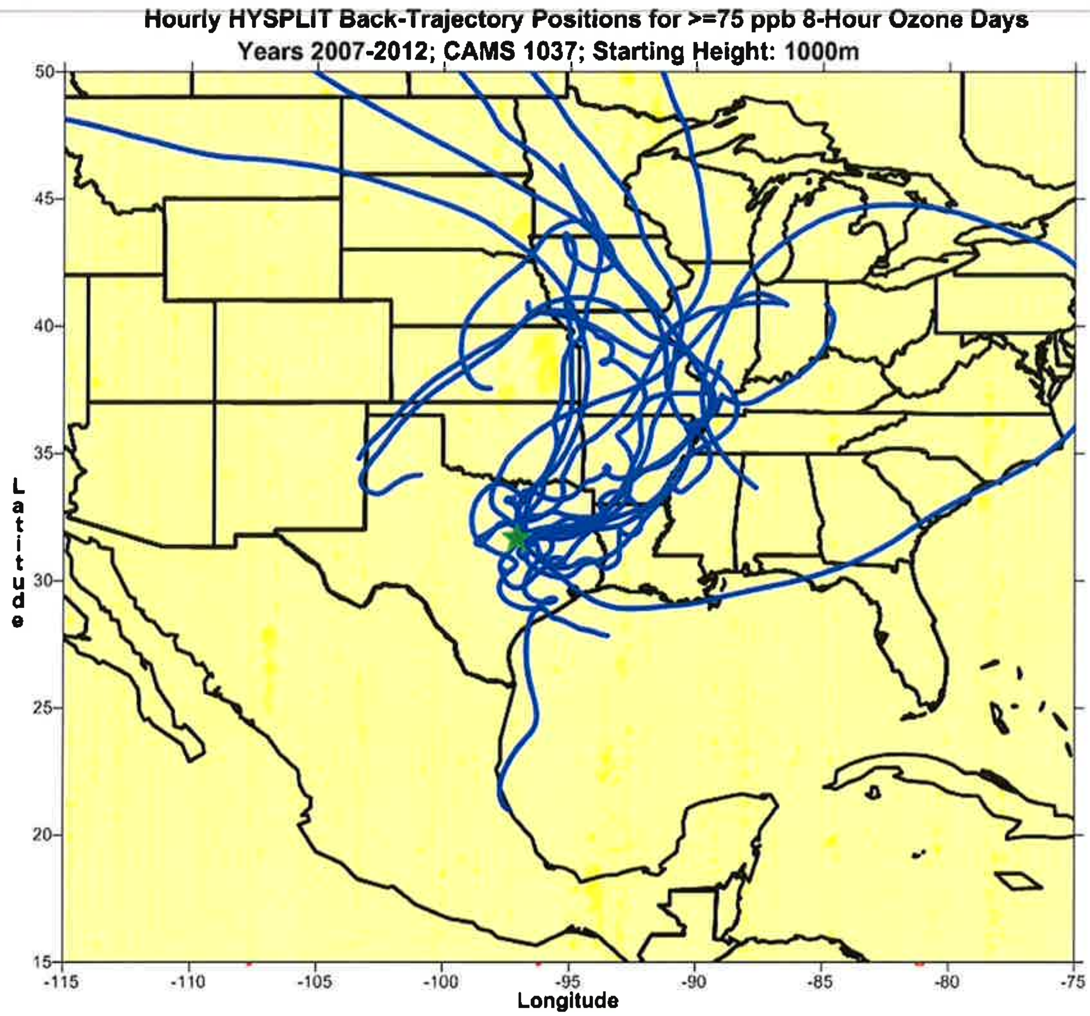


Figure 2-21. Inter-state back-trajectories (based on 5-day HYSPLIT back-trajectories initiated at 1 km AGL) during 2007-2012 for the 17 high ozone days at CAMS 1037. The green star denotes the location of the Waco monitor.

Overall, these analyses found that the necessary (but not sufficient) criteria for high ozone concentrations at the Waco monitor were local meteorological conditions conducive to the accumulation and formation of ozone near the surface (warm temperatures, light wind speeds) as well as the occurrence of large-scale lower-tropospheric atmospheric circulation features favorable for the long-range transport of air of recent continental (as opposed to maritime) origin into the HOTCOG area.

2.4 Ozone Modeling

A June 2006 Comprehensive Air Quality Model with Extensions (CAMx; ENVIRON, 2014) ozone model was developed from inputs provided by the TCEQ to the Texas Near Nonattainment Areas. The nested 36/12/4 km modeling grids are shown in Figure 2-22. The Weather Research and Forecasting Model (WRF; Skamarock et al., 2005) was used to develop meteorological fields (winds, temperatures, pressures, precipitation) for CAMx. Day-specific emission inventories for June 2006 were also developed by the TCEQ, as described in Section 2.2.

Figure 2-22. TCEQ 36/12/4 km CAMx nested modeling grids for the Texas ozone modeling of June 2006. 36 km grid is outlined in black. The 12 km grid outlined in blue, and the 4 km grid is outlined in green. TCEQ figure from http://www.tceq.texas.gov/airquality/airmod/rider8/modeling/domain.

HOTCOG ran and evaluated this base case ozone model at ozone monitors in the HOTCOG area, at rural monitors along the Texas border with Louisiana and Oklahoma, and at rural monitors in the Southeastern U.S. and Ohio River Valley (Kemball-Cook et al., 2014). The model performed well in central Texas, but had a high bias at Texas rural border monitors and in the Southeastern U.S. and Ohio River Valley. Note that the Waco monitor was not active in 2006, so the monitor was evaluated at nearby monitoring sites in Temple and Italy.

Ozone source apportionment modeling was carried out with the 2006 model. Although the Waco monitor was not active in 2006, source apportionment analyses were performed for the current location of the Waco monitor. The source apportionment results showed that ozone formation in the HOTCOG area is limited by the amount of available NOx. This finding is consistent with the weekday/weekend analysis and the emission inventory analysis, which indicated that the VOC emission inventory for the 6-county area is dominated by biogenic VOCs. The abundance of biogenic VOC ensures that there is always enough VOC available to form ozone so that the amount of ozone formed is determined by the amount of NOx emissions. This finding means that emission control strategy development in the HOTCOG area should focus on controlling NOx emission sources rather than VOC sources.

The ozone source apportionment results indicated that, on average, transported ozone contributed far more to HOTCOG area ozone than local sources during the June 2006 episode. Emissions within the 6-county area accounted for 10 ppb of the episode average 8-hour average ozone at the Waco monitor location, while transport accounted for 65 ppb (Figure 2-23). The local HOTCOG contribution to the daily maximum 8-hour average ozone varied from day to day depending on the wind direction, but reached a maximum of 24 ppb (Kemball-Cook et al., 2014). The magnitude of this impact indicates that local emissions control measures can be effective in reducing ozone in the HOTCOG area.

The ozone source apportionment results were analyzed to determine which HOTCOG emissions source categories make the largest contributions to HOTCOG area ozone levels (Figure 2-24; Figure 2-25). The categories with the largest ozone impacts were on-road and off-road mobile sources, elevated point sources, and oil and gas sources. On-road mobile sources made the largest episode maximum and episode average contribution to ozone at the Waco monitor location. The next largest episode maximum contribution was made by elevated point sources, followed by oil and gas sources. The elevated point source NOx emission inventory is dominated by power plant emissions; there are two large power plants located in the vicinity of the Waco monitor. The largest contributor to oil and gas ozone impacts was NOx emissions from wellhead compressor engines.

During the summer of 2013, the TCEQ made a 2012 anthropogenic emission inventory available to ENVIRON for use in the development of an ozone forecasting system for the State of Texas (Johnson et al., 2013). A 2012 typical day emission inventory was developed for the June 2006 episode and was used to assess how emissions changes from 2006 to 2012 affect HOTCOG area ozone under the meteorological conditions of June 2006. NOx and VOC emissions changes are shown in Figure 2-17 and Figure 2-18, respectively

The CAMx run using 2012 emissions in the 2006 Rider 8 modeling platform showed decreases in HOTCOG area ozone throughout the modeling episode relative to 2006 emissions. There were six days in which the daily maximum 8-hour average ozone exceeded 75 ppb in the 2006 emissions run, but no days over 75 ppb in the 2012 emissions run. The episode average HOTCOG contribution dropped from 10 ppb in the 2006 emissions run to 5 ppb in the 2012 emissions run (Figure 2-23).

The relative contributions of transported ozone and local ozone due to emissions sources within the 6-county HOTCOG area were similar in nature in both 2006 and 2012. In the 2006 emissions run, transport contributed far more (65 ppb) to ozone at the Waco monitor than did HOTCOG area emissions sources (10 ppb). This was also true in the 2012 emissions run, in which transport contributed 53 ppb and the HOTCOG area sources contributed 5 ppb.

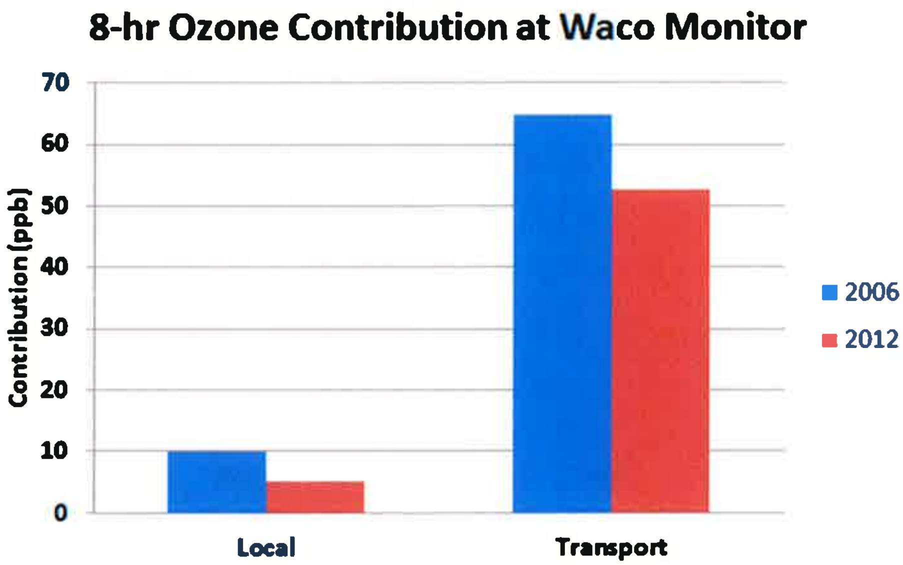


Figure 2-23. Episode average 8-hour ozone contribution to the location of the Waco Mazanec monitor.

The Waco monitor episode maximum and episode average ozone contributions from each emissions source category are shown in Figure 2-24 and Figure 2-25, respectively. In 2006, the largest value of the maximum contribution comes from on-road mobile source category (~10 ppb). On-road mobile sources also make the largest episode average contribution to ozone at the Waco monitor location. The next largest value of the maximum contribution in 2006 comes from elevated point sources. It is reasonable that the Waco monitor location should have a large maximum contribution from point sources, because there are two large EGUs, the Limestone and Big Brown facilities located nearby (Figure 2-8). Elevated point sources are the largest component of the 6-county area's NOx emission inventory. The episode average contribution from elevated point sources is lower than that of on-road and off-road mobiles sources, despite the fact that its NOx emissions are larger (Figure 2-8). This is because contributions from elevated points are more dependent on the wind direction, while on-road and off-road mobile sources are distributed more evenly across the 6-county area and so make a more consistent contribution to ozone at the Waco monitor.

Oil and gas sources make the third largest maximum contribution to ozone at the Waco monitor in 2006 and make the 4^{th} largest contribution to the episode average value. Total NOx emissions from oil and gas are 4^{th} largest source category, following elevated points and on-road and off-road mobile, which is consistent with the episode average ozone contribution results. The episode maximum contribution for oil and gas is larger than that of off-road sources, which has larger total emissions, but is a more evenly distributed across the HOTCOG area. In the 6-county area, natural gas production is concentrated in Limestone and Freestone Counties (Figure 2-13). Therefore, the contribution of oil and gas sources to ozone at the Waco monitor location depends on whether the wind direction is favorable for transport from Limestone and Freestone to the monitor. When the ozone plume from this smaller but more concentrated source affects the Waco monitor location, it has a higher maximum impact than the larger off-road mobile emissions source, which is more evenly distributed and has a more diffuse plume.

All source categories except low points sources and non-oil and gas area sources show decreases in ozone contribution of a ppb or more in 2012 relative to 2006. On-road mobile sources show the largest decrease in ozone contribution of all source categories, followed by oil and gas and non-road sources. These changes are consistent with the NOx emissions decreases shown in Figure 2-17 and Figure 2-18.

The change in anthropogenic emission inventory from 2006 to 2012 in the June 2006 episode produces large decreases in modeled ozone in the HOTCOG area. This is not consistent with the flat design value and 4th high 8-hour ozone value trends shown in Figure 2-2, however, meteorological as well as emissions changes can play a role in observed ozone trends and a full ozone model for the year 2012 must be developed to fully evaluate the effects of emissions changes between 2006 and 2012 on HOTCOG area ozone levels. This is an area for future work.

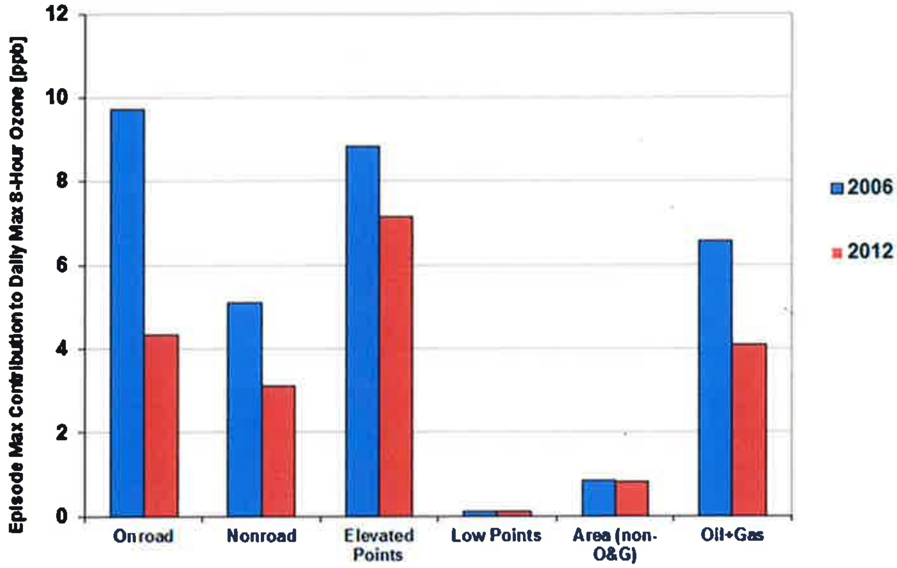


Figure 2-24. Episode maximum contribution to Waco Mazanec monitor location ozone from HOTCOG 6-county area emissions.

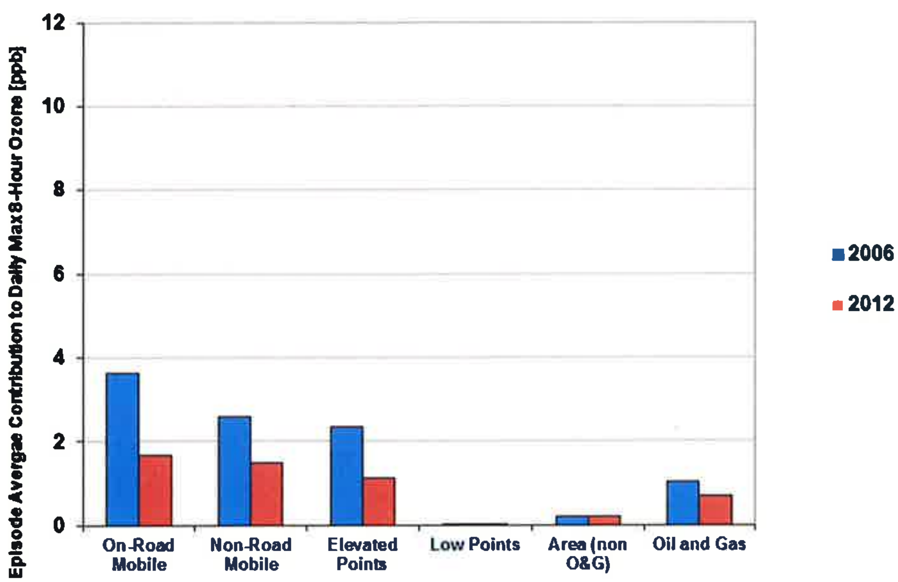


Figure 2-25. Episode average contribution to Waco Mazanec monitor location ozone from HOTCOG 6-county area emissions.

The HOTCOG AQAC is undertaking local NOx emissions control strategies designed to reduce ozone in the 6-county area (see Section 4). Different emissions source categories have different spatial and temporal distributions which can affect the magnitude of their ozone impacts. For example, an emissions reduction in a NOx source category that is broadly distributed across the HOTCOG area may have a different ozone impacts than the same NOx emission reduction made at a point source of emissions such as an EGU or industrial facility. The HOTCOG AQAC is implementing NOx emissions reductions for heavy duty diesel vehicles (HDDV) and gas compressor engines used in natural gas production. These two source categories have different spatial and temporal distributions. The ozone impacts of NOx reductions in these two source categories were investigated in an emissions reduction sensitivity test. For both source categories, a 5 tpd NOx emissions reduction was made to the TCEQ 2012 emission inventory. The magnitude of the emissions reduction is arbitrary and is designed to produce a response in the ozone model that is large enough to illustrate potential differences in ozone due to reductions in these two source categories.

Figure 2-26 shows that the 5 tpd NOx emission reduction results in a maximum reduction in 8-hour ozone of 1 ppb. The area with the largest ozone decrease is located within and to the north/northwest of Freestone and Limestone Counties, where the emissions reductions were made. The maximum plot suggests the influence of south/southeasterly and north/northeasterly winds during many of the high ozone periods during the June episode. At the location of the Waco monitor, the maximum ozone reduction was approximately 0.6 ppb. The average ozone impact plot indicates that the ozone reduction was largest within Limestone and Freestone and adjacent counties, and reached a peak value of 0.3 ppb.

Figure 2-27 shows the ozone impacts of the HDDV sensitivity test. The impacts were calculated in the same way as for the gas compressor test. The episode average plot indicates that the largest average impacts occurred within and to the north of the Waco metropolitan area. The maximum impact plot is similar to Figure 2-26 in that the presence of south-southeasterly and north-northeasterly winds during the highest ozone periods may be inferred from the location of the impacts, consistent with the wind rose and back trajectory analyses in Figure 2-20 and Figure 2-21.

Maximum ozone impacts are smaller in the HDDV test than in the gas compressor test. This is because the NOx emissions reductions in the gas compressor case were made only in two counties, while in the HDDV case, the emissions reductions were spread out across the 6-county area, causing the ozone reductions to be more evenly distributed. The temporal allocation profile for HDDV is such that the emissions reductions occur mainly during the day, when ozone is formed in the presence of sunlight. For compressors, the emissions reduction was taken equally across all hours of the day because compressor engines typically run continuously. Therefore, half of the compressor emissions reduction occurred at night, while the much of the HDDV reduction occurred during the day. This result indicates the importance of the spatial distribution of emissions for ozone reductions. The maximum ozone impact of the HDDV reduction was 0.8 ppb while the peak value of the average ozone reduction was 0.2 ppb.

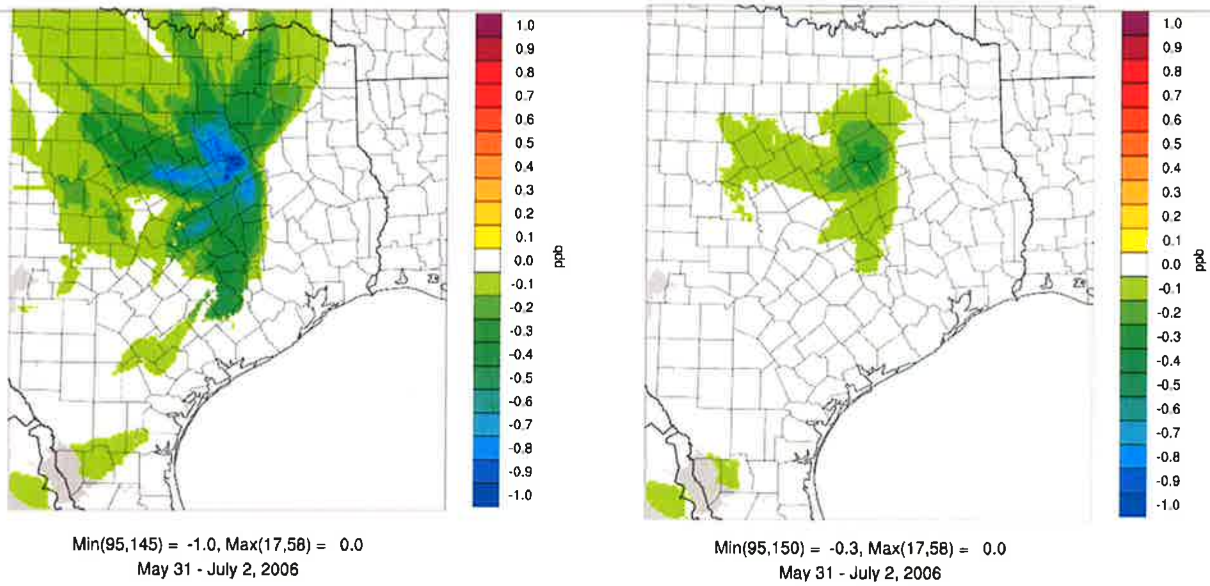


Figure 2-26. Changes in MDA8 ozone (ppb) resulting from 5 ton per day reduction in compressor engine NOx emissions. Left panel: episode maximum difference. Right panel: episode average. Differences were calculated only for times when MDA >60 ppb. Gray shading denotes grid cells that do not have any days where MDA8 > 60 ppb.

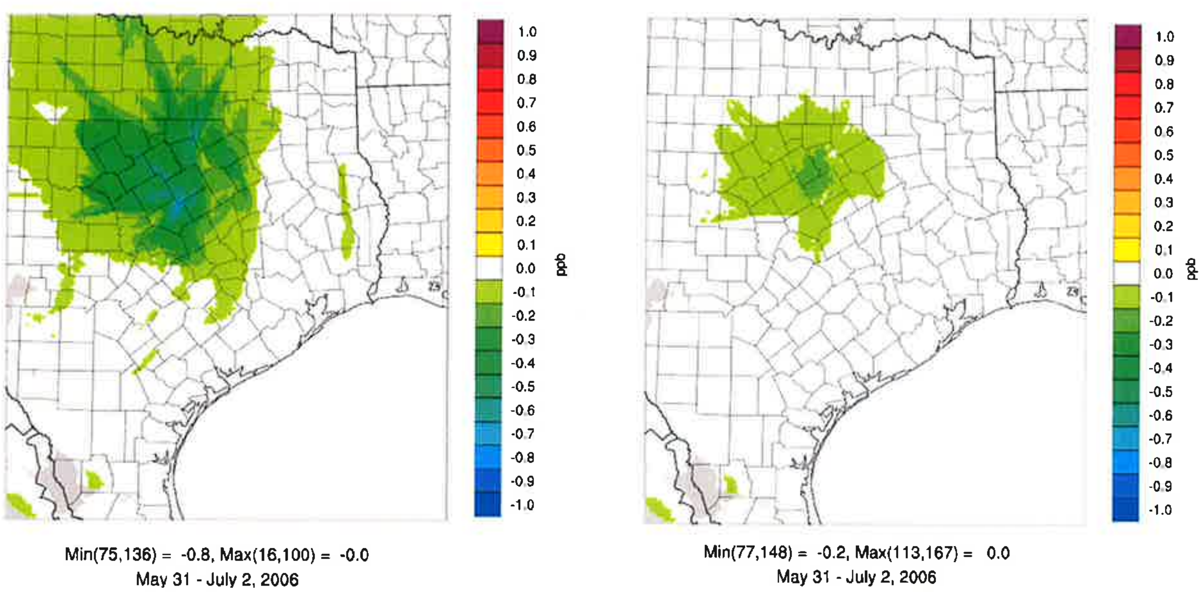


Figure 2-27. Changes in MDA8 ozone (ppb) resulting from 5 ton per day reduction in HDDV NOx emissions. Left panel: episode maximum difference. Right panel: episode average. Differences were calculated only for times when MDA >60 ppb. Gray shading denotes grid cells that do not have any days where MDA8 > 60 ppb.

3.0 STAKEHOLDER INVOLVEMENT

3.1 HOTCOG Air Quality Advisory Committee

In January 2010, the HOTCOG Air Quality Advisory Committee (AQAC) was formed in response to the Waco area's inclusion in the Texas Rider 8 Program for Near Nonattainment Areas and the potential for a new, more stringent ozone NAAQS which could have led to the HOTCOG area's designation as a nonattainment area. Although a more stringent NAAQS was not adopted, and the area remains in attainment of the NAAQS, the AQAC has worked vigorously to study local ozone air quality and to develop voluntary programs that improve air quality while protecting the regional economy. The AQAC meets monthly and has carried out a variety of activities which are described in Section 4. The AQAC includes representatives from local government, industry, the TCEQ, and private citizens and organizational support is provided by HOTCOG. The members of the AQAC are listed in Table 3-1.

Table 3-1. HOTCOG AQAC Members.

Falen Bohannon – Heart of Texas Council of Governments Environmental Planner
Bryan Ferguson - Mayor of Robinson
Chris Evilia - Waco Metropolitan Planning Organization
Jack Stiffler - Marathon Norco Aerospace
Alan Stover- Baylor University
Dick Van Dyke – Heart of Texas Economic Development District
Frank Patterson - Waco/McLennan County Emergency Management Coordinator
Malcolm Duncan, Jr. - Mayor of Waco
John Hendrickson - Waco Transit
Kathy French/Bill Peterson - LS Power
Kris Collins - Waco Chamber Economic Development
Matt Groveton - Limestone County Emergency Management Coordinator
Ed Kabobel – Texas Department of Transportation
Rebecca Sheesley, Baylor University
Polly Porter – Texas Commission on Environmental Quality
Randy Riggs - Private Citizen
Don Montgomery - Luminant
Steve Sharp - Falls County Judge
Trey Buzbee - Brazos River Authority
Wiley Stem - Waco City Manager

4.0 DESCRIPTION OF MEASURES AND PROGRAMS

In this section, we describe programs and measures aimed at improving ozone air quality in the 6-county HOTCOG area. These programs and measures were implemented by the HOTCOG AQAC and are either currently in place or are planned for the near future (i.e. 2014-2015).

4.1 Participation in TCEQ Rider 8 Program

Since 2010, the HOTCOG area has participated in the TCEQ's Rider 8 Program, which is designed to help Texas Near Nonattainment Areas (NNAs) maintain compliance with the ozone NAAQS. This program allows the NNAs to receive funding for their air quality planning efforts and to leverage the TCEQ's ongoing emission inventory development and photochemical modeling.

The TCEQ has established the following goals for the Texas NNAs under the Rider 8 Program[3]:

- Develop a conceptual understanding of local ozone formation processes;
- Evaluate local emissions inventories developed by the TCEQ (identifying possible areas of improvement);
- Analyze local ambient air quality monitoring
- Identify local emissions controls for future in-depth study
- Assess potential local monitoring networks and recommend enhancements or special studies;
- emissions inventory improvements;
- Implement local emission control strategies;
- Use a photochemical modeling episode developed by the TCEQ to analyze ozone sources and conduct sensitivity tests
- Improve public understanding of the ozone problem and motivate the public to voluntarily reduce its contribution to ozone pollution; and
- Involve local stakeholders in local air quality planning so that these efforts have broad support within local communities.

The Rider 8 program activities align well with HOTCOG's participation in Ozone Advance.

4.1.1 Technical Studies Carried out Under the Rider 8 Program

Under the Rider 8 Program, the HOTCOG AQAC has developed a conceptual model of ozone formation (McGaughey et al., 2010a, 2012; Parker et al., 2013) and made recommendations regarding the ambient monitoring network (McGaughey et al., 2010b), evaluated TCEQ emission inventories (Kemball-Cook et al., 2010) and recommended inventory improvements (Kemball-Cook et al., 2012). The AQAC has carried out a field study to examine the prevalence of heavy duty diesel vehicle idling at local truck stops (ENVIRON, 2013b) and analyzed potential local emissions control strategies (DenBleyker et al., 2013). AQAC has also performed photochemical modeling to evaluate the relative importance of ozone transport and local

[3] http://www.tceq.texas.gov/airquality/airmod/rider8/rider8-background

emissions in causing high ozone in the 6-county area, and has performed emissions sensitivity tests to evaluate the relative effectiveness of proposed local emission control strategies. The Rider 8 program also provides funding for the measures and programs described below.

All HOTCOG technical reports may be found at http://www.breatheeasywaco.org/

4.1.2 Emissions Reduction Measure: Gas Compressor Engine Retrofits

The HOTCOG AQAC's emission inventory analysis, photochemical modeling and control strategy evaluation (DenBleyker et al., 2013) work suggested that control of NOx emissions from compressor engines associated with natural gas production can reduce the local contribution to ozone in the 6-county area. Stationary gas compressor engines are distributed throughout active gas well sites in Freestone, Limestone and Hill Counties (Figure 2-13). Gas compressor engines typically run continuously for 24 hours per day throughout most of the year. Many of these engines are rich-burn engines with no emissions control systems. 3-way catalytic converters targeting NOx, CO and hydrocarbon emissions reductions will be installed on rich-burn natural gas-fired stationary gas compressor engines at gas well sites in Freestone and Limestone Counties. The target engines will be rich-burn engines that are under 240 hp in size and are therefore exempt from the East Texas Combustion Rule. Candidate engines will be selected in coordination with natural gas producer owner/operators on a voluntary basis.

Once suitable engines are selected, a catalytic converter package appropriate to each engine will be selected for purchase, and the engines will be evaluated to determine whether a suitable air-fuel ratio controller (AFRC) is present. If an AFRC is needed, one will be purchased and installed on the engine and any welding and fitting necessary to install the catalytic converter will be performed. Following installation of the catalytic converter, emissions testing will be conducted following 40 CFR Part 60 Appendix A emissions testing methods for the first catalytic converter installation. Rigorous 40 CFR Part 60 Appendix A emissions testing will be performed for the first engine retrofit in order to quantify the emissions reduction and establish the effectiveness of this control strategy for gas compressor engines in the HOTCOG area. Once the effectiveness of this control strategy is established, less-costly PEMS emissions monitoring will be performed for subsequent engine retrofits to confirm that the catalyst on each additional engine is working as intended. This will reduce the cost of the project and allow more engines to be retrofitted so that a greater NOx reduction is achieved. The number of gas compressor engines that can be retrofitted will depend upon obtaining access to suitable engines, actual costs to retrofit each engine and available funding.

Schedule for Implementation: Project will be completed by June 1, 2015

Responsible Party: All technical work will be carried out by ENVIRON under contract to HOTCOG with funding provided through the Texas Rider 8 Program. Review of technical work will be performed by the HOTCOG AQAC and the TCEQ. If industry partners for this emissions reduction measure cannot be found, funding allotted for this measure will be reallocated to the municipal fleet retrofit/replacement emissions reduction measure described below.

4.1.3 Emissions Reduction Measure: Municipal Fleet Diesel Engine Retrofit/Replacement

The HOTCOG AQAC's emission inventory analysis, photochemical modeling and control strategy evaluation work also suggested that control of NOx emissions from heavy duty diesel vehicles is another effective means to reduce the local contribution to HOTCOG area ozone. Control strategies selected focus on heavy-duty diesel vehicles because they emit NOx at a higher rate per mile and often drive more miles per year than light-duty vehicles. During 2014-15, the AQAC plans to carry out diesel engine repowers and/or diesel vehicle replacements for locally-operating municipal fleet vehicles if suitable vehicles can be identified. The AQAC will review HOTCOG area municipal fleets of light-duty, medium-duty and heavy-duty diesel vehicles to identify candidates for an engine repower and/or a vehicle replacement. Consideration will be given to the age of the vehicle, technical feasibility of repowering/replacing, the current usage of the vehicle, and the cost per vehicle repower or replacement. Repowering will install an engine meeting a later model year emission standard for NOx (dependent on technical feasibility constraints). Replacement will be conducted to an engine meeting the latest model year emission standard for NOx (0.20 g/bhp-hr). HOTCOG area municipal vehicle fleets will be analyzed to identify candidate engine(s) or vehicle(s), identify engine replacements or vehicle replacements, obtain quotes, and document the emissions benefits of the repower or replacement. Cost estimates for diesel engine repowers or diesel vehicle replacements will be made after the municipal vehicle fleet is analyzed. The number of diesel engine repowers and/or diesel vehicle replacements will depend upon obtaining access to suitable vehicles, actual costs and available funding.

Schedule for Implementation: Project will be completed by June 1, 2015

Responsible Party: All technical work will be carried out by ENVIRON under contract to HOTCOG with funding provided through the Rider 8 Program. Review of technical work will be performed by the HOTCOG AQAC and the TCEQ.

4.1.4 Emissions Reduction/Public Outreach Measure: Bicycle Rack Installation Program

Replacing motor vehicle trips with bicycle trips reduces ozone precursor emissions from the motor vehicle trips saved. The HOTCOG AQAC has determined that the lack of bicycle parking is a barrier to increased bicycle commuting within the 6-county HOTCOG area. The purpose of this outreach project is to create safe places for bicycle parking, thereby encouraging trips that might not be otherwise performed by bicycle.

The AQAC will determine suitable locations for bicycle parking sites based on anticipated levels of use and visibility by modes of transport other than bicycle (e.g. traffic counts). The AQAC will then purchase bicycle parking racks and shall provide them to the communities, who will be required to provide the labor to remove existing pavement from the sites, install the bicycle parking racks, and replace the pavement. The bicycle parking racks will be used as an advertising space on which to raise public awareness about ozone air quality in the HOTCOG area.

The AQAC plans to advertise the availability and location of the bicycle parking facilities on its web site and at local events. In order to determine the effectiveness of the program, the AQAC will observe usage of the racks on a monthly basis at various times of day and/or days of the week to determine whether usage is increasing, decreasing or not significantly changing. The AQAC will then estimate the number of bicycle trips to/from each bicycle parking site and then estimate the amount of visibility achieved by the outreach effort.

Schedule for Implementation: Project will be completed by August 1, 2015

Responsible Party: The bike rack program will be implemented by HOTCOG with funding provided through the Rider 8 Program. Review of the Bicycle Rack Program will be provided by the TCEQ.

4.1.5 Public Outreach Programs

The AQAC carries out a number of public outreach activities under the Rider 8 Program. The AQAC maintains a public web site to facilitate public access to air quality information and updates on technical and outreach activities (http://www.breatheeasywaco.org/). The website provides information on ozone and specific actions citizens can take to improve air quality as well as contact information for citizens who would like to become more involved in addressing local air quality issues. The website shows TCEQ air quality forecasts for current and upcoming days and notes whether high ozone is expected in the Waco area during the next few days. The AQAC documents traffic on its website by counting the number of times the web site is "hit" during each quarter. HOTCOG also maintains a Facebook page dedicated to increasing public awareness about ozone. The website is updated when the TCEQ's daily ozone forecast indicates that a high ozone day is expected for the Waco area and provides information on specific actions citizens can take to reduce ozone in the 6-county area. The website address is: https://www.facebook.com/AirQualityHOTCOG?filter=1.

The AQAC has provided air quality-themed signage for public buses in the area. Figure 4-1 shows a bus wrap for a City of Waco Public Transportation Bus. Routes for the bus are varied so that it travels in McLennan County and throughout the Waco area, and the bus is used for Baylor University events and other local special events. There is a QR code on the back of the bus that provides direct access to the BreatheEasyWaco.org website. The lifetime for the bus wrap is three years. Similar air quality-themed signage was also placed on 10 rural transportation buses with routes in the other five HOTCOG counties.

Schedule for Implementation: Ongoing.

Responsible Party: All public outreach programs will be implemented by HOTCOG with funding provided through the Rider 8 Program. Review of outreach programs will be provided by the TCEQ.

Figure 4-1. Air-quality bus wrap on a City of Waco Public Transportation Bus.

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