APPENDIX B

Weight of Evidence Analysis

Weight of Evidence

San Joaquin Valley

Attainment Plan for the 0.075 ppm 8-Hour Ozone SIP

May 2016

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1 Introduction

This weight-of-evidence (WOE) document provides support for the modeled attainment demonstration that projects the San Joaquin Valley (Valley or SJV) air basin will attain the National Ambient Air Quality Standard (NAAQS or standard) of 0.075 parts per million (ppm) for 8-hour ozone by 2031.

This introduction includes a brief description of the elements of a WOE analysis, a physical context for the processes that lead to ozone formation in the Valley, and an assessment of current ozone air quality in the Valley. The remainder of the document provides a broad foundation of information that corroborates the modeled attainment demonstration.

1.1 Elements Commonly Included in an Attainment Demonstration

The attainment demonstration portion of a State Implementation Plan (SIP) consists of the analyses used to determine whether the current control strategy provides the reductions necessary to meet the standard by the specified attainment year. This attainment demonstration includes photochemical modeling which predicts that projected controls on ozone-forming emissions will result in an 8-hour design value for the Valley that is below the level of the national standard of 0.075 ppm by 2031.

Because of the inherent uncertainties in photochemical modeling, the U.S. Environmental Protection Agency (EPA) requires states to supplement the modeling results with a WOE assessment. The WOE assessment provides a set of analyses that complement the photochemical modeling. In this document, these analyses include consideration of measured air quality, emissions inventories, and meteorological data. All analysis methods have innate strengths and weaknesses, so examining an air quality problem in a variety of ways can help to offset the limitations and uncertainties inherent to individual methods. This approach also provides a better understanding of the overall problem, as well as insight about the level and mix of emissions controls needed for attainment.

The scope of the WOE analysis is different for each nonattainment area, with the level of appropriate detail dependent upon the complexity of the air quality problem, how far into the future the attainment deadline is, and the amount of data and modeling available. In this case, the Valley is moving towards attainment of the 8-hour ozone standard, and the projected attainment date (2031) is based on multiple methods to evaluate the modeling results. This document summarizes the analyses that provide a WOE assessment that complement the model results.

1.2 Physical Context

Ozone forms in the lower atmosphere through a complex set of processes that are initiated by sunlight; therefore, ozone is called a photochemical pollutant. The sun's energy also drives meteorological processes through diurnal cycles from sunrise to

sunrise and through seasonal cycles from winter to winter. As a result of these photochemical and meteorological processes, the "ozone season" with relatively high ambient ozone levels in California's San Joaquin Valley is defined, for this document, as May through October.

The San Joaquin Valley is located in the Central Valley of California, in a semi-arid climate with long, hot, dry summers, and mild winters. The Valley is also situated between two mountain ranges which meet in the south of the Valley near Bakersfield. On the west side of the Valley is the Coastal mountain range and on the east side is the Sierra Nevada mountain range. During the summer season, a high pressure system builds up over the eastern Pacific Ocean and a thermal low pressure system forms over the desert in the southwestern United States; this produces hot, dry conditions that cause thermally driven wind flow patterns across the Valley. These meteorological conditions cause poor dispersion and stagnation which are conducive to the formation of elevated ozone concentrations.

Wind speed plays a significant role in the dispersion of air pollutants. Figure 1 depicts the typical daytime and nighttime wind flow patterns during the ozone season in the Valley. The dominant wind flow pattern during the daytime in the Valley is from the northwest to the southeast. Surface winds, known as the Delta Breeze, enter the Valley from the northwest through the delta passes in the Coastal Range. The airflow generally moves from Stockton to Bakersfield, carrying ozone and the precursor emissions that contribute to ozone formation from both the San Francisco Bay area and the Sacramento Valley.

The effect of transport is seen in the accumulation of ozone in the central and southern portions of the Valley. Historically, the cities of Parlier (downwind of Fresno) and Clovis, and the communities of Edison and Arvin (downwind of Bakersfield) have often experienced the highest ozone levels in the Valley. High ozone levels can also occur closer to emission sources. In recent years, the highest ozone levels have occurred in the cities of Clovis and Fresno. In the Valley, high ozone has a large component that is due to local emission production, as the ozone is generally lowest for each city at the upwind site, increases in the city, and is highest at downwind locations.

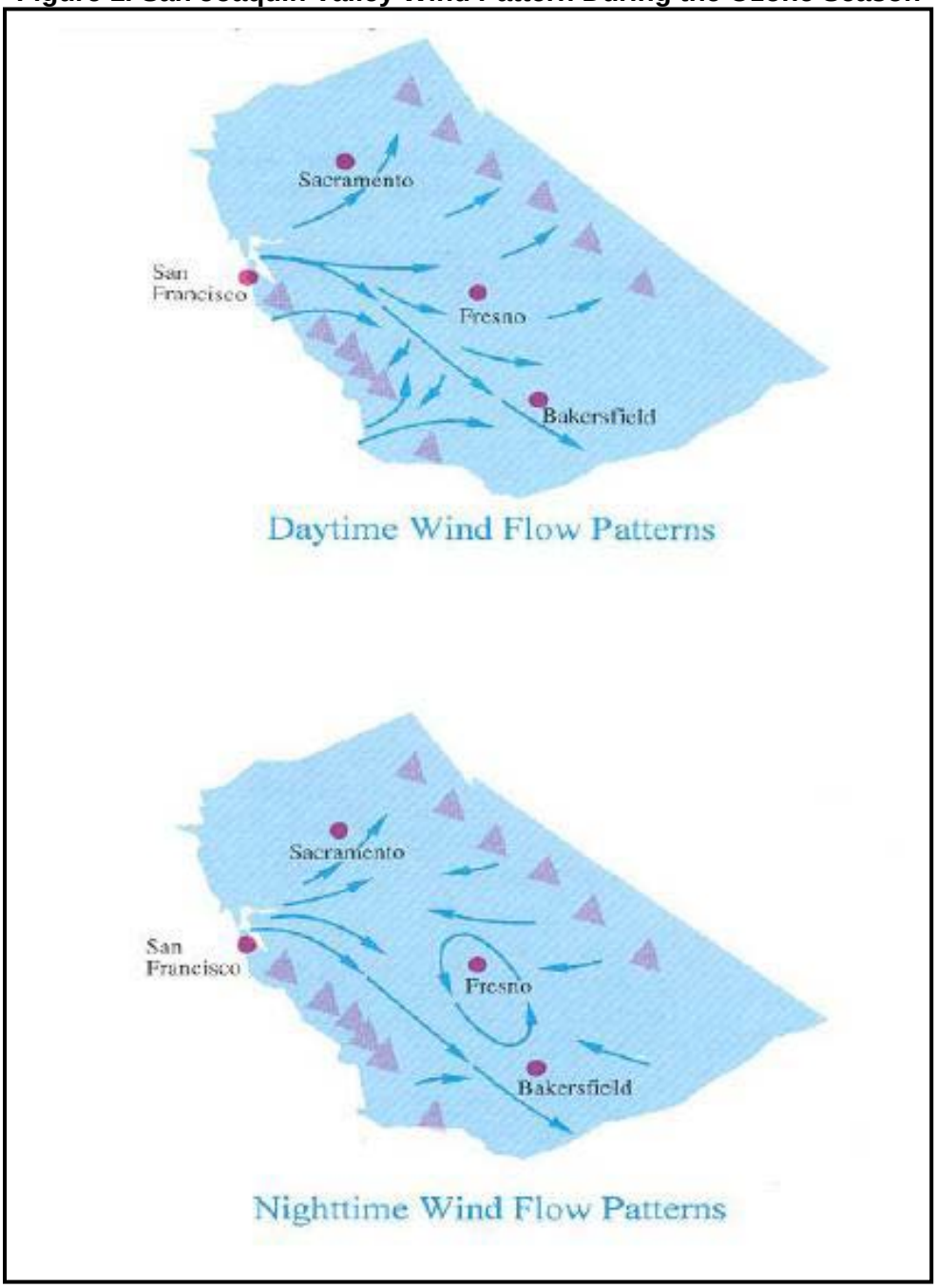
At night, the general northwest to southeast surface wind flow pattern continues along the western portion of the Valley; however, some nighttime wind circulation changes also occur when:

1) The airflow is no longer able to exit the southern end of the Valley because it encounters cooler drainage winds from the surrounding mountains.
2) A nocturnal jet stream approximately 1,000 feet above the surface flows at speeds up to 33 miles per hour (mph), transporting air rapidly into the southern portion of the Valley; however, the mountains surrounding the southern end of the Valley cause the air to turn counterclockwise and flow back toward the north along the eastern edge of the Valley. This flow, referred to as the Fresno eddy,

circulates the pollution plume back toward Fresno, where it encounters more ozone precursors.

3) Pollutants carried in the upslope mountain flow during the day via daytime heating are carried back downslope toward the Valley floor via drainage flows caused by nocturnal surface cooling.

Figure 1. San Joaquin Valley Wind Pattern During the Ozone Season



Source: http://www.valleyair.org/Air_Quality_Plans/OzoneOneHourPlan2013/05AppendixAAmbientAnalysis.pdf

A third of the basin population lives in the northern Valley. This lowland area is bordered by the Sacramento Valley and Delta lowland to the north, the central portion of the San Joaquin Valley to the south, and by mountains on the other two sides. Because of the marine influence, which extends into this area through gaps in the Coastal Range to the west, the northern Valley experiences a more temperate climate than the rest of the basin. These cooler temperatures and the predominant air flow patterns generally favor better ozone air quality.

In contrast to the northern Valley, most of the Valley population lives in the central and southern portions of the basin, in and around the Fresno and Bakersfield urban areas. Sites in the central and southern areas exceed the national standard by the greatest margin, and geography, emissions, and climate pose significant challenges to air quality progress. Similar to the northern Valley, the central and southern Valley are also low lying areas, flanked by mountains on their west and east sides. The southern Valley represents the terminus of the Valley and is flanked by mountains to the south, as well. The surrounding mountains in both areas act as barriers to air flow, and combined with recirculation patterns and stable air, trap emissions and pollutants. The higher temperatures and more stagnant conditions in these two regions lead to a build-up of ozone and overall poorer air quality.

1.3 Recent Air Quality

The San Joaquin Valley has one of the most challenging ozone problems in the nation, and is one of only two nonattainment areas classified as extreme. Currently only one site attains the national 8-hour ozone standard. However, recent trends are showing that ozone has become increasingly more responsive to emissions reductions, and the Valley's highest ozone levels today are much lower than they were just 10 years ago.

Table 1 shows the current operational sites in the Valley and their most recent design values. The scope of this document includes official data submitted through 2014. A preliminary look at 2015 using available official data, supplemented with preliminary data, is evaluated at the end of this document. The northern region has the lowest values in the Valley. Stockton-Hazelton Street is the only site below the current standard of 0.075 ppm with a 2014 design value of 0.069 ppm**.**
Tranquility-32650 West Adams Avenue also meets the standard at 0.075 ppm. The highest site in the northern region is Turlock-S Minaret Street with a design value of 0.084 ppm. Peak sites in the central region are Clovis-N Villa Avenue (0.095 ppm) and Parlier (0.092 ppm), which have the highest design values in the Valley. Finally, the highest sites in the southern region are Bakersfield-Municipal Airport and Sequoia and Kings Canyon National Park with design values of 0.091 ppm in 2014.

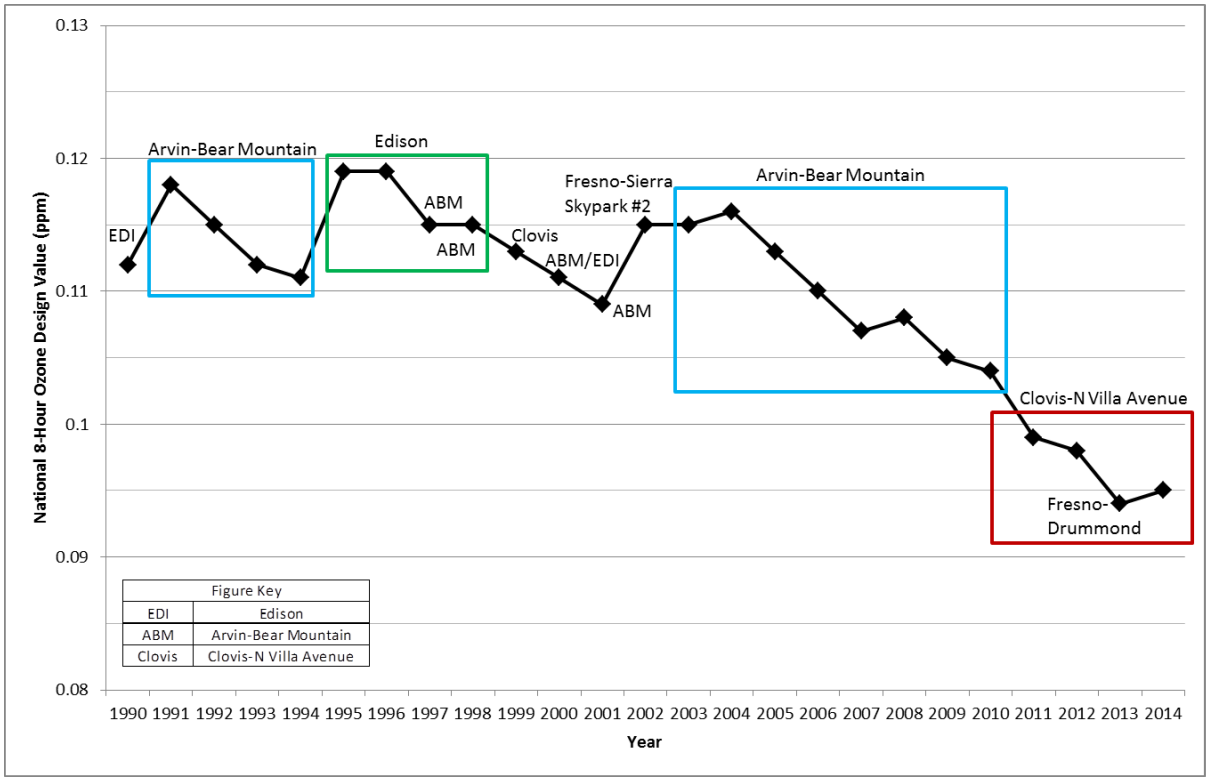
Table 1. Recent Design Values for Sites Currently Operating in the SJV (in ppm)

	County	Site	2012	2013	2014
Northern	Merced	Merced-S Coffee Avenue	0.083	0.081	0.081
	San Joaquin	Stockton-Hazelton Street	0.069	0.067	0.069
	San Joaquin	Tracy-Airport	0.080	0.079	0.079
	Stanislaus	Modesto-14th Street	0.075	0.075	0.078
	Stanislaus	Turlock-S Minaret Street	0.088	0.086	0.084
Central	Fresno	Clovis-N Villa Avenue	0.098	0.094	0.095
	Fresno	Fresno-1st Street/Fresno-Garland	0.094	0.089	0.089
	Fresno	Fresno-Drummond Street	0.095	0.094	0.088
	Fresno	Fresno-Sierra Skypark #2	0.092	0.088	0.087
	Fresno	Parlier	0.092	0.092	0.092
	Fresno	Tranquility-32650 West Adams Avenue	0.077	0.077	0.075
	Kings	Hanford-S Irwin Street	0.090	0.084	0.084
	Madera	Madera-28261 Avenue 14	0.086	0.084	0.084
	Madera	Madera-Pump Yard	0.078	0.079	0.081
Southern	Kern	Arvin-Di Giorgio	0.091	0.089	0.088
	Kern	Bakersfield-5558 California Avenue	0.089	0.086	0.085
	Kern	Bakersfield-Municipal Airport	N/A	N/A	0.091
	Kern	Edison	0.093	0.086	0.084
	Kern	Maricopa-Stanislaus Street	0.087	0.084	0.079
	Kern	Oildale-3311 Manor Street	0.089	0.084	0.081
	Kern	Shafter-Walker Street	0.086	0.082	0.081
	Tulare	Porterville-1839 Newcomb Street	0.090	0.088	0.081
	Tulare	Sequoia and Kings Canyon National Park	0.095	0.093	0.091
	Tulare	Sequoia National Park-Lower Kaweah	0.081	0.085	0.086
	Tulare	Visalia-N Church Street	0.087	0.080	0.080

2 Assessment of Valleywide Air Quality Progress

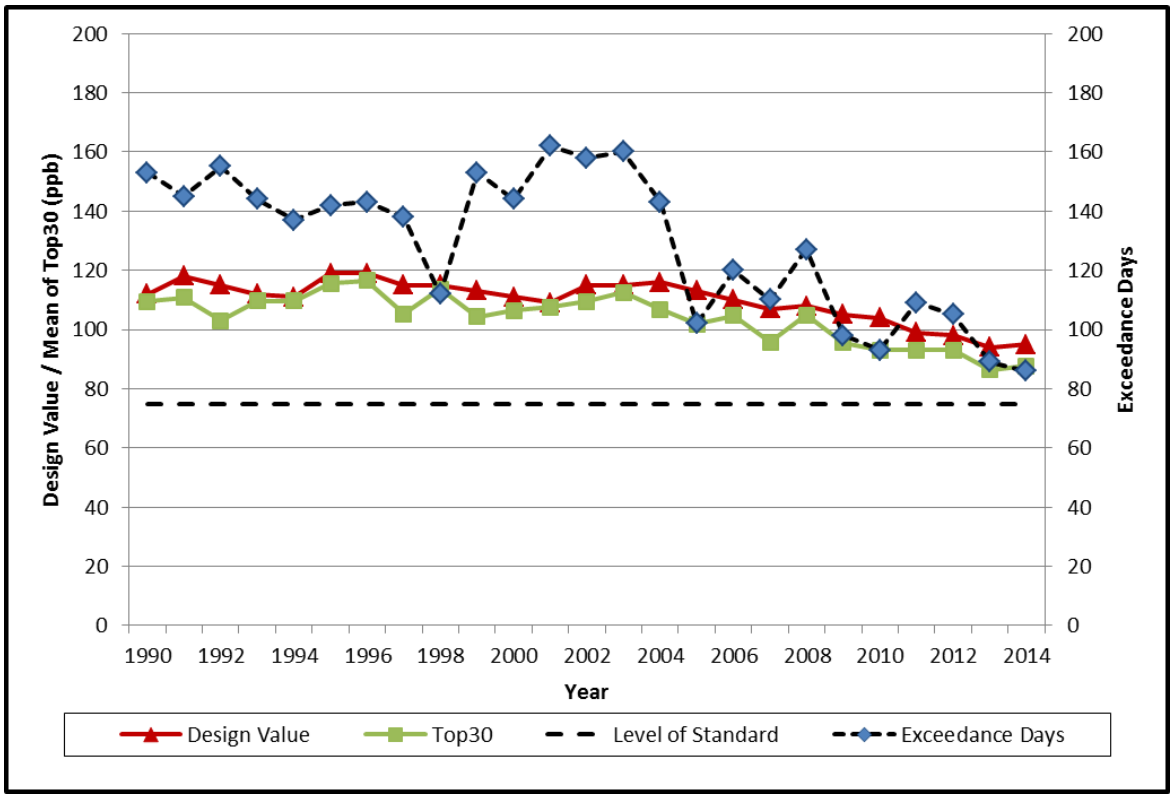
Figure 2 shows the basinwide design value trend from 1990 to 2014. Over the last 20 years, the design site has alternated between the central region (Clovis-N Villa Avenue, Fresno-Drummond, or Fresno-Sierra Skypark #2) and the southern region (Edison and/or Arvin-Bear Mountain). The Valley experienced modest progress between the 1990s and early 2000s, but since 2004, there has been a consistent and substantial trend towards lower ozone levels.

Figure 2. Design Value Trend for the San Joaquin Valley Air Basin



Trends for three air quality indicators – design value, exceedance days, and mean of top 30 – are provided for the air basin from 1990-2014 in Figure 3. These three indicators address different aspects of ozone air quality, and together provide information to evaluate overall progress in reducing ozone exposure as well as attaining the standard. The design value (DV), U.S. EPA's compliance metric, is the average of the fourth highest daily maximum 8-hour concentration in each year measured over a consecutive three year period. A site meets the standard when its design value is less than or equal to 0.075 ppm, the effective level of the standard. The mean of top 30 is a stable and responsive measure of progress as it represents the trend in the upper 8 percent of daily maximum 8-hour ozone levels during the year. Finally, the exceedance day metric shows how many days in a year the 8-hour ozone was above the standard. Due to the nature of this metric, exceedance days will generally show the most year-to-year variability. However, it is still an important metric to consider, as it does provide a measure of the frequency of exposure. Similar to the design value, the mean of top 30 and exceedance days have shown the most progress since 2004. Although there is some year-to-year variability such as the 2008 ozone season which was heavily impacted by wildfires, every metric has shown considerable progress over the past decade.

Figure 3. Ozone Trends (1990-2014) in the San Joaquin Valley Air Basin



3 Recent Trends (2004-2014)

In the early 2000s, almost the entire Valley exceeded the 8-hour ozone standard, and the standard was exceeded somewhere in the Valley approximately 150 days during the ozone season each year. However, ozone air quality has improved throughout the region, with the basinwide design value (highest design value at any site in the basin) declining by 18 percent between 2004 and 2014, and basinwide exceedance days declining by 40 percent.

3.1 Basinwide Perspective

As shown in Figure 4, which is a magnified version of Figure 3 for years 2004-2014, there is a steady decline of the two more stable metrics, the design value and the mean of the top 30, as well as the number of exceedance days.

Figure 4. Recent Ozone Trends (2004-2014) in the San Joaquin Valley Air Basin

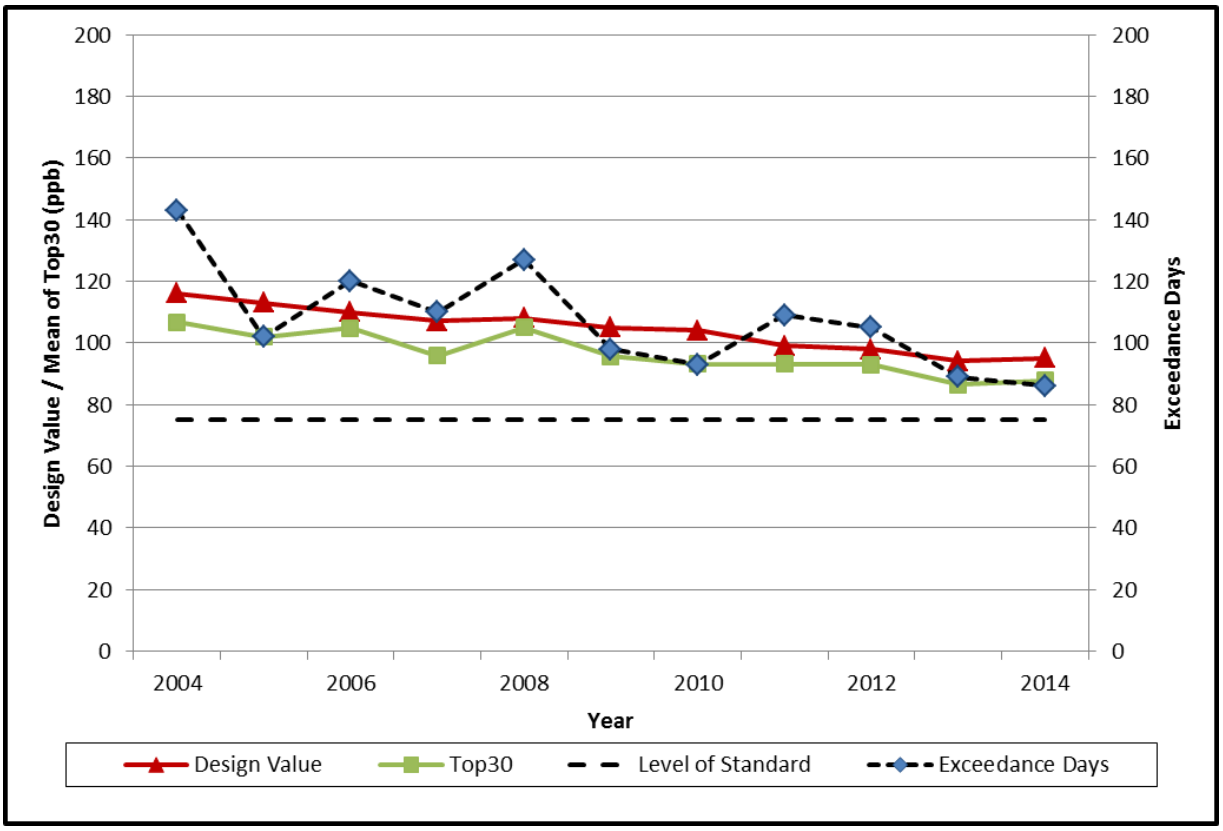
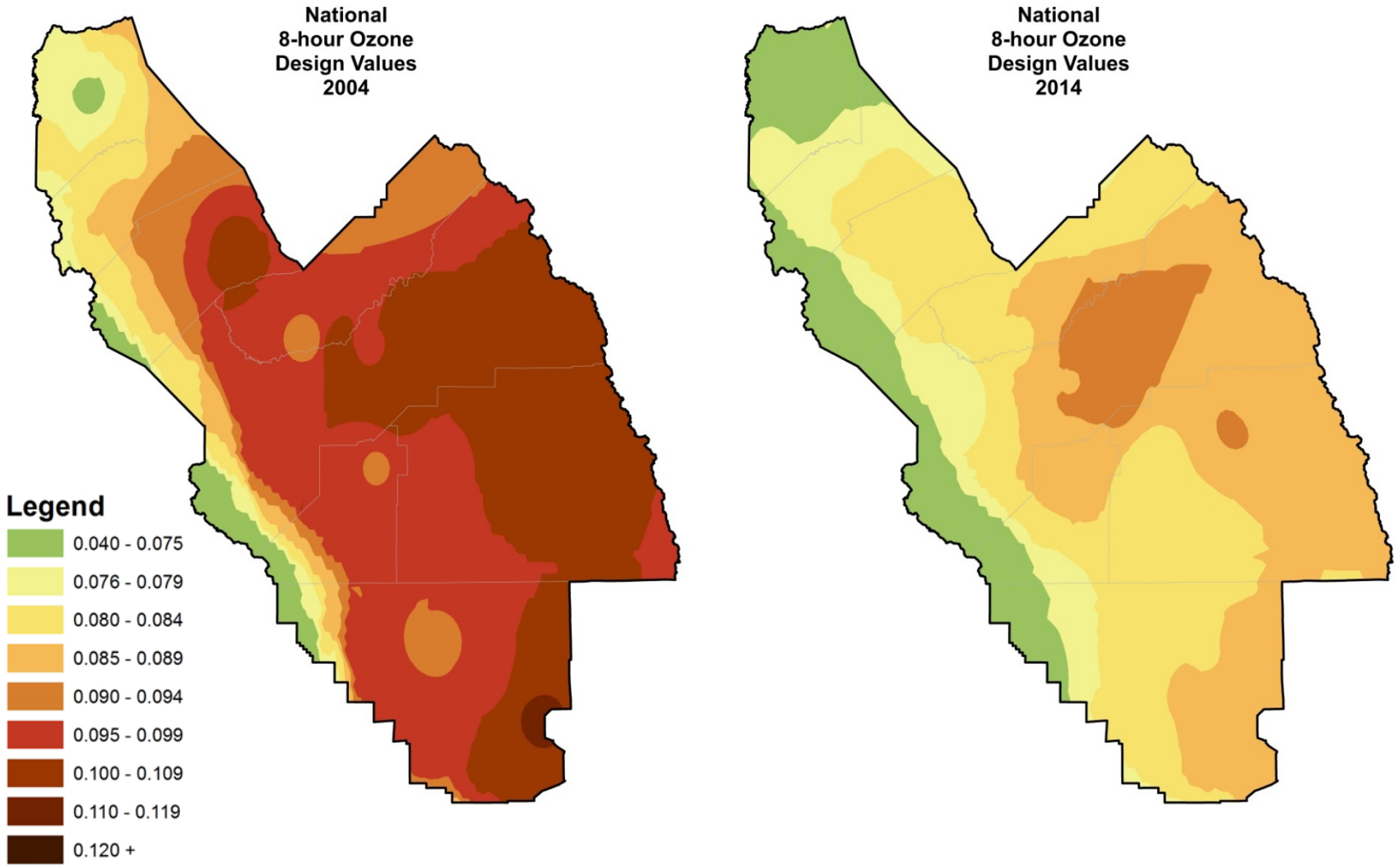


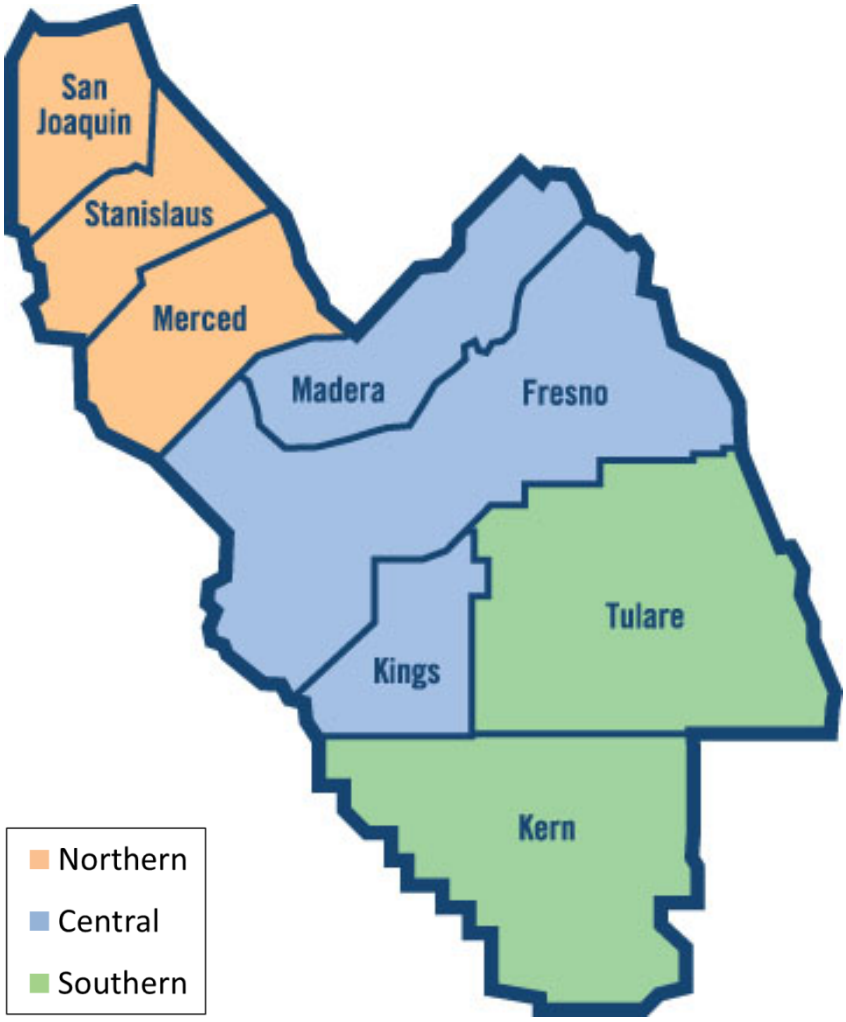
Figure 5 illustrates the progress that has been made in reducing the spatial extent of design values in the Valley. In 2002-2004, most of the Valley was far above the 0.075 ppm ozone standard. Today, a larger portion of the Valley is in attainment, all of the regions are significantly closer to the level of the standard, and the extent of the ozone problem is diminishing.


National
8-hour Ozone
Design Values
2004
National
8-hour Ozone
Design Values
2014
Legend
0.040 - 0.075
0.076 - 0.079
0.080 - 0.084
0.085 - 0.089
0.090 - 0.094
0.095 - 0.099
0.100 - 0.109
0.110 - 0.119
0.120 +

3.2 Regional Trends

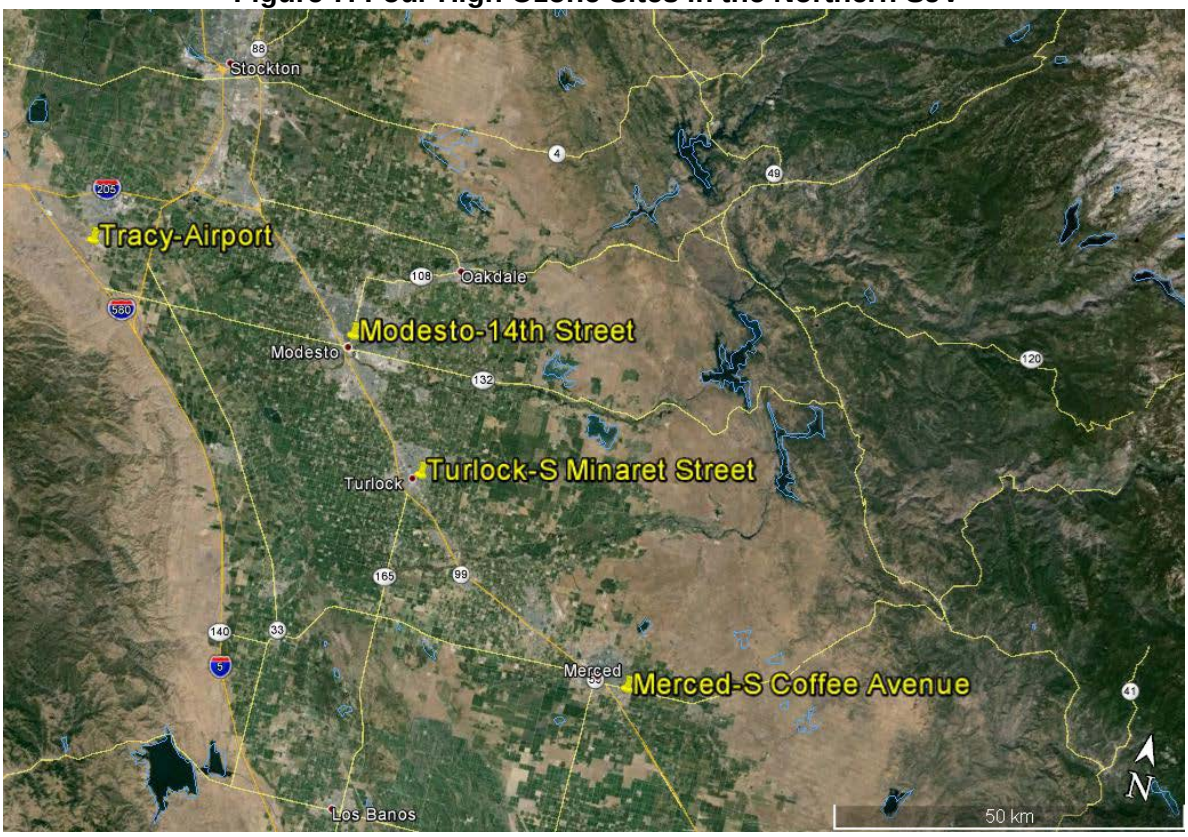
For the purpose of this analysis, the Valley is split up into three different regions: northern, central, and southern. Figure 6 shows a map of the Valley and each county, split into the three regions. The following section shows trends for the highest sites in each region from 2004 through 2014. Data for the Fresno-1st Street and Fresno-Garland sites have been merged into one data record because U.S. EPA considers Fresno-Garland an official replacement for the Fresno-1st Street monitor. A map of the locations of these monitoring sites in each region is shown in Figures 7, 12, 17, and 22.

Figure 6. Counties and Regions in the San Joaquin Valley



Source: https://www.valleyair.org/General_info/aboutdist.htm

Figure 7. Four High Ozone Sites in the Northern SJV



Figures 8 through 11 show trends of selected sites in the northern region over the past decade. All of the sites are very close to the standard. The highest site in 2004, Merced-S Coffee Avenue, has had over a 20 percent decrease in design value (from 0.102 to 0.081 ppm), and a 53 percent decrease in exceedance days (from 47 to 22). Design values at Modesto-14th Street decreased by 6 percent and the site is now nearing the level of the standard (from 0.083 to 0.078 ppm). The northern region also demonstrates how local ozone production is a large contributor for the highest ozone values. The upwind site, Stockton-Hazelton Street, is the only site that is in attainment of the standard, at 0.069 ppm (from Table 1). Moving south along the predominant wind flow direction, ozone levels increase at Modesto-14th Street (0.078 ppm), and are highest at the downwind sites of Turlock-S Minaret Street and Merced-S Coffee Avenue (0.084 and 0.081 ppm, respectively).

Figure 8. Ozone Trends for Merced-S Coffee Ave

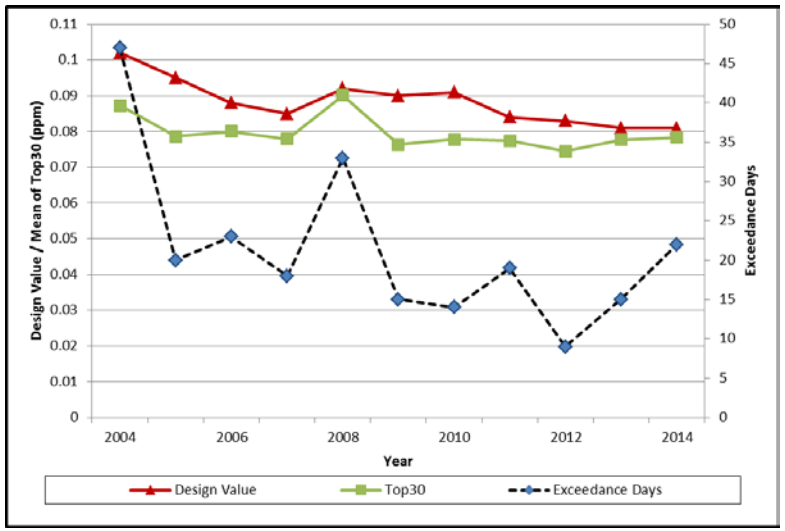


Figure 9. Ozone Trends for Turlock-S Minaret St

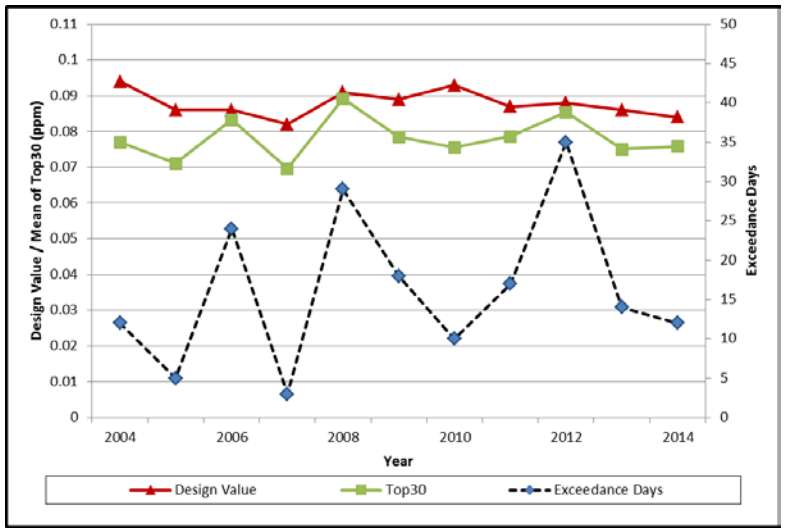


Figure 10. Ozone Trends for Tracy-Airport

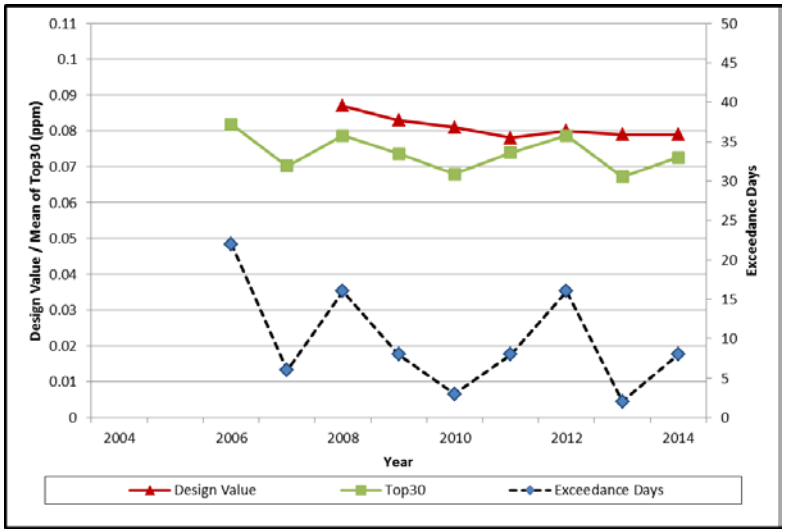


Figure 11. Ozone Trends for Modesto-14th St

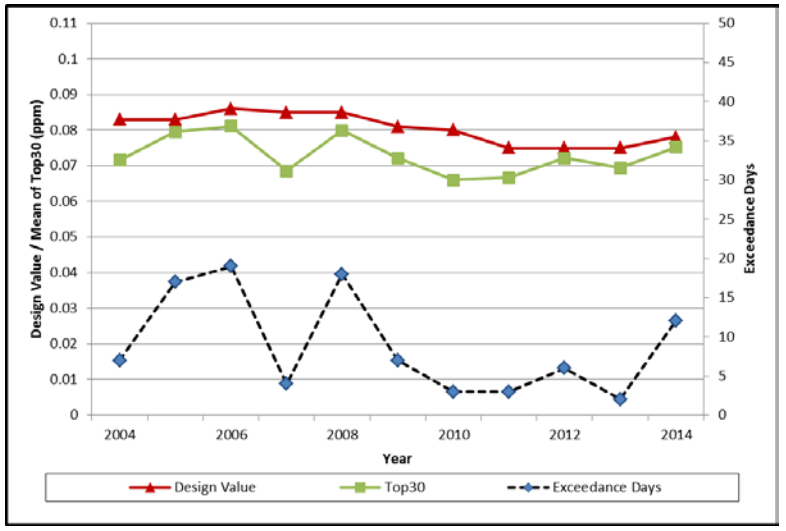
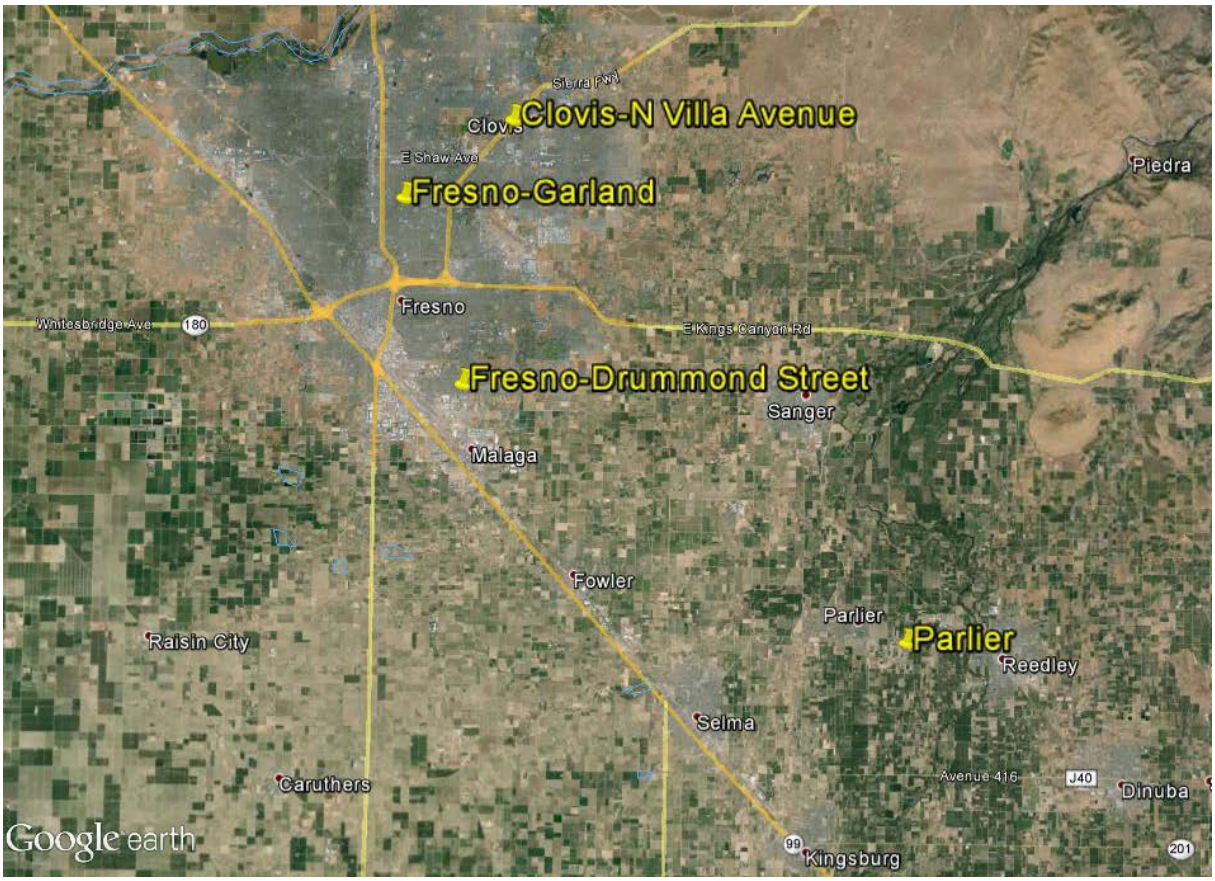


Figure 12. Four High Ozone Sites in the Central SJV



Figures 13 through 16 show trends for selected sites in the central region. This region currently records the highest ozone values in the Valley. The more northern sites in this region, such as Madera-Pump Yard and Fresno-Sierra Skypark #2 (not depicted) now have the lowest design values. In this time period, these sites had decreases in design value of 9 percent (0.089 to 0.081 ppm) and 16 percent (0.104 to 0.087 ppm), respectively. Fresno-Drummond had a 13 percent drop in design value (0.101 to 0.088 ppm), Parlier had a 12 percent drop (0.104 to 0.092 ppm), and Fresno-1st Street/Garland had a 13 percent drop (0.102 to 0.089 ppm). Clovis-N Villa Avenue showed similar levels for all metrics in 2014 compared to 2004, but has been steadily decreasing since 2010. The other two metrics show greater year-to-year variability for each site, with modest progress for the top 30 and exceedance days. Additional discussion of trends in the central region is provided in subsequent sections.

Figure 13. Ozone Trends for Clovis-N Villa Ave

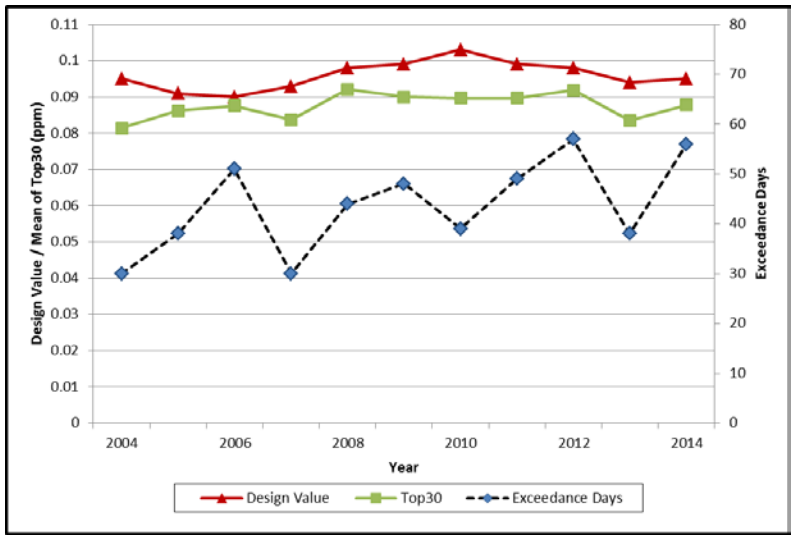


Figure 14. Ozone Trends Fresno-Drummond

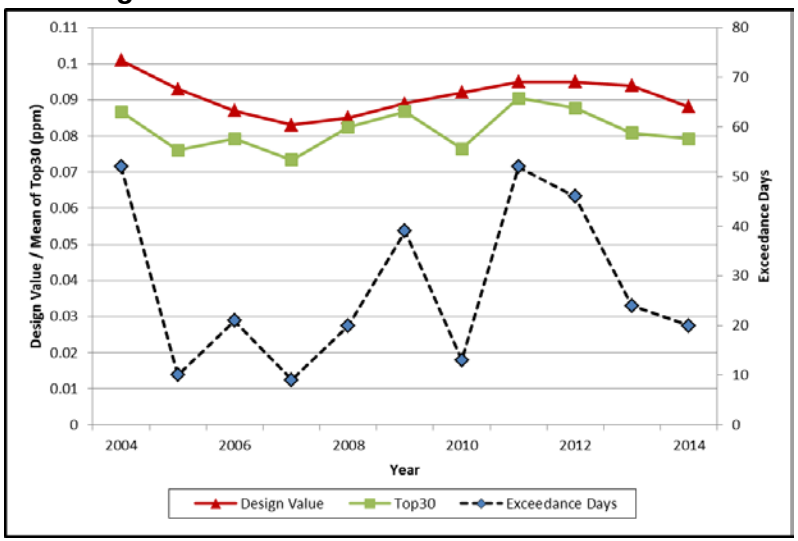


Figure 15. Ozone Trends for Parlier

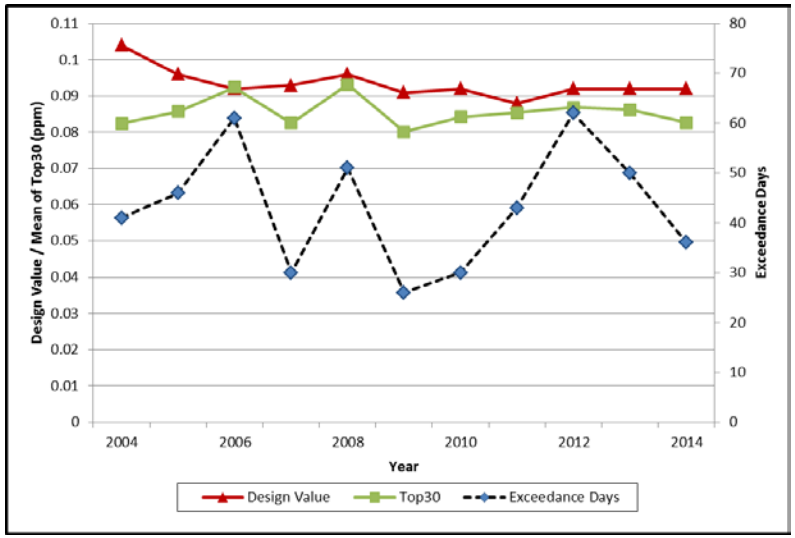


Figure 16. Ozone Trends for Fresno-1st St/Garland

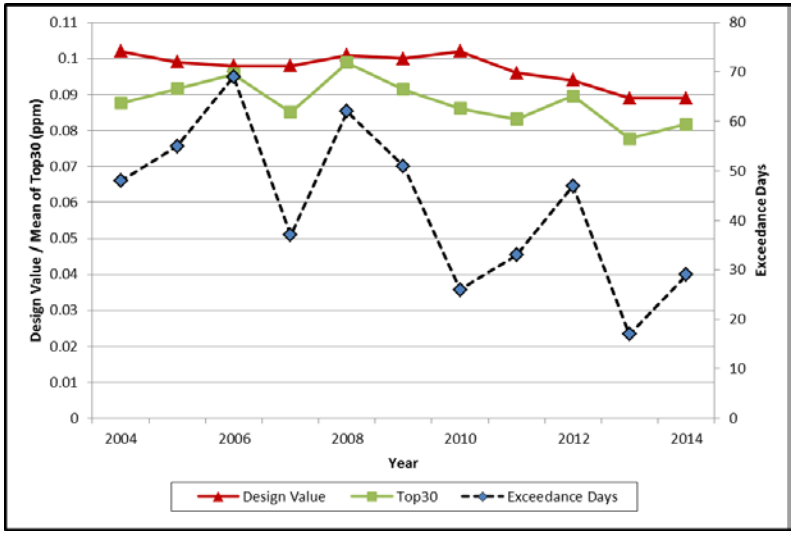


Figure 17. Four High Ozone Sites in the Southern SJV

Figures 18 through 21 show trends for the selected sites in the southern region. In the past, the Valley's highest 8-hour concentrations occurred in the southern region. However, all of the sites in this region have shown considerable progress since 2004. As demonstrated by Edison and Bakersfield-5558 California Ave, this region has showed the most progress since 2010. These two sites had relatively flat trends for design values from 2004 to 2010, but have had a steady decrease since then. Since 2004, Edison and Bakersfield-5558 California Ave have shown a 17 percent (0.101 to 0.084 ppm) and a 12 percent (0.097 to 0.085 ppm) decrease in design value, respectively. Similar to the design value, the top 30 and exceedance day metrics are showing steady declines, especially since 2010, but with a bit more year-to-year variability. Arvin-Di Giorgio was established in 2010 as a replacement site for Arvin-Bear Mountain, which was shut down after the 2010 ozone season when the lease for that site was terminated, and both sites have been the highest site in the region in this time frame. In combination, the Arvin sites show significant decreases in ozone over the last ten years. Bakersfield-Municipal Airport is a new site, established in July 2012. As previously shown in Table 1, this site has only had one design value since its inception, 0.091 ppm in 2014. As a recently established site, there is insufficient history to present a meaningful trend alongside the trends shown for the other four sites.

Figure 18. Ozone Trends for Arvin-Bear Mountain

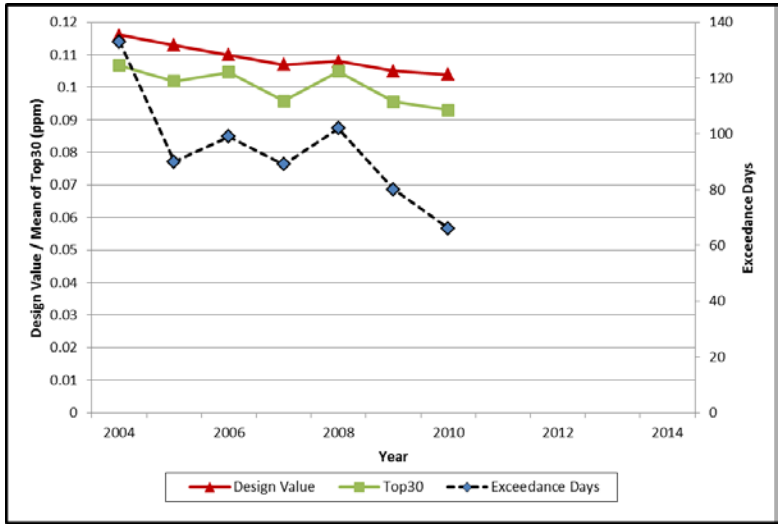


Figure 19. Ozone Trends for Edison

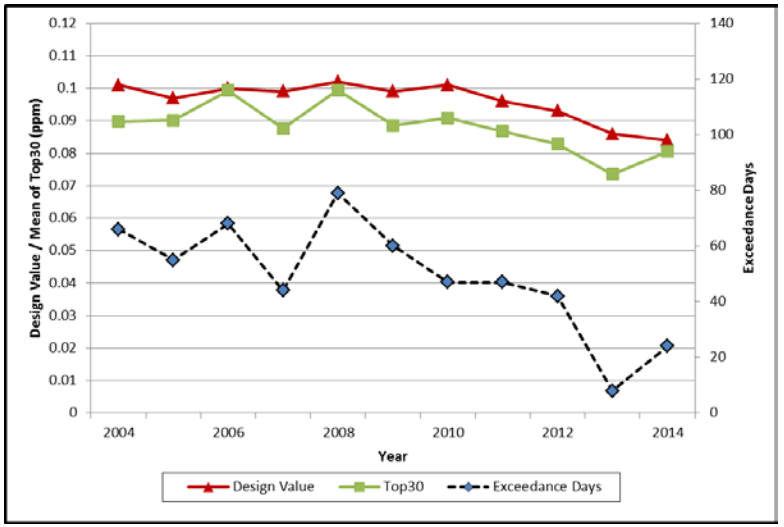


Figure 20. Ozone Trends for Arvin-Di Giorgio

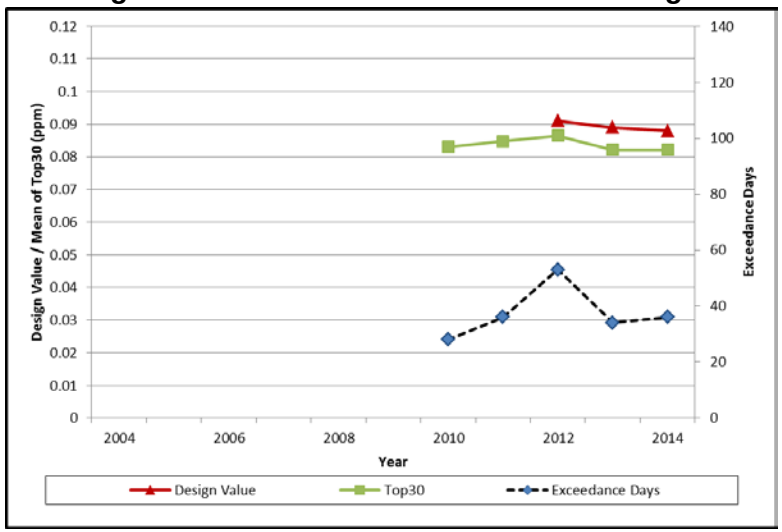


Figure 21. Ozone Trends for Bakersfield-5558 Ca Ave

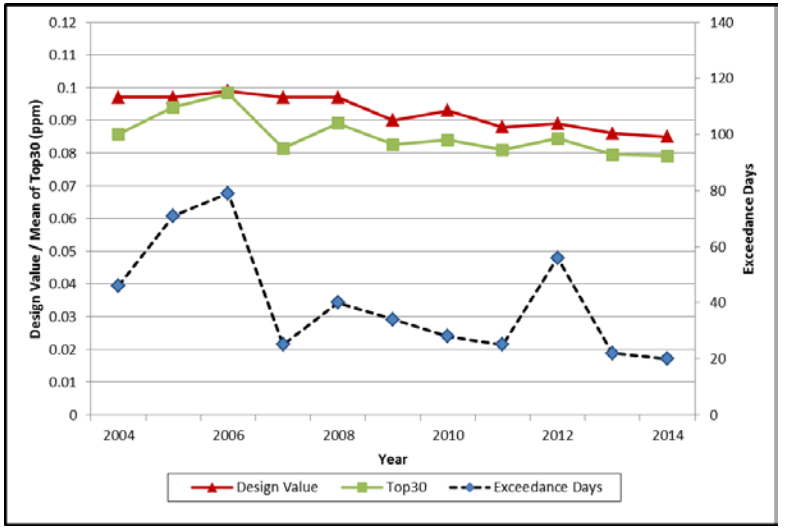


Figure 22. Two High Ozone Sites in Sequoia National Park

Figures 23 and 24 show trends at the two sites in Sequoia National Park within Tulare County. These sites have unique dynamics, as they are elevated, downwind sites, far away from any urban center. In addition, as oxides of nitrogen (NOx) emissions and ozone reach these sites, the remaining NOx may react with large amount of biogenic emissions in these areas to form ozone. Sequoia and Kings Canyon National Park has shown a 13 percent decrease in design value (0.105 to 0.091 ppm), an 11 percent decrease in top 30 (0.094 to 0.084 ppm), and a 46 percent decrease in exceedance days (94 to 51). Sequoia National Park-Lower Kaweah has shown a 15 percent decrease in design value (0.101 to 0.086 ppm), a 9 percent decrease in top 30 (0.088 to 0.080 ppm), and a 35 percent decrease in exceedance days (49 to 32).

Figure 23. Ozone Trends for Sequoia and Kings Canyon National Park

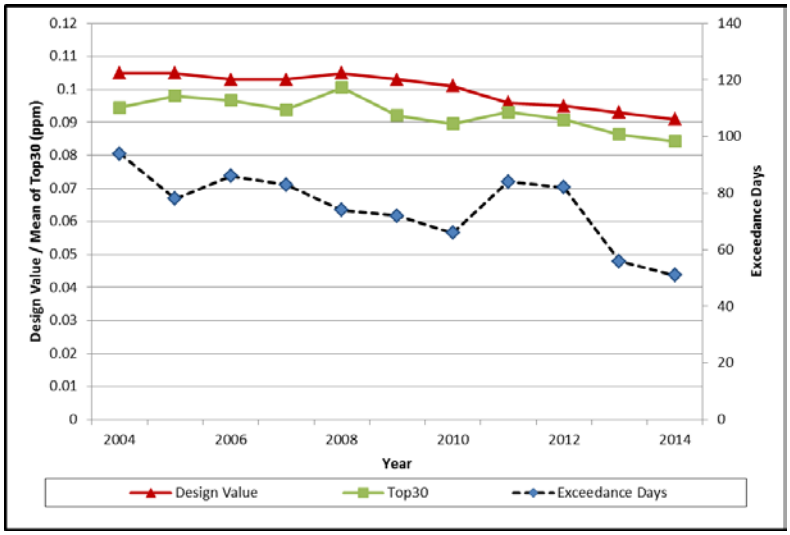
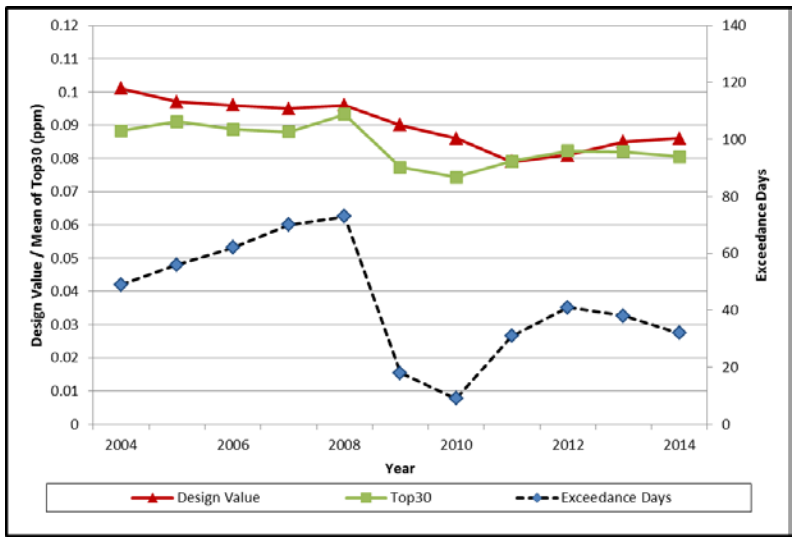


Figure 24. Ozone Trends for Sequoia National Park-Lower Kaweah



4 Meteorology and Air Quality Trends

The meteorological and photochemical processes leading to ozone formation are complex involving interactions both at the surface and in the upper air. The previous trends discussion looked at air quality as measured at ambient monitoring sites, without any consideration of or adjustment for meteorological variability.

The following discussions characterize the general meteorological conditions to evaluate the aptness of using 2012 as a base year for modeling, as well as analyzing long-term ozone trends having been "adjusted" for meteorological variability. These analyses are an effort to better understand the impact of meteorology on air quality and thereby track improvements attributable to emissions reductions.

4.1 Suitability of 2012 as a Base Year for Modeling

Two analyses of meteorological conditions during recent ozone seasons are presented below. The first is a statistical analysis of annual ozone-forming potential (OFP) using data mining software, and the second is a simple tabular comparison of the frequencies of relevant meteorological conditions by month and year.

4.1.1 Ozone-Forming Potential

Within an ozone season, day-to-day differences in meteorological conditions strongly affect the daily maximum levels of ambient ozone, thus days differ in their OFP. Ozone levels are affected by factors in addition to meteorology, such as variations in emissions, but for this discussion OFP is limited to meteorological effects represented by the meteorological data used in this analysis.

Annual OFP is an aggregate summary of daily OFP values within each year. Annual OFP differs from year to year because meteorological conditions that favor higher or lower daily OFP differ in their frequencies from year to year.

In April 2007, U.S. EPA expanded the scope of photochemical modeling required for ozone attainment demonstrations. Previously, attainment modeling was based on a few multi-day episodes when ozone levels were unusually high, especially at the design site(s). Now, however, attainment modeling must address a wider range of conditions and locations when and where ozone levels exceed the 8-hour standard for ozone.

The U.S. EPA's current draft modeling guidance released in 2014[1] includes the following: (1) "it is recommended to use a recent base year period" and (2) the base year period should include "time periods in which observed concentrations are close to

[1] Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze - December 2014 DRAFT (https://www.epa.gov/ttn/scram/guidance/guide/Draft_O3-PM-RH_Modeling_Guidance-2014.pdf).

the appropriate base year design value … and ensure there are a sufficient number of days so that the modeled attainment test applied at each monitor violating the NAAQS is based on multiple days." The first guideline concerning "recent years" focused attention on evaluating the years 2010 to 2013. The second guideline concerning "sufficient days" to support for the modeled attainment test led to an OFP summary based on the 40 days with the highest meteorologically-based OFP.

Each ozone season from 2000 through 2013 was summarized based on daily OFP values within the season. Three different summaries – a whole season view, a Top 40 view, and a Top 8 view – were considered. The whole season includes a mixture of high and low OFP values. The Top 8 view includes the highest OFP conditions but lacks the additional breadth that the U.S. EPA guidance recommends. Therefore, the Top 40 view was selected as a practical approach with respect to the new scope for attainment modeling. The average of the 40 highest daily OFP values is used to rank each year with respect to the other years.

For the central region of the Valley, the overall relationship between daily OFP (predicted daily max 8-hour ozone based on meteorology) and the observed daily max 8-hour ozone for 2005-2007, the selected baseline period for this analysis, is shown in Figure 25, which exhibits an excellent linear fit (R^2=0.87). The relationship for the southern region is shown in Figure 26, which also exhibits an excellent linear fit (R^2=0.83).

This document shows the results of the most recent annual OFP analysis for the central and southern regions of the San Joaquin Valley air basin. The analysis was done with TreeNet[2]. Table 2 shows the annual rankings with respect to OFP based on the top 40 days each year. A separate ranking is given to the two important regions, the central region and the southern region. An overall basin ranking is then based on the average of the two regional ranks. Based on the OFP values in Table 2 for the most recent four years, 2012 ranks highest overall and for both regions. In addition, when compared to the 14 years from 2000 to 2013, 2012 has the fourth highest overall ranking.

[2] TreeNet, a commercial product of Salford Systems, implements the principle of "stochastic gradient boosting" in the context of CART (classification and regression trees) modeling. The developer's website has freely available materials that explain these products (https://www.salford-systems.com/).

Figure 25. OFP vs Observed Daily Max 8-Hour Ozone in Central SJV

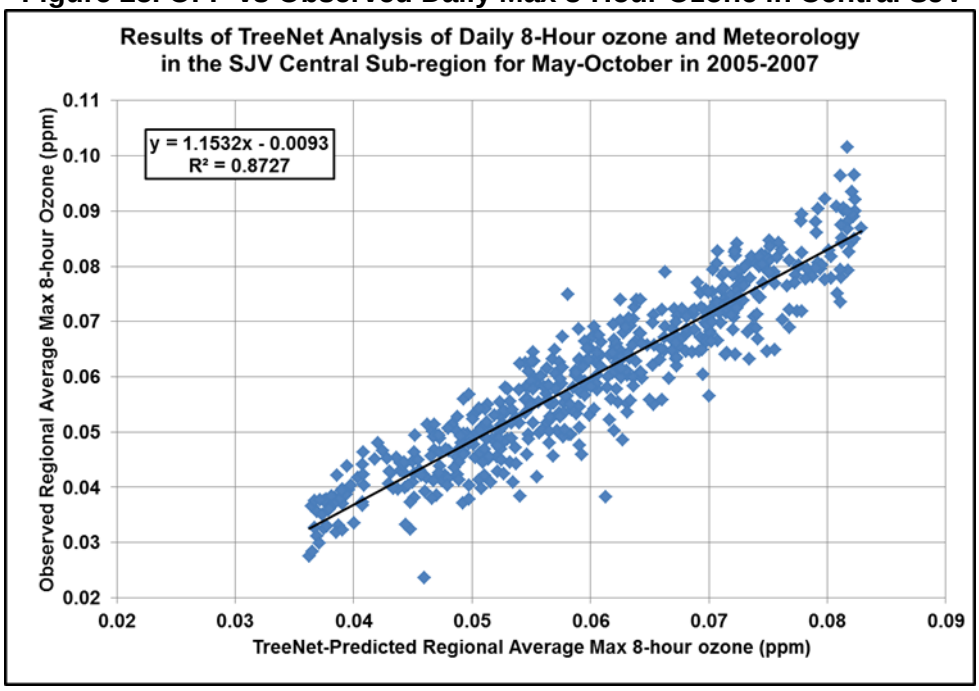


Figure 26. OFP vs Observed Daily Max 8-Hour Ozone in Southern SJV

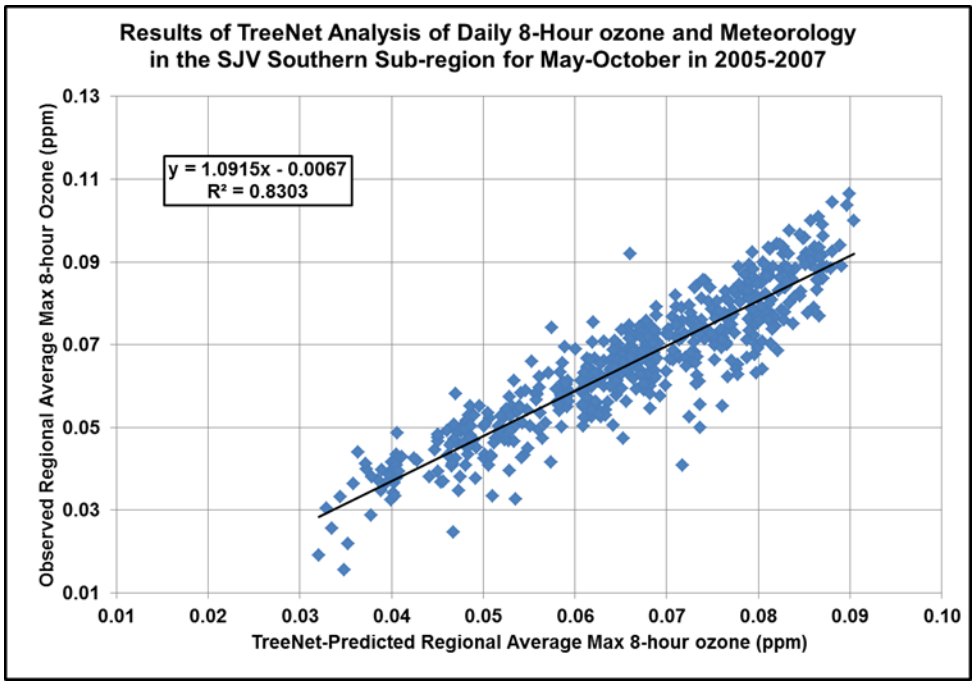


Table 2. OFP Ranking by Year

Annual rank for Ozone-Forming Potential (highest = 1) Based on the Average of the Top 40 OFP Values in Each Year			
Year	Basin Rank	Central SJV	Southern SJV
2000	10.5	11	10
2001	6	7	5
2002	6.5	5	8
2003	2	2	2
2004	12.5	12	13
2005	6.5	4	9
2006	1	1	1
2007	14	14	14
2008	10.5	10	11
2009	3	3	3
2010	12.5	13	12
2011	8	9	7
2012	5	6	4
2013	7	8	6

4.1.2 Ozone-related Meteorological Conditions by Month and Year

Relationships between meteorological conditions and ozone have been studied for more than three decades. Though many different statistical methods have been used to study ozone and meteorology, several categories of meteorological variables have repeatedly provided predictive power.[3] High ozone levels typically occur on days with strong sunlight, high temperatures, trapping inversions, and light recirculating winds. Ozone seasons in which these types of conditions occur frequently are most suitable for use as a base-case in SIP modeling needed to demonstrate future attainment of an ozone standard.

Tables 3-8 offer a broad view of the frequencies of meteorological conditions in the Valley that favor different ozone levels from lowest to highest. Each table addresses one meteorological variable for 1996 to 2013 by month (May-October).

Strong sunlight is present on almost all days from May to October in the Valley. Surface temperature is represented by the midday (10 a.m.- 4 p.m.) average temperature in the central region (Table 3) and the southern region (Table 4). Trapping inversions are represented in two tables: one for the temperature aloft at the 850 mb pressure height (Table 5) and one for the difference between temperature aloft and surface

[3] Thompson, M. L., Reynolds, J., Cox, L. H., Guttorp, P., Sampson, P. D., 2001. A review of statistical methods for the meteorological adjustment of tropospheric ozone. Atmospheric Environment 35, 617-630.

temperature, an indicator of atmospheric stability (Table 6). Winds are represented by the midday (10 a.m.- 4 p.m.) average wind speed in the central region (Table 7) and the southern region (Table 8).

In each table, monthly quintiles are used. All of the observed values in a month for all of the years together were used to determine that month's quintiles, the 20th, 40th, 60th, 80th, and 100th percentiles. So, each row in a table represents 20 percent of observed values within that month over all the years. This allows the distribution of values for one year to be compared to the distributions for all the other years.

For example, the value "12" in the first row and third column of Table 2 means that 12 days in May 1996 had midday average temperatures up to 24.0 ^{o}C in the central region. The "13" below the "12" means that 13 days that month had temperatures higher than 24.0 ^{o}C and up to 27.9 ^{o}C. The cut-points are the same for all months and all years and were chosen so each category accounts for 20 percent or 1/5th of the data (hence, "quintiles") through all of the years. The 21 days in the highest quintile in August 2012 indicates that month had more days in that high-temperature category than any other August. The row of data below the table is the total number of days each year from May-October in the highest category for surface temperature. And, 2012 had more of such days (45) than any other year during 2010 through 2013.

In each table, the 2012 column is highlighted to facilitate comparisons to the other years. In addition, one or two rows below the table show the sum across months of the days with conditions most conducive to high ozone levels. Where two rows are given the row that is desirable is identified.

With respect to surface temperature, shown in Tables 3 and 4, 2012 had the most days in the highest quintile among the most recent four years. Table 5 presents the distributions for temperatures aloft (T850) and shows that 2012 had the most days in the highest quintile among the most recent four years. These results are important because the surface temperature and the temperature aloft are the meteorological variables most closely associated with high OFP.

With respect to atmospheric stability (Table 6) and wind speed (Tables 7 and 8), 2012 was ranked neither highest nor lowest. In the statistical modeling results, wind speed was the second most important variable for some months in the central region of the Valley, though it always ranked below the temperature variables in the southern region.

Table 3. Quintiles for Midday (10 a.m. to 4 p.m.) Average Surface Temperature in the Central SJV

month	SJVC st (°C)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
5	24.0	12	5	27	17	12	1	12	16	14	14	10	6	15	4	22	20	**8**	9
5	27.9	13	8	4	9	9	11	11	6	8	11	10	14	9	11	6	9	**9**	11
5	30.7	3	13		3	5	4	6	3	5	3	5	8	1	9	3	1	**9**	7
5	33.3	3	5		2	2	6		3	3	3	5	3	2	5		1	**5**	3
5	41.2					3	9	2	3	1		1		4	2				1
6	24.0	3	3	9	5	3		1	2	2	6	2	3	1	7	2	9	**5**	
6	27.9	5	9	12	5	3	6	7	9	6	14	4	1	7	12	8	4	**6**	7
6	30.7	10	10	5	8	6	9	12	7	13	6	10	15	5	1	10	9	**8**	8
6	33.3	3	5	4	8	9	3	5	5	8	3	2	6	10	4	6	5	**6**	8
6	41.2	9	3		4	9	12	5	7	1	1	12	5	7	6	4	3	**5**	7
7	24.0																		
7	27.9		1	5	5	7	4			1				1			6	**2**	
7	30.7	4	10	4	14	8	10	4	2	4	3	2	9	3	4	8	4	**5**	3
7	33.3	5	14	8	4	10	8	16	7	14	6	9	10	14	10	12	11	**13**	9
7	41.2	22	6	14	8	6	9	11	22	12	22	20	12	13	17	11	10	**11**	19
8	24.0				1											2			
8	27.9	2	2	2	7	3	3	3	2	4	1	4	2	1	2	2			2
8	30.7	8	13	4	10	8	6	12	11	7	5	8	6	4	7	7	6	**3**	8
8	33.3	4	9	9	7	8	8	7	12	9	7	15	11	11	11	14	19	**7**	14
8	41.2	17	7	16	6	12	14	9	6	11	18	4	12	15	11	6	6	**21**	7
9	24.0	2		9		5		6		7	5	4	8	1	3	3	1		4
9	27.9	8	10	6	5	7	9	5	6	4	12	6	7	7	4	6	4	**1**	9
9	30.7	12	7	4	15	11	8	4	9	6	8	11	11	5	4	10	5	**7**	7
9	33.3	7	8	4	9	4	10	6	7	7	5	5	1	12	8	4	13	**17**	6
9	41.2	1	5	7	1	3	3	9	8	6		4	3	5	11	7	7	**5**	4
10	24.0	18	21	23	9	20	14	21	4	19	20	23	23	13	24	19	16	**14**	14
10	27.9	7	7	7	15	8	10	6	18	9	9	8	7	16	7	4	12	**12**	16
10	30.7	2	2	1	4	1	4	4	9	3	2		1	1		5	3	**1**	1
10	33.3	3	1		3	2	2							1		3		**1**	
10	41.2	1					1											**3**	
	Top 20% total =	50	21	37	19	33	48	36	46	31	41	41	32	44	47	28	26	**45**	38

* Surface Temperature quintile (20th, 40th, 60th, 80th, and 100th percentiles for mid-day average surface temperatrue across the ozone seasons for 2000-2013)

Table 4. Quintiles for Midday (10 a.m. to 4 p.m.) Average Surface Temperature in the Southern SJV

month	SJVS st (°C)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
5	24.7	9	5	29	17	11	1	12	15	15	15	9	6	14	3	22	18	**7**	11
5	28.7	15	8	2	9	11	9	11	7	7	8	8	13	10	13	5	11	**10**	9
5	31.6	4	12		2	3	6	6	4	6	5	8	8	1	9	4		**7**	6
5	34.0	3	5		3	3	7		2	2	3	5	4	2	3		2	**7**	4
5	41.4		1			3	8	2	3	1		1		4	3				1
6	24.7	3	3	9	5	3		1		2	6	1	2	2	6	2	8	**6**	1
6	28.7	5	14	11	6	4	5	5	10	8	13	3	2	6	11	7	5	**5**	5
6	31.6	11	6	7	7	5	10	14	4	13	7	10	15	4	4	11	7	**7**	10
6	34.0	3	5	3	7	5	4	5	9	6	2	4	7	13	3	6	5	**6**	7
6	41.4	8	2		5	13	11	5	7	1	2	12	4	5	6	4	5	**6**	7
7	24.7																		
7	28.7		2	5	4	7	3			1			1				5	**2**	
7	31.6	5	9	4	13	10	10	5	1	5	4	2	12	7	5	7	6	**5**	1
7	34.0	6	15	12	8	8	7	14	11	15	4	8	6	13	7	12	10	**12**	7
7	41.4	20	5	10	6	6	11	12	19	10	23	21	12	11	19	12	10	**12**	23
8	24.7				2											1			
8	28.7	3	8	4	8	3	2	4	4	4	1	1	3	2	2	3			
8	31.6	8	9	5	8	6	7	8	11	9	5	8	9	3	7	7	5	**3**	10
8	34.0	6	9	6	7	13	8	10	8	9	7	17	7	11	10	13	20	**6**	14
8	41.4	14	5	16	6	9	14	9	8	9	18	5	12	15	12	7	6	**22**	7
9	24.7	3	3	11		8		6		7	6	2	9	1	2	3			4
9	28.7	9	10	6	6	6	7	5	6	5	11	6	8	6	5	7	5	**1**	7
9	31.6	9	7	3	15	10	5	1	9	6	9	10	9	8	4	9	5	**7**	9
9	34.0	8	7	5	9	3	15	10	6	7	4	6	1	10	6	4	12	**16**	6
9	41.4	1	3	5		3	3	8	9	5		6	3	5	13	7	8	**6**	4
10	24.7	19	21	23	9	19	11	21	5	18	20	23	23	13	23	21	16	**16**	15
10	28.7	6	7	7	15	9	13	5	16	10	7	7	7	15	8	3	12	**10**	16
10	31.6	3	2	1	4	1	3	3	10	2	3	1	1	2		5	3	**1**	
10	34.0	1	1		3	2	1	2		1	1			1		2		**1**	
10	41.4	2					3											**3**	
Top 20% total =		45	16	31	17	34	50	36	46	26	43	45	31	40	53	30	29	**49**	42

* Surface Temperature quintile (20th, 40th, 60th, 80th, and 100th percentiles for mid-day average surface temperatrue across the ozone seasons for 2000-2013)

Table 5. Quintiles for T850; Average of 4 a.m. and 4 p.m. Temperatures at 850 mb Height (~1500 m) at Oakland, CA

month	T850* (°C)	_1996	_1997	_1998	_1999	_2000	_2001	_2002	_2003	_2004	_2005	_2006	_2007	_2008	_2009	_2010	_2011	_2012	_2013
5	11.7	17	6	31	16	15	2	16	14	18	19	12	7	17	6	23	22	**10**	14
5	16.0	10	14		8	8	8	12	8	8	5	9	13	6	11	8	6	**10**	8
5	18.8	2	7		2	3	8	1	4	3	4	5	11	3	7		3	**9**	7
5	21.4	2	4		5	2	9	2	3	2	3	4		1	4			**2**	2
5	29.4					3	4		2			1		4	3				
6	11.7	4	5	11	6	4	2	1		3	11	2	3	2	12	7	9	**8**	3
6	16.0	4	11	11	8	4	11	5	9	3	13	7	5	7	8	8	6	**7**	8
6	18.8	9	7	7	7	5	6	12	8	12	4	6	13	3	2	10	10	**6**	6
6	21.4	5	5	1	6	6	7	9	4	10	2	6	7	14	4	2	3	**6**	5
6	29.4	8	2		3	11	4	3	9	2		9	2	4	4	3	2	**3**	8
7	11.7		1			1							2				3	**1**	
7	16.0	1	1	2	8	7	6			2	1		1		4		5	**3**	
7	18.8	3	11	10	11	10	8	2	3	4	1	6	7	4	3	5	3	**8**	1
7	21.4	6	15	8	3	8	5	13	7	14	5	7	8	14	3	12	9	**13**	11
7	29.4	21	3	11	9	5	12	16	21	11	24	18	13	13	21	14	11	**6**	19
8	11.7		1		4			3	3				1		1	3	2		
8	16.0		9	3	8	2	2	3	5	6		1	2	2	3	3			6
8	18.8	8	9	4	6	9	7	4	8	9	4	11	9	5	8	5	6	**3**	12
8	21.4	5	6	9	6	10	7	9	11	5	13	17	6	11	8	15	18	**8**	9
8	29.4	18	6	15	7	10	15	12	4	11	14	2	13	13	11	5	5	**20**	4
9	11.7	4	1	6		7	1	5		4	7	2	11	2	3	3	1		6
9	16.0	6	9	11	3	6	4	5	5	4	9	3	8	3	4	9	3	**1**	9
9	18.8	11	10	2	4	9	14	4	3	7	9	11	2	9	4	7	3	**3**	7
9	21.4	8	9	5	15	3	9	6	6	9	5	7	6	10	6	3	10	**22**	2
9	29.4	1	1	6	8	5	2	10	16	6		7	3	6	13	8	13	**4**	6
10	11.7	16	15	18	3	17	5	9	3	16	13	12	20	8	11	17	11	**11**	10
10	16.0	5	10	13	9	8	10	15	4	4	12	14	7	7	13	4	8	**9**	15
10	18.8	3	4		12	1	9	4	16	8	6	5	2	14	7	4	6	**5**	6
10	21.4	3	2		7	4	3	2	2	2			2	2		4	6	**1**	
10	29.4	4				1	4	1	6	1						2		**5**	
Top 20% total =		52	12	32	27	35	41	42	58	31	38	37	31	40	52	32	31	**38**	37

* T850 quintile (20th, 40th, 60th, 80th, and 100th percentiles for T850 across the ozone seasons for 2000-2013)

Table 6. Quintiles for Atmospheric Stability (T850avg minus the sjvs-stmid6) in the Southern SJV

month	sjvs_stability (°C)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
5	-14.6	16	12	21	5	14	9	20	9	15	12	12	13	8	8	17	19	12	17
5	-13.4	6	11	4	8	9	8	8	7	7	10	9	6	8	8	5	6	12	7
5	-12.4	5	6	2	8	4	8	1	6	3	7	4	5	8	6	5	5	4	5
5	-11.1	2	2	1	4	4	4	1	6	5	1	3	6	5	5	3	1	1	2
5	-2.0	2		3	6		2	1	3	1	1	3	1	2	4	1		2	
6	-14.6	4	9	8	10	5	18	5	3	3	14	9	10	5	8	18	12	18	9
6	-13.4	11	9	8	9	5	10	10	9	2	11	8	8	11	12	8	8	5	9
6	-12.4	9	5	4	7	9	2	5	7	8	5	6	8	9	5	2	8	4	4
6	-11.1	4	4	8	3	8		7	4	8		3	3	4	5	2	2	3	2
6	-2.0	2	3	2	1	3		3	7	9		4	1	1					6
7	-14.6	1	2	6	5	6	3		3	1	2	6	4		7		9	7	6
7	-13.4	5	7	5	5	8	13	7	3	6	3	7	3	2	5	7	11	12	8
7	-12.4	8	9	4	6	9	5	11	8	12	7	6	7	13	7	7	5	6	6
7	-11.1	11	10	12	13	5	4	5	10	11	15	10	11	7	5	15	3	5	7
7	-2.0	6	3	4	2	3	6	8	7	1	4	2	6	9	7	2	3	1	4
8	-14.6		7	2	7	3	5	1	6	1	2	2	4	5	7	6	2	1	10
8	-13.4	6	4	4	6	5	5	4	10	5	8	11	4	7	8	7	10	5	11
8	-12.4	6	10	8	10	9	8	7	9	15	8	10	11	7	5	6	8	10	8
8	-11.1	7	9	11	6	12	7	5	4	8	10	8	7	11	6	8	9	11	1
8	-2.0	12	1	6	2	2	6	14	2	2	3		5	1	5	4	2	4	1
9	-14.6	4	8	3	1	7	3	5	1	2	5	6	7	3	3	2	1	4	9
9	-13.4	6	6	6	2	6	8	5	4	3	5	2	8	4	4	8		3	5
9	-12.4	8	9	4	1	4	3	5	7	8	6	5	4	8	7	8	6	7	7
9	-11.1	8	3	6	11	4	12	11	7	12	3	8	4	9	12	4	14	9	5
9	-2.0	4	4	11	15	9	4	4	11	5	11	9	7	6	4	8	9	7	4
10	-14.6	1	5	1	1	3	2				4	4	6	2		3	3	5	
10	-13.4	2	1	3	2	4	1		2	3	2	1	4	3	6	4	2	3	3
10	-12.4	2	4	5	3	3	2	8	1	3	5	2	3	6	3	1	2	2	8
10	-11.1	5	5	8	4	6	5	3	6	5	5	5	4	3	4	6	4	6	9
10	-2.0	21	16	14	21	16	21	20	22	20	15	19	14	17	18	17	20	15	11
	Top 20% total =	47	27	40	47	33	39	50	52	38	34	37	34	36	38	32	34	29	26

* Stability quintile (20th, 40th, 60th, 80th, and 100th percentiles for daily average stability (T850avg - sjvs_stmid6) across the ozone seasons for 2000-2013)

Table 7. Quintiles for Midday (10 a.m. to 4 p.m.) Average Wind Speed in the Central SJV

month	sjvc wss (m/s)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
5	2.0	0	0	2	1	3	9	2	6	0	3	2	1	6	4	3	4	**3**	2
5	2.2	3	3	4	5	4	8	5	5	7	5	5	8	7	5	7	3	**11**	5
5	2.5	2	5	5	5	4	2	5	8	5	9	7	5	4	5	4	6	**5**	3
5	2.8	8	6	8	6	5	4	6	6	10	3	5	8	5	6	4	3	**1**	5
5	8.5	18	17	12	14	15	8	13	6	9	11	12	9	9	11	13	15	**11**	16
6	2.0	1	0	6	0	3	2	0	2	0	2	2	0	2	1	0	3	**2**	1
6	2.2	3	0	7	5	7	2	6	10	4	8	5	2	6	5	3	7	**4**	4
6	2.5	5	6	6	4	5	9	4	7	5	7	6	10	9	8	3	7	**3**	3
6	2.8	12	10	5	10	10	7	11	8	11	4	12	12	3	13	8	7	**8**	8
6	8.5	9	14	6	11	5	10	9	3	10	9	5	6	10	3	16	6	**13**	14
7	2.0	0	0	0	0	0	3	2	1	0	0	0	3	3	2	2	1	**3**	4
7	2.2	4	4	5	5	8	3	4	7	6	7	8	6	6	2	8	10	**8**	8
7	2.5	12	6	16	10	10	13	15	11	7	7	7	5	4	12	6	12	**6**	6
7	2.8	9	11	6	10	8	11	7	6	13	11	10	12	10	6	11	7	**10**	12
7	8.5	6	10	4	6	5	1	3	6	5	6	6	5	8	9	4	1	**4**	1
8	2.0	1	1	3	2	6	3	2	3	2	2	1	3	3	4	5	6	**3**	3
8	2.2	7	4	11	3	8	6	12	8	11	3	13	10	11	5	12	12	**7**	10
8	2.5	9	11	10	8	8	14	9	10	7	12	12	11	8	8	7	8	**7**	6
8	2.8	10	8	7	10	4	5	6	8	7	11	5	3	6	11	5	4	**14**	6
8	8.5	4	7	0	8	5	3	2	2	4	3	0	4	3	3	2	1	**0**	6
9	2.0	3	8	5	5	12	9	8	14	8	6	10	10	15	10	9	8	**17**	8
9	2.2	9	12	13	2	7	6	6	6	9	7	12	4	6	8	9	10	**6**	5
9	2.5	8	4	3	13	4	8	8	5	4	10	2	4	4	2	8	8	**3**	6
9	2.8	7	2	5	8	3	3	3	3	2	3	3	5	4	5	2	2	**3**	3
9	8.5	3	4	4	2	4	4	5	2	7	4	3	7	1	5	2	2	**1**	8
10	2.0	13	17	15	22	18	17	23	23	19	16	20	17	22	16	21	23	**19**	22
10	2.2	6	5	5	3	2	7	6	2	3	5	6	2	2	5	3	4	**5**	4
10	2.5	3	2	3	2	2	3	0	2	1	4	2	1	1	1	2	1	**1**	1
10	2.8	3	3	1	2	5	3	1	1	2	3	2	2	2	3	1	1	**2**	1
10	8.5	6	4	7	2	4	1	1	3	6	3	1	9	4	6	4	2	**4**	3
(desireable)	Low 40% total =	50	54	76	53	78	75	76	87	69	64	84	66	89	67	82	91	**88**	76
(undesireable)	Top 20% total =	46	56	33	43	38	27	33	22	41	36	27	40	35	37	41	27	**33**	48

* Surface wind speed quintile (20th, 40th, 60th, 80th, and 100th percentiles for mid-day average wind speed across the ozone seasons for 2000-2013)

Table 8. Quintiles for Midday (10 a.m. to 4 p.m.) Average Wind Speed in the Southern SJV

month	sjvc wss (m/s)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
5	3.2	2	1	17	3	7	2	0	6	0	11	3	2	6	1	6	4	**5**	4
5	3.7	7	6	4	11	6	8	8	9	3	6	4	5	9	6	6	8	**8**	7
5	4.2	12	7	4	9	6	7	6	5	10	6	10	6	4	10	5	7	**5**	6
5	4.8	5	12	5	4	5	7	11	5	11	5	7	10	7	8	6	7	**8**	8
5	11.2	5	5	1	4	7	7	6	6	7	3	7	8	5	6	8	5	**5**	6
6	3.2	9	2	2	4	2	2	1	1	0	6	1	3	3	3	1	4	**4**	0
6	3.7	3	1	13	2	8	8	1	4	2	1	2	4	1	7	3	3	**2**	5
6	4.2	5	4	6	6	2	3	8	4	4	5	3	7	9	10	8	4	**5**	11
6	4.8	4	7	5	9	9	7	8	11	13	10	13	5	6	5	6	12	**9**	7
6	11.2	9	16	4	9	9	10	12	10	11	8	11	11	11	5	12	7	**10**	7
7	3.2	0	3	2	1	0	1	1	2	0	0	2	5	2	3	1	2	**5**	6
7	3.7	2	1	8	9	8	6	3	5	6	0	2	7	2	6	5	3	**4**	3
7	4.2	9	3	8	8	8	9	3	3	3	1	3	9	8	6	8	6	**6**	6
7	4.8	7	8	10	8	10	9	7	8	8	10	8	6	8	10	10	12	**8**	8
7	11.2	13	16	3	5	5	6	17	13	14	20	16	4	11	6	7	8	**8**	8
8	3.2	3	11	3	4	3	0	1	7	1	2	1	7	2	5	1	3	**2**	3
8	3.7	6	8	7	7	8	3	7	6	3	1	4	10	8	6	8	10	**6**	9
8	4.2	11	4	9	7	9	10	5	4	7	4	8	5	13	11	5	12	**8**	11
8	4.8	6	5	7	6	6	7	11	10	14	9	8	4	4	6	7	5	**5**	6
8	11.2	5	3	5	7	5	11	7	4	6	15	10	5	4	3	10	1	**10**	2
9	3.2	5	12	11	8	12	8	4	6	5	3	4	9	6	11	9	6	**6**	17
9	3.7	12	8	7	6	9	7	6	6	8	5	8	12	12	9	7	10	**13**	6
9	4.2	10	4	6	8	2	9	12	5	5	8	6	7	10	5	6	7	**10**	3
9	4.8	3	5	2	4	5	5	2	5	9	7	7	0	2	1	6	5	**1**	3
9	11.2	0	1	4	4	2	1	6	8	3	7	5	2	0	4	2	2	**0**	1
10	3.2	22	22	15	18	16	17	16	16	15	19	17	18	15	21	21	25	**15**	17
10	3.7	4	4	9	7	11	6	6	6	10	3	9	4	9	6	3	2	**8**	9
10	4.2	3	2	5	2	2	6	6	6	2	5	1	0	3	0	2	1	**6**	2
10	4.8	0	0	0	3	0	1	1	1	1	3	2	1	0	2	1	3	**1**	0
10	11.2	2	3	2	1	2	1	2	2	3	1	2	8	4	2	4	0	**1**	3
(desireable)	Low 40% total =	75	79	98	80	90	68	54	74	53	57	57	86	75	84	71	80	**78**	86
(undesireable)	Top 20% total =	34	44	19	30	30	36	50	43	44	54	51	38	35	26	43	23	**34**	27
* Surface wind speed quintile (20th, 40th, 60th, 80th, and 100th percentiles for mid-day average wind speed across the ozone seasons for 2000-2013)																			

The combined picture from Tables 3-8 indicates that the meteorological conditions present in the 2012 ozone season make the best choice among recent years (2010-2013) as a base-case for SIP modeling of ozone in the San Joaquin Valley. This conclusion is based on two different evaluations of meteorological conditions in the Valley during the ozone seasons of 2000-2013.

4.2 Meteorology-adjusted Ozone Trends – Seasonal Averages by Region

In addition to an evaluation of trends in OFP and variations in meteorological variables, when observed trends are adjusted to compensate for periods of atypical meteorology, the "meteorology-adjusted" trends reveal more clearly the impact of emissions reductions.

This section presents observed and meteorology-adjusted trends for the season (May-October) average of daily maximum 8-hour ozone in three regions of the Valley from 2007-2014. Although these trends do not relate directly to attainment of the national 8-hour ozone standard, they do offer a broad-based perspective on the response of ambient ozone levels to strategic reductions in emissions of NOx and volatile organic compounds (VOC).

4.2.1 Meteorology and Ozone

Large variations in daily maximum 8-hour ozone concentrations are normally observed within an ozone season (May-October). These variations are due to differences in meteorology, emissions, and other factors, all of which affect ambient ozone levels. Years differ in the frequencies of low-ozone versus high-ozone meteorological conditions, and the year-to-year fluctuations in these frequencies can sometimes mask the extent to which the ozone air quality trends represent changes in emissions.

Datasets containing daily maximum 8-hour ozone and a variety of meteorological variables were prepared for the northern, central, and southern regions of the Valley. Each data set included the variables shown in Table 9.

Table 9. List of Observed (upper-air and surface) and Derived Variables Used in CART

Variables	Description	Unit
Surface		
Wind Speed	Midday 6 hour (10 a.m.- 4 p.m.) average	m/s
Temperature	Midday 6 hour (10 a.m.- 4 p.m.) average, daily average	°C
Dew Point	Midday 6 hour (10 a.m.- 4 p.m.) average	°C
Relative Humidity	Midday 6 hour (10 a.m.- 4 p.m.) average	%
Upper-air (500, 700, 850 mb)		
Temperature	a.m., p.m., average	°C
Geopotential Height	a.m., p.m., average	m
Transport		
Distance	24-hour back trajectory	Km
Total Distance	24-hour back trajectory	Km
Direction	Aerial direction from North	Degree
Sector	Total 8 sectors (1-8)	Unitless
Stability		
AM Stability	Upper-air temperature at 5 a.m. minus surface daily maximum temperature	°C
Average Stability	Upper-air daily average temperature minus surface daily average temperature	°C
Mixing Height	Depth of lower mixing atmosphere	m

The data for 2009, 2010, and 2011 were used as a "calibration period" with which to establish a baseline for 8-hour ozone in relation to meteorology. The daily maximum 8-hour ozone data and the daily meteorological data in the calibration period were used to develop rules for classifying days into meteorological groups in such a way that the total variability of 8-hour ozone within the groups is as small as possible. This was done using a data mining tool, called Classification and Regression Trees (CART),[4] which automatically selects the most effective meteorological variables for this purpose. The classification rules were based on the data for the three-year period 2009-2011 with the reasonable assumption that emissions were relatively stable during this period and together the years included a wide range of meteorological conditions. Once the classification rules were developed, they were used to classify the remaining days in the 2007-2014 ozone seasons.

The frequencies of days in the meteorological classes fluctuated from year to year. For each year, the class frequencies were linked to the class averages for the calibration period to produce a "predicted seasonal average". The difference between the predicted seasonal average and the calibration period's baseline average was

[4] The developer's web site has freely available information regarding CART (www.salford-systems.com)

used to “meteorology-adjust” the observed seasonal average. The resulting meteorology-adjusted trends are shown alongside the observed trends in Figures 27-29.

4.2.2 Meteorology-adjusted Trends for Season Average Daily-Max 8-hour Ozone

In this analysis, each daily maximum 8-hour ozone value was averaged over the ozone season, within each region, from 2007-2014. These season average trends may differ from trends for other indicators, such as design values, that highlight changes in the higher end of the distribution of ozone concentrations.

Figures 27-29 show observed and meteorology-adjusted data with a linear trend fitted to the adjusted data. The linear trend represents the best available general assessment of the response of season-average 8-hour ozone to emissions of NOx and VOC. Note that season-average trends are expected to improve at a slower rate compared to trends in “peak” indicators (such as design value and mean of top 30).

- For the northern region, the linear fit to the meteorology-adjusted data in Figure 27 shows a mild downward trend.

- For the central region, the linear fit to the meteorology-adjusted data in Figure 28 shows a flat trend.

- For the southern region, the linear fit to the meteorology-adjusted data in Figure 29 shows a substantial overall decline of almost 1.5 ppb per year.

These season average trends are generally similar to the patterns observed in the other metrics. Additional discussion on how these relate to the response to emission reductions based on the ozone chemistry of the region is provided in subsequent sections.

Figure 27. Meteorology-adjusted Season Average of Daily Maximum 8-Hour Ozone Concentrations for Northern SJV

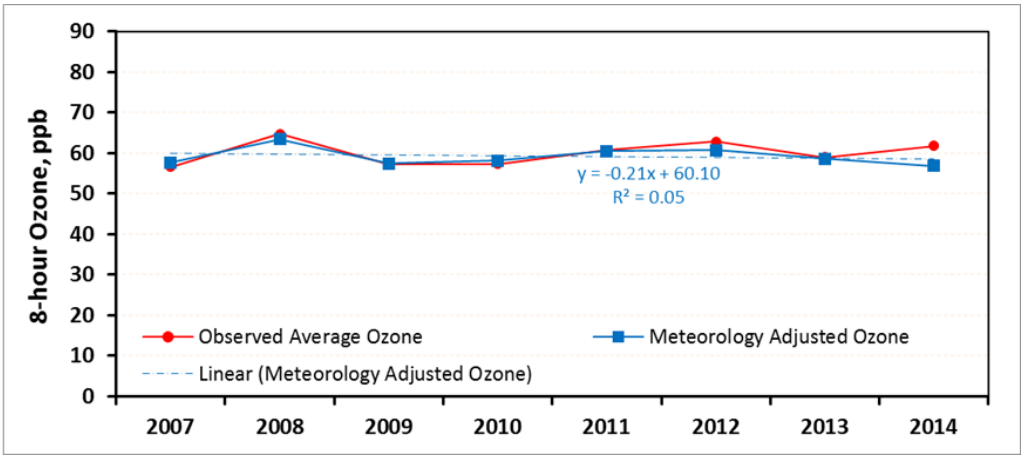


Figure 28. Meteorology-adjusted Season Average of Daily Maximum 8-hour Ozone Concentrations for Central SJV

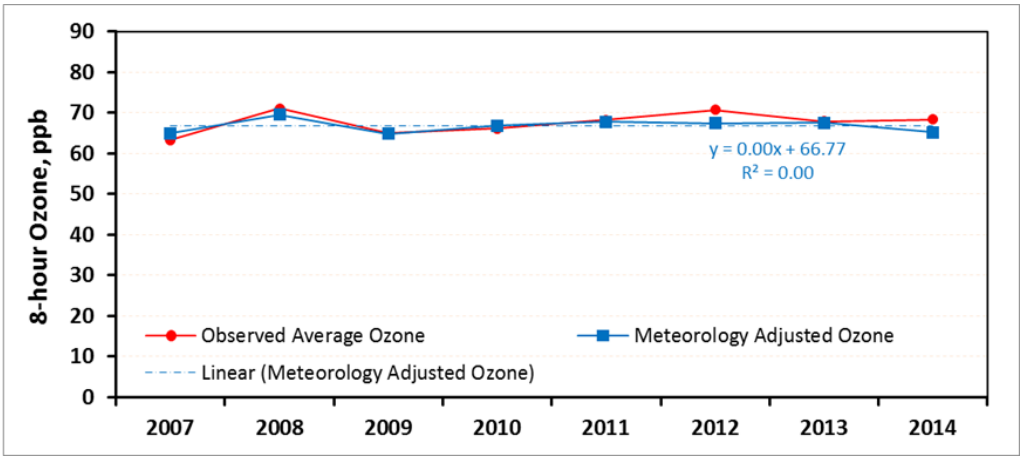
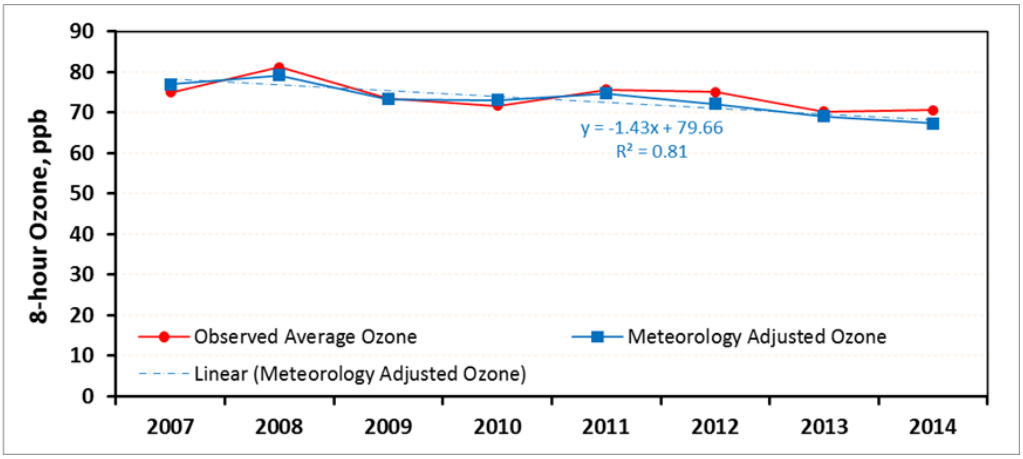


Figure 29. Meteorology-adjusted Season Average of Daily Maximum 8-hour Ozone Concentrations for Southern SJV

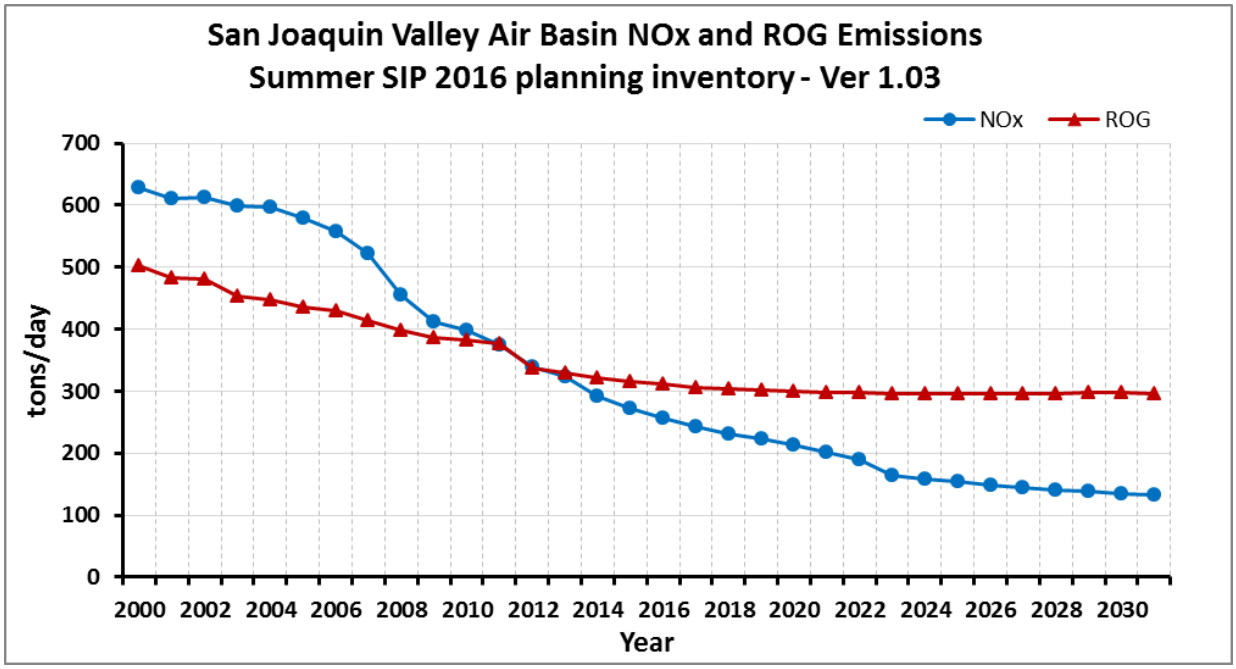


5 Trends in Precursor Emissions

Tropospheric ozone is a secondary pollutant that is formed by NOx and VOCs (also referred to as reactive organic gases, or ROG) through complex non-linear photochemical reactions. Anthropogenic emissions from mobile sources, industrial facilities and electric utilities, gasoline vapors, and chemical solvents are some of the major sources of NOx and ROG. Vegetation is also a major source of ROG emissions.

Emissions control programs have substantially reduced the amounts of both NOx and ROG emitted by various sources throughout the Valley. Emissions trends, excluding emissions from natural sources, for NOx and ROG in the Valley as a whole are shown in Figure 30. All emission inventory values are based on the California Air Resources Board's (ARB) California Emission Projection Analysis Model (CEPAM) for the 2016 Ozone SIP version 1.03 with external adjustments, using 2012 as the base year. The figure shows that from 2000-2031, anthropogenic NOx is forecasted to decrease by 79 percent and ROG by 41 percent.

Figure 30. Overall Anthropogenic NOx and ROG Emissions Trends for the SJV



The relative amount of ROG emissions compared to NOx, or ROG/NOx ratio, is an important consideration when planning emissions reduction strategies. For higher ROG/NOx ratios, ROG emissions reductions will generally be less effective in lowering ozone while NOx emissions reductions will be more effective. This is known as a NOx-limited regime. A ROG-limited regime occurs when the ROG/NOx ratios are lower, indicating higher NOx emissions. In this regime, ROG emissions reductions will be more effective than NOx emissions in reducing ozone concentrations.

Looking forward from 2012, the 2031 emissions represent approximately a 60 percent decrease in NOx and a 12 percent decrease in ROG. Accordingly, the ROG/NOx ratio for anthropogenic emissions in 2031 is expected to be over twice the ratio that prevailed in 2012. The ratio of ambient ROG to ambient NOx would be greater than the ROG/NOx ratio based upon anthropogenic emissions. This is because biogenic ROG is the majority of the total ROG inventory in the Valley for most of the ozone season, while biogenic NOx is a tiny fraction of the total NOx inventory. The trend towards higher ROG/NOx ratios in the Valley indicates that the area will become more NOx-limited, thus NOx controls will become increasingly more effective for lowering ozone concentrations.

Trends in summer emissions of anthropogenic NOx and ROG for the central region are shown in Figure 31 and for the southern region in Figure 32. These trends show similarities that reflect the valleywide implementation of significant control programs for both NOx and ROG. Similar to the Valley as a whole, in the central and southern regions of the Valley, the inventory shows greater reductions in NOx (an average of 47 percent in the two regions) than ROG (an average of 35 percent in those regions) from 2000-2012, with that pattern continuing through 2031. The key feature of these trends is that the southern region, with a higher ROG/NOx ratio than the central region, appears to have transitioned to a NOx-sensitive regime first.

Figure 31. Anthropogenic NOx and ROG Emissions Trends for the Central SJV

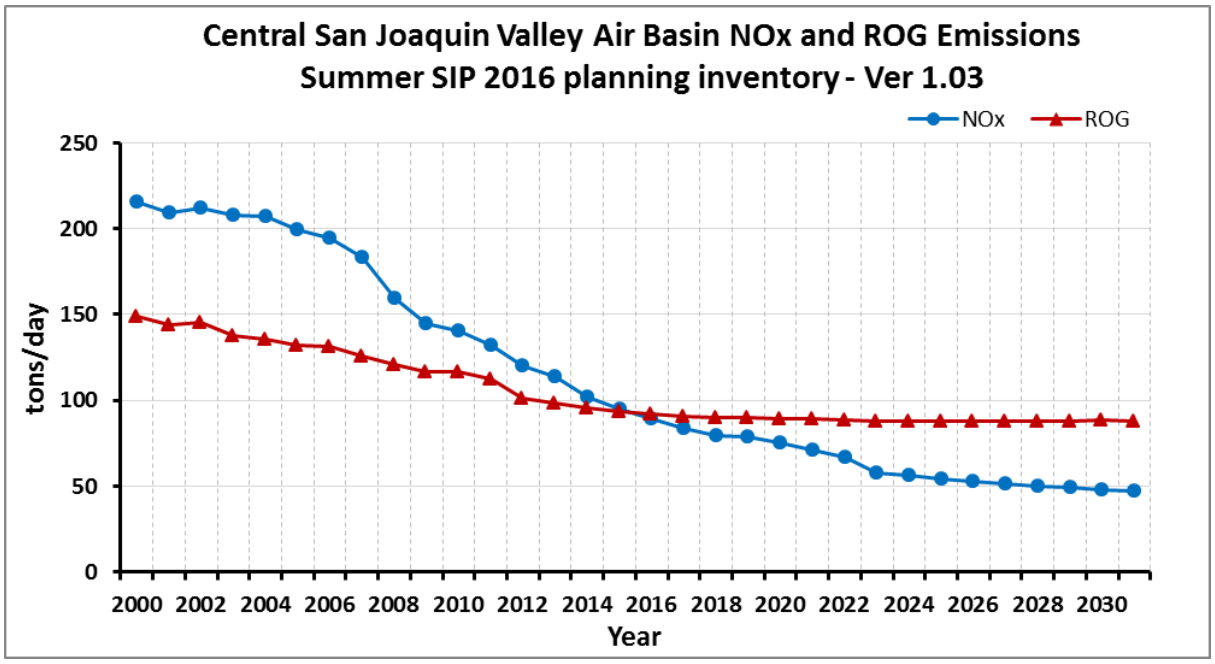
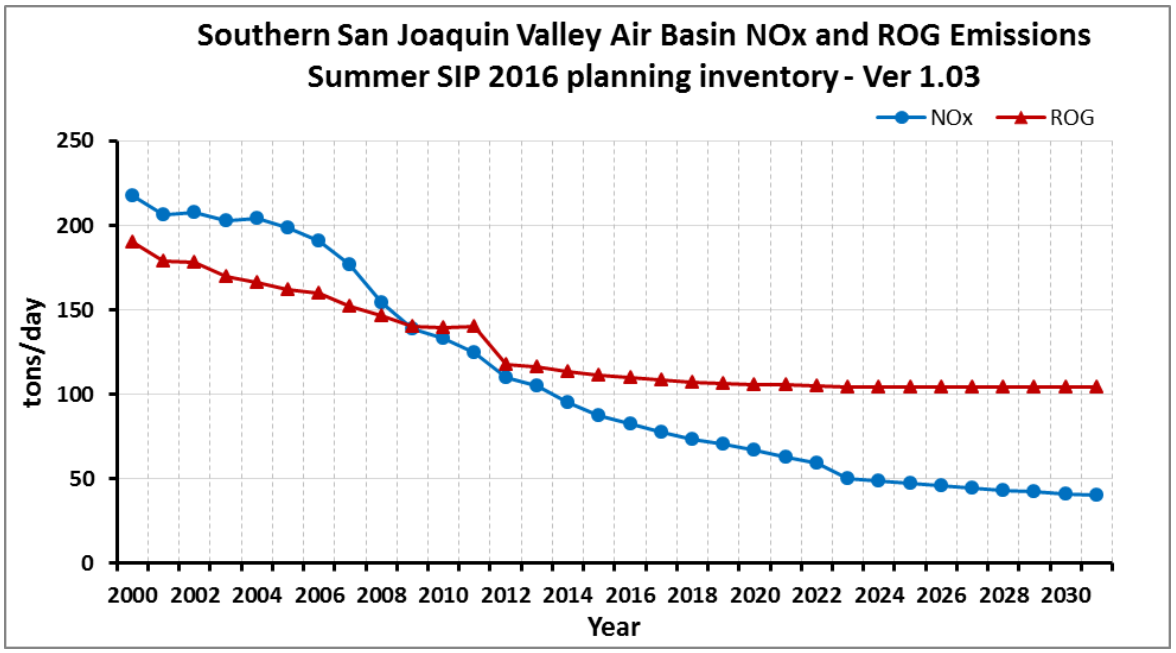


Figure 32. Anthropogenic NOx and ROG Emissions Trends for the Southern SJV



The county-by-county trends in Figures 33 and 34 have largely similar shapes but differ in the magnitude of the emissions, with the highest NOx and ROG emissions in Kern and Fresno counties. Note that Fresno County has higher NOx emissions, and Kern County has higher ROG emissions.

Figure 33. Summer NOx Emissions by County

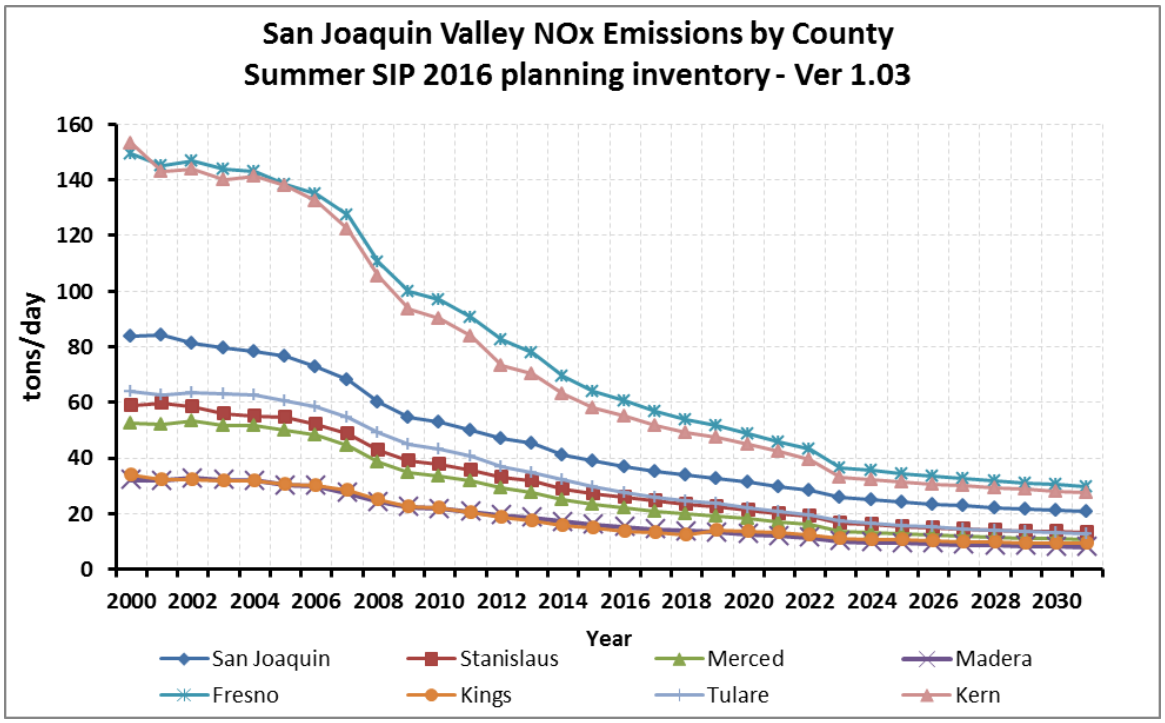
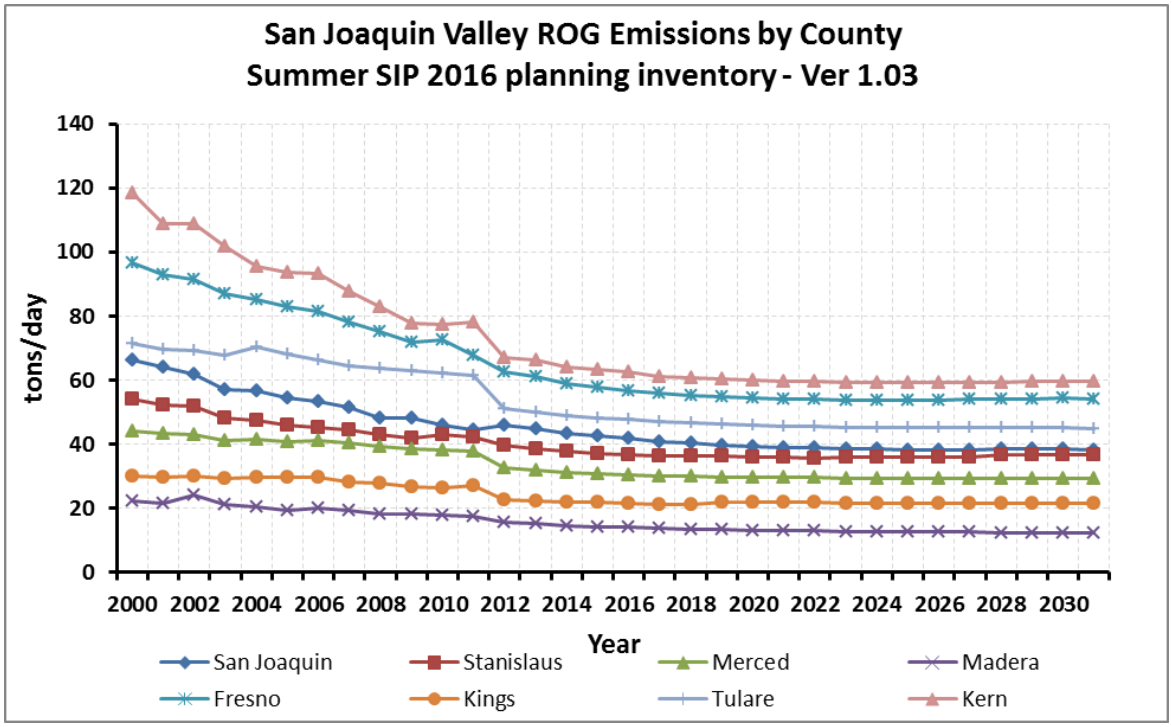


Figure 34. Summer ROG Emissions by County



6 Trends for Ozone Precursor Concentrations

This section presents trends in the primary ozone precursors, NOx and VOC. The data are from a special-purpose network of Photochemical Assessment Monitoring Stations (PAMS) where both NOx and VOC are measured side-by-side. The PAMS network operates during the summer ozone season and collects VOC samples that represent different parts of the day. The work done for this WOE was patterned after previous WOE analyses that focused on the morning hours between 5:00 a.m. and 8:00 a.m. in July and August, when the ambient concentrations of ozone precursor emissions are highest, during the morning commute hours.

The VOC data discussed here are the sum of 55 chemical species, sometimes called Non-Methane Organic Compounds (NMOC), a subset of VOC. These data are known to be lower than total VOC by percentages that differ by location.

The PAMS reactivity metric quantifies the relative impacts of each species on ozone formation. Using the maximum incremental reactivity (MIR) scale, this reactivity-weighted metric is a more meaningful measurement for how ambient VOC plays a role in forming ozone.

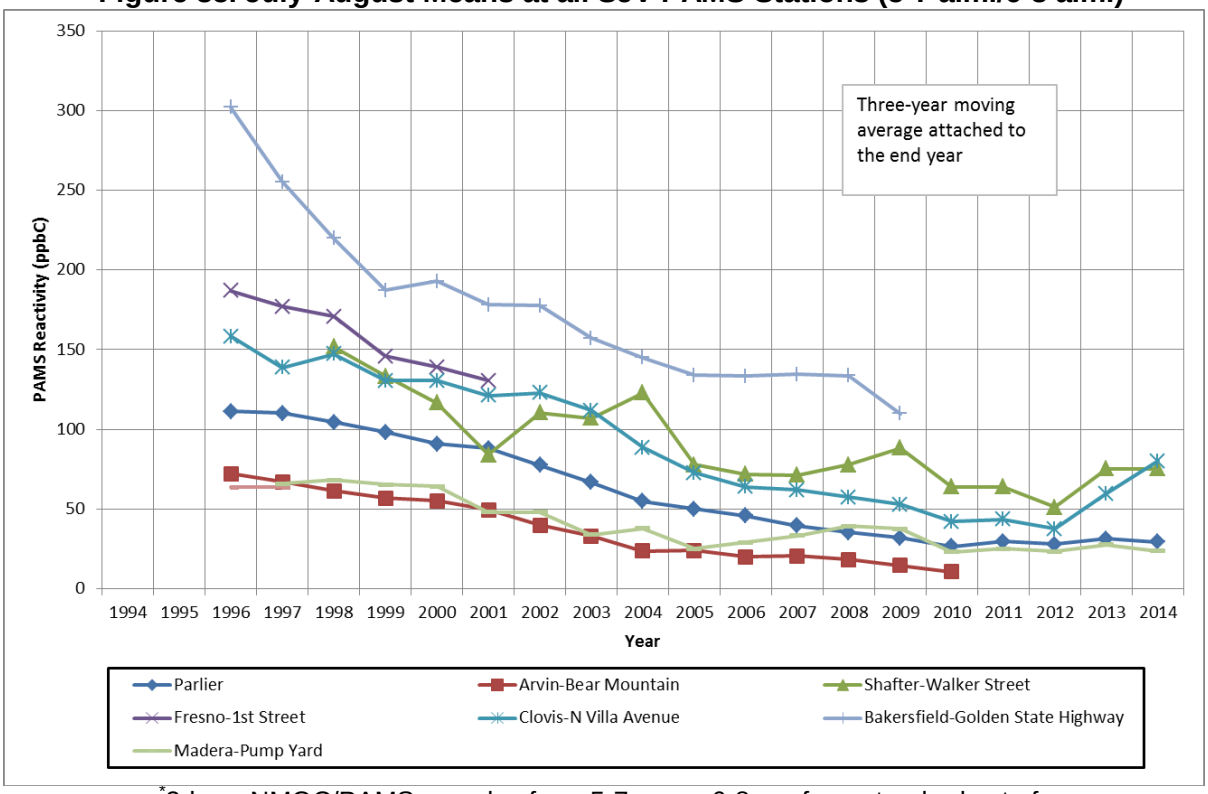
VOC is not measured at many of the monitors in the routine ambient network. The routine network of NOx monitors, however, is extensive, and is discussed in a subsequent section.

6.1 Analysis of PAMS Data

The data were collected and filtered for the months of July and August because these two months tend to be during the peak of the ozone season. In addition, NMOC data were not consistently available for other months in the PAMS network. PAMS data is measured and collected periodically throughout the day, and most observations tend to represent a three hour period. As such, it was important also to filter for a certain time period of the day. Data from the 5:00 a.m.- 7:00 a.m. PDT and 6:00 a.m.- 8:00 a.m. PDT periods were selected. This time period was chosen because it represents the hours before photochemistry (and therefore ozone formation) is triggered, and at a time when ozone precursor are at higher levels.

From 1994 to 2014, ambient VOC concentrations decreased significantly throughout the Valley. Trends for each site shown in Figure 35 show a long term downward trend towards lower VOC levels in every region. The ambient VOC levels are consistent with the emissions inventory trends, with the southern region (Bakersfield-Golden State Highway and Shafter-Walker Street) having higher levels than the central region (Fresno-1st Street, Clovis-N Villa Avenue, and Parlier). Because the sites in the southern region have higher VOC levels, it would take comparatively fewer NOx reductions in order for that region to transition to a NOx-limited regime, and ultimately show a response with lower ozone levels.

Figure 35. July-August Means at all SJV PAMS Stations (5-7 a.m./6-8 a.m.)*



*3-hour NMOC/PAMS samples from 5-7 am or 6-8 am for a standard set of 55 compounds. Some samples with extreme mixing ratios for one or more compounds were identified and excluded. Data for 2008 and 2012 were not available for this area during the chosen months and hours.

6.2 Analysis of Routine Ambient NOx Data

The trends in the previous section represent ambient ROG and NOx at sites in the limited PAMS network during July and August for the hours between 5:00 a.m. and 8:00 a.m. This section will focus on all sites in the Valley that measure NOx, providing a broader basis for assessing trends. These concentrations are averages measured over the May-October season for all hours in the day, from 1990-2014.

Figures 36, 37, and 38 show NOx trends for each site in the northern, central, and southern regions, respectively. All figures use three-year averages attached to the end year to show a trend less sensitive to year-to-year variation. Ambient NOx in each of the regions is on a steady decline. All sites, especially the ones with the highest concentration, show substantial NOx decreases over the past 20 years. On average, the sites in the central region and southern regions had a decrease of about 40 percent from 2000-2012. The overall trend in ambient NOx measurements is consistent with the emissions inventory data.

Figure 36. Northern SJV Trends for Ambient 24-hour NOx from May-October

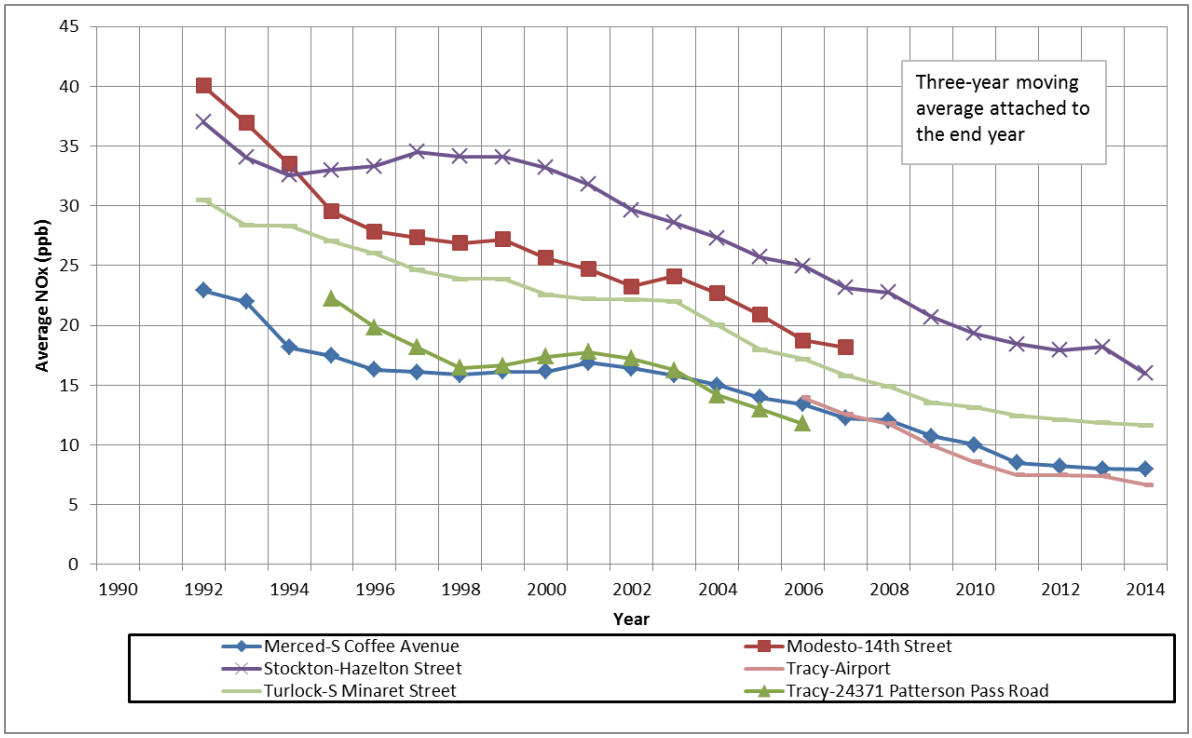


Figure 37. Central SJV Trends for Ambient 24-hour NOx from May-October

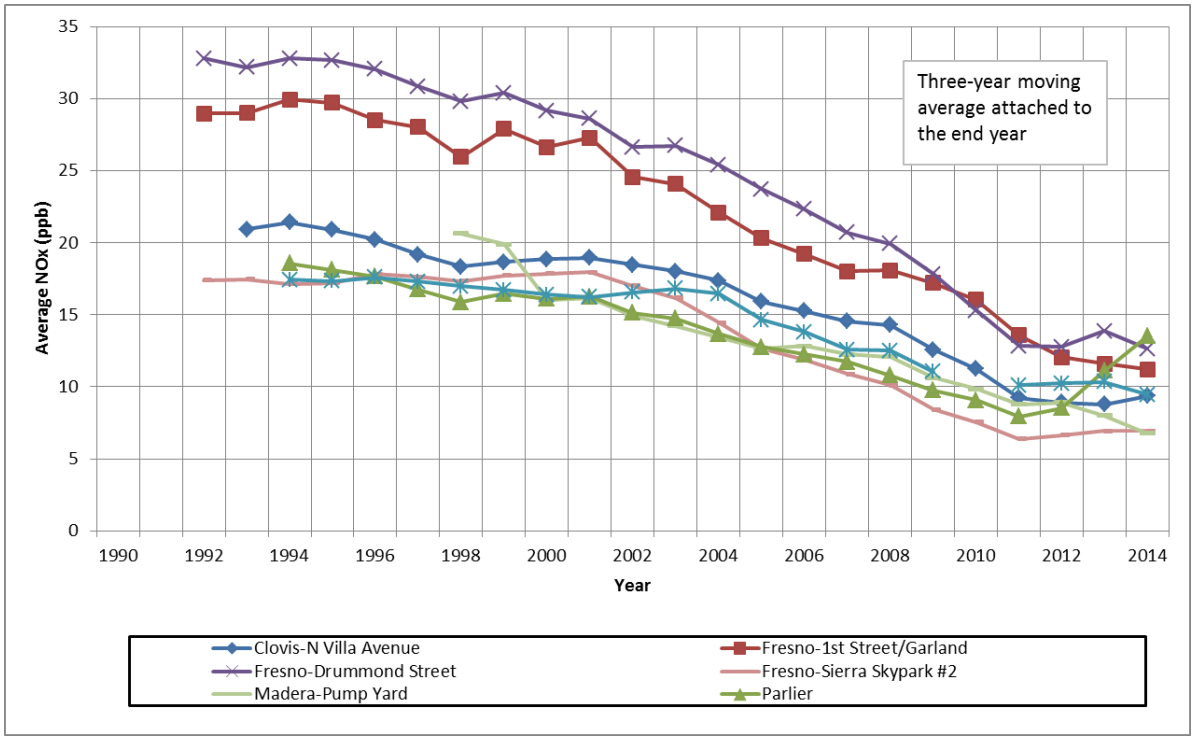
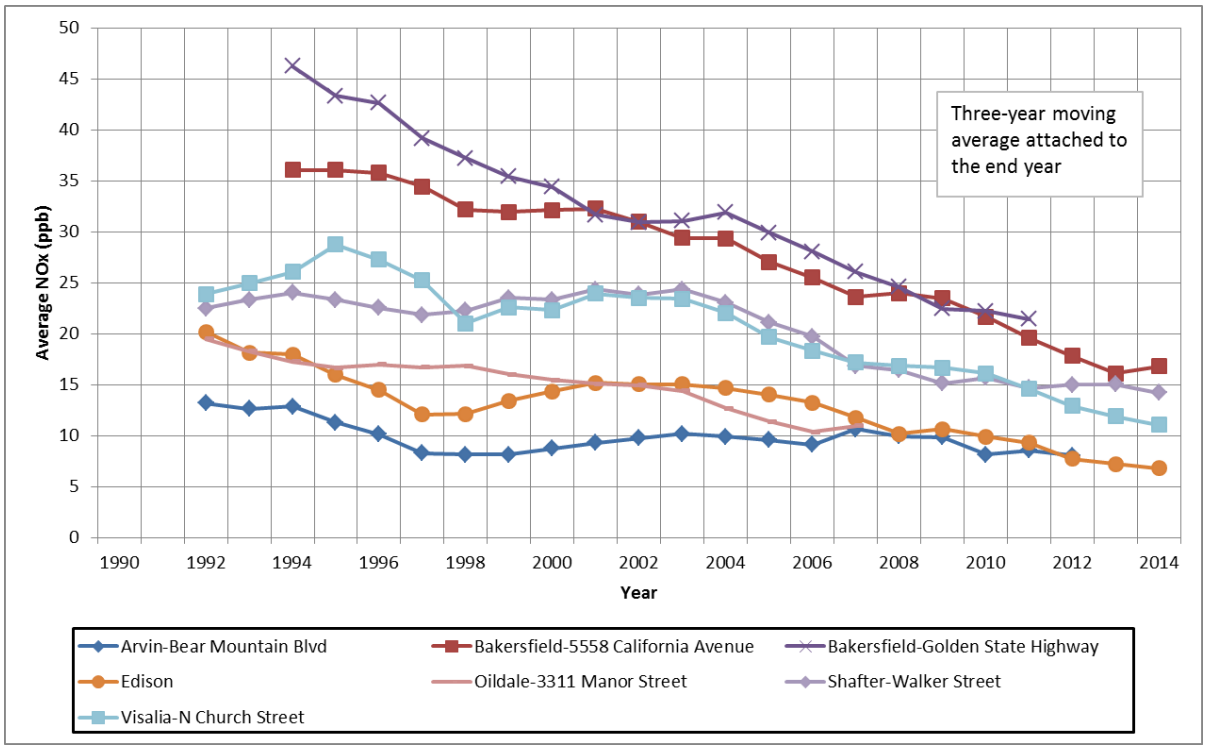


Figure 38. Southern SJV Trends for Ambient 24-hour NOx from May-October



7 Weekend Effect in the San Joaquin Valley

The “ozone weekend effect” (WE) is a well-known phenomenon in many urbanized areas where emissions of ozone precursors decrease substantially on weekends while the measured levels of ozone increase on weekends.

The WE is not uniformly present in California’s urban areas. In the five year period from 2005 through 2009, the WE was approximately 33 percent (the average 8-hour maximum ozone averaged 33 percent higher on weekends than on weekdays) at San Bernardino in the South Coast Air Basin, but the WE was only 3 percent at Clovis in the San Joaquin Valley.

Weekend effect values for the northern, central, and southern regions of the Valley are shown in Table 10 on a site-by-site basis and a regional average basis. A widely held view of the WE is that high WE values are consistent with a VOC-sensitive regime, while low (especially negative) WE values are consistent with a NOx-sensitive regime. In a VOC-sensitive regime, reductions in NOx emissions may have a counterproductive effect. In a NOx-sensitive regime, reductions in NOx emissions are expected to reduce ambient ozone levels. These varying effects of NOx reductions are due to the non-linear chemistry of ozone formation involving NOx and VOC.

In many places, NOx emissions are substantially lower on weekends compared to weekdays.[5] In some cases, a strong WE is present, while in others, a reverse WE is present, with weekend ozone being lower than weekday ozone. The WE values shown in Table 10 may indicate that regions of the San Joaquin Valley differ in their sensitivity to NOx and VOC emissions.

In the northern region of the Valley, the average WE decreased from 10.0 percent in 2000-2004 to 2.3 percent in 2010-2014. These values are consistent with scientific and modeling assessments indicating the northern region was in a VOC-sensitive regime, is now in a period of transition, and will soon be in a NOx-sensitive regime.

In the central region of the Valley, the average WE decreased from 3.3 and 3.4 percent in 2000-2004 and 2005-2009 down to 0.3 percent in 2010-2014. These values are consistent with scientific and modeling assessments indicating the central region was in a transition period from VOC-sensitivity to NOx-sensitivity, and has been in a NOx-sensitive regime in more recent years.

In the southern region of the Valley, the average WE decreased from 1.8 and 2.6 percent in 2000-2004 and 2005-2009 to -0.8 percent in 2010-2014. These values are consistent with scientific and modeling assessments indicating the southern region transitioned from a VOC-sensitive regime and has been in a NOx-sensitive regime for most of the last decade. The ozone weekday-weekend analyses corroborate that the central and southern regions are already in a NOx-limited regime and the northern region will soon be transitioning into one.

In addition to the results in Table 10, the ozone weekend effect was evaluated for two elevated downwind sites, Sequoia-Kings Canyon and Sequoia-Lower Kaweah. At Sequoia-Kings Canyon, the WE values were 0.1 percent in 2000-2004, -1.7 percent in 2005-2009, and -2.5 percent in 2010-2014. At Sequoia-Lower Kaweah, the WE values were -0.5 percent in 2000-2004, -1.8 percent in 2005-2009, and -2.7 percent in 2010-2014. These results indicate that reductions in anthropogenic NOx emissions in the heavily populated regions of the Valley are be expected to reduce ozone at elevated down-wind sites, consistent with both recent air quality trends and modeling results.

[5] http://www.arb.ca.gov/research/weekendeffect/arb-final/wee_tsd_ch5_3.pdf

Table 10. Average Weekend Effect*

Sub-region and Site	2000 to 2004	2005 to 2009	2010 to 2014
SJV - Northern			
Merced – South Coffee	1.1	0.1	-1.5
Modesto – 14th Street	11.3	9.9	4.0
Stockton – Hazelton	14.8	11.8	5.9
Stockton – East Mariposa	9.9	8.2	-0.6
Tracy – Patterson Pass Road	7.9	9.9	4.5
Turlock – South Minaret	6.2	5.3	1.7
Average	**10.0**	**7.5**	**2.3**
SJV - Central			
Clovis	4.0	3.0	1.0
Fresno – Drummond	6.2	6.1	2.4
Fresno – First Street & Garland	2.2	4.1	0.5
Fresno – Sierra Sky Park #2	1.4	3.6	-0.4
Hanford – South Irwin	1.2	0.6	-0.5
Madera – Pump Yard	1.4	1.3	-2.3
Parlier	3.2	1.3	-0.7
Visalia	6.9	7.8	2.1
Average	**3.3**	**3.5**	**0.3**
SJV – Southern			
Arvin – Bear Mtn. Rd. & Di Giorgio	0.6	1.4	-3.5
Bakersfield – CA Avenue	3.1	3.7	0.4
Edison	2.9	3.5	-1.1
Maricopa	0.5	1.5	-1.0
Oildale	1.8	2.9	1.0
Shafter	1.8	2.6	-0.7
Average	**1.8**	**2.6**	**-0.8**

* (Weekend avg. - Weekday avg.) / (Weekday avg.) x 100. A positive value means the average Weekend ozone was X.X percent higher with respect to the average Weekday ozone.

8 Modeled Attainment Projections

Regional photochemical modeling assessment was performed by ARB following U.S. EPA's modeling guidance. Multiple modeling metrics were evaluated to determine whether the Valley would attain by 2031. These metrics are briefly described below and in more detail in the modeling appendix in this *2016 Plan for the 0.075 ppm 8-hour Ozone Standard*.

Previously, modeling results were used in a direct or deterministic sense, mainly because computing resources were sufficient to simulate very few episodes (one in most cases). From those simulations, a limited number of days were used to determine future year attainment. However, current modeling guidance recommends using the model results in a relative sense (using relative response factors or RRFs) in the context of the 8-hour ozone standard. A model attainment demonstration must utilize the top ten modeled days at each monitoring site when projecting design values into the future. Therefore, for this 8-hour ozone plan, the simulations covered five months (May-September 2031) of ozone concentrations. Overall, the modeling shows a strong response to lower NOx emissions based on inventory projections with current emission reductions programs.

8.1 Single RRF Approach

The first approach was to use the model in a relative sense following the procedure in the 8-hour ozone modeling guidance. Accordingly, a single average RRF was calculated for each site in Table 11, and each reference year design value was multiplied by the corresponding RRF. This approach is used to predict future ozone levels in the Valley's attainment demonstration.

The design values based on the single average RRF approach are shown in the fourth column (2031 DV single RRF) in Table 11. These future design values are projected at levels below the standard for all stations, with Clovis-N Villa Avenue predicted to be the highest site at 74 parts per billion (ppb), or 0.074 ppm. Therefore, based on a single RRF approach for each site, the 0.075 ppm 8-hour ozone standard will be met at all sites in the San Joaquin Valley in 2031.

8.2 Comparison of Single vs. Band RRF

The second metric is based on the recognition that higher ozone concentrations are generally more responsive than lower ozone concentrations to the control of precursors. Results of the band RRF approach are included here as they further inform the attainment outlook for the Valley.

The band RRF method accounts for differences in model response to emissions controls at varying ozone levels by grouping the simulated ozone into bands of lower, medium, and higher ozone mixing ratios. A separate RRF is calculated for each ozone band following a similar approach to the single RRF.

The fifth column of Table 11 lists the 2031 design values calculated using banded RRFs. As was the case with the single RRF method, these modeling results suggest that Clovis-N Villa Avenue will be the high site in the future, with a 2031 design value of 72 ppb. Similar to the single RRF approach, the modeling indicates that all sites in the San Joaquin Valley will meet the standard by 2031.

Table 11. Modeled Design Value Projections (ppb)

	County	Site Name	Weighted 2012 Design Value	2031 DV (single RRF)	2031 DV (band RRF)
Northern	Merced	Merced-S Coffee Avenue	81.7	65	64
	San Joaquin	Stockton-Hazelton Street	68.3	57	--
	San Joaquin	Tracy-Airport	79.3	66	66
	Stanislaus	Modesto-14th Street	76.0	61	61
	Stanislaus	Turlock-S Minaret Street	86.0	69	65
Central	Fresno	Clovis-N Villa Avenue	95.7	74	72
	Fresno	Fresno-1st Street/Fresno-Garland	90.7	70	--
	Fresno	Fresno-Drummond Street	92.3	71	67
	Fresno	Fresno-Sierra Skypark #2	89.0	68	63
	Fresno	Parlier	92.0	69	66
	Fresno	Tranquility-32650 West Adams Avenue	76.3	60	--
	Kings	Hanford-S Irwin Street	86.0	64	--
	Madera	Madera-28261 Avenue 14	84.7	65	62
	Madera	Madera-Pump Yard	79.3	61	60
Southern	Kern	Arvin-Di Giorgio	89.3	64	65
	Kern	Bakersfield-5558 California Avenue	86.7	65	65
	Kern	Edison	87.7	64	66
	Kern	Maricopa-Stanislaus Street	83.3	63	61
	Kern	Oildale-3311 Manor Street	84.7	65	65
	Kern	Shafter-Walker Street	83.0	62	60
	Tulare	Porterville-1839 Newcomb Street	86.3	63	62
	Tulare	Sequoia and Kings Canyon Natl Park	93.0	65	65
	Tulare	Sequoia Natl Park-Lower Kaweah	84.0	61	62
	Tulare	Visalia-N Church Street	82.3	60	61

9 Corroborating Studies

The design value trends, emissions inventory, and ambient precursor concentrations are all consistent with the conclusions presented in recent work by Pusede and Cohen,[6] who studied the effects of temperature, NOx, and reactivity-weighted VOC (analogous to PAMS reactivity) on the frequency of high ozone days in the San Joaquin Valley. The study included observed data from 1995 to 2010. Monitoring sites for which data were evaluated were chosen based on location upwind, within, and downwind of three cities. The authors classified the Valley into northern, central, and southern regions. The assessment was done to estimate the probability of exceeding the California 8-hour average ozone standard of 0.070 ppm, which is also relevant to the new national ozone standard set in 2015. The manuscript described changes in the frequency of high ozone days based on routine observed data as mentioned above to provide direct insight into the probabilistic response of ozone to emissions reductions.

The authors inferred from the study results that chemical production and not meteorology dominated the statistics of State standard ozone exceedances in the Valley. Results also indicate that local ozone production plays a larger role as the number of exceedance days increased from upwind to downwind sites which underscores the importance of controlling local sources of emissions in the Valley. Over the study period, decreases in reactive VOC were shown to dramatically reduce the frequency of exceedance days for the State 8-hour ozone standard, particularly at moderate temperatures (28-33°C). While the publication addressed ozone production over a range of temperatures, the interactions of ozone precursors at higher temperatures (34-45°C) are most significant with respect to highest ozone concentrations and attainment of the national 8-hour ozone standard. At these higher temperatures, ozone production in the southern region of the Valley became NOx-sensitive in the 2007-2010 timeframe. The study noted that with NOx reductions projected to occur in the post 2010 timeframe on the basis of local, State and national rulemakings, the Valley was poised to experience improved ozone air quality. Indeed, as emissions have continued to decrease since 2010, ozone levels have responded as predicted in this study.

The study concluded that in the northern region, the downwind site at Merced is already in a NOx-limited regime. The other sites will show a more delayed response to NOx reductions, after the transition to a NOx-limited regime occurs.

No completely consistent and reliable thresholds are available to separate VOC-limited conditions from NOx-limited conditions in all regions. Nevertheless, the southern and central regions of the Valley typically have very high VOC/NOx ratios in the ambient air during the peak months of the ozone season. A key cause of the

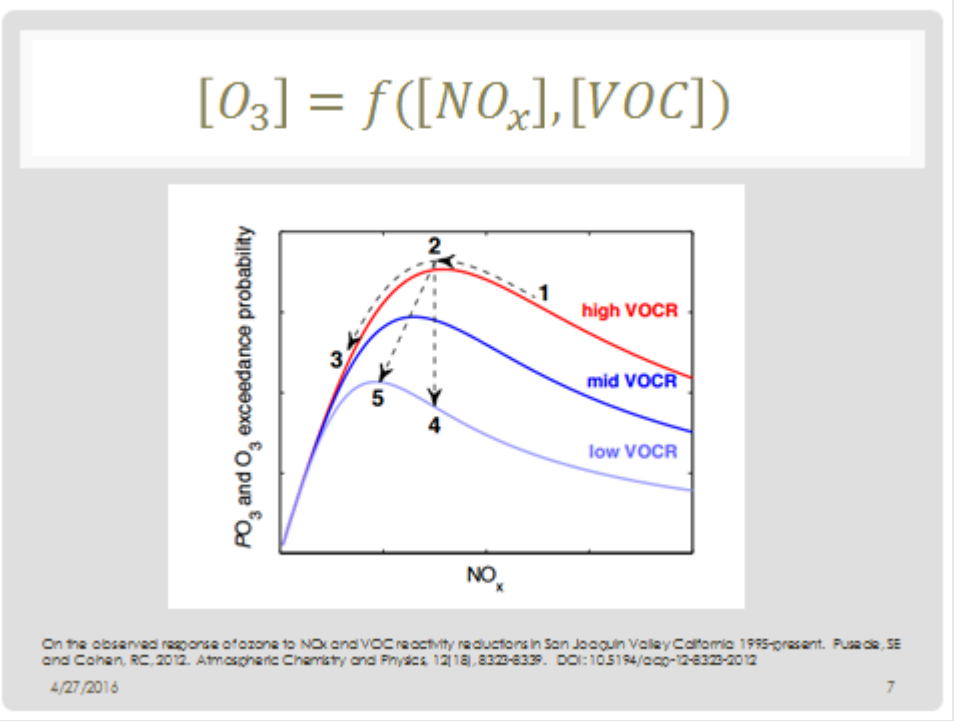
[6] S. E. Pusede and R. C. Cohen, On the observed response of ozone to NOx and VOC reactivity reductions in San Joaquin Valley California 1995–present, Atmos. Chem. Phys., 12, 8323-8339, 2012.

VOC/NOx ratios during these months is high levels of biogenic VOC emissions, which may be three to seven times the anthropogenic VOC emissions. The biogenic VOC emissions also tend to include many "reactive" compounds which enhance the effective VOC/NOx ratio. Accordingly, the VOC/NOx ratios in the Valley's ambient air that represents emissions from biogenic sources as well as human activities are much greater than the VOC/NOx ratios from an emissions inventory that represents only human activities.

In the following figure taken from Pusede and Cohen, the Valley air would be represented by the top (red) curve. The WOE now indicates that the southern and central regions of the Valley are now on the downhill path (from the 2 to the 3), where NOx emissions reductions should rapidly reduce levels of ozone in the ambient air.

Pusede and Cohen also showed that the ozone chemistry in the central region in 2007-2010 was nearer to peak ozone production than in the southern region. Therefore, while NOx emission reductions were expected to result in lower peak ozone concentrations, progress in the central region would be outpaced by progress in the southern region.

Figure 39. Response of Ozone to NOx and VOC Reactivity Reductions



This evidence corroborates results of the modeling analyses, which indicate that NOx reductions will be relatively more effective than VOC reductions in reducing ozone concentrations in the Valley.

10 Preliminary Look: 2015 Ozone Data

While this WOE focuses on official ozone data submitted through 2014, most of the data from 2015 are already submitted. For the data that have not been submitted yet, staff used the Air Quality and Meteorological Information System (AQMIS) for preliminary data. Using these two data sets, it is possible to look at preliminary numbers for trends continuing through 2015.

As pointed out earlier, Clovis-N Villa Avenue and Parlier are the sites that currently have the highest ozone concentrations in the Valley. The 2015 data for these two sites show a decrease in the design value. Clovis-N Villa Avenue had a 2 ppb decrease in design value, while Parlier's design value decreased by 1 ppb. As Table 12 shows below, almost all sites in the Valley show a decrease in design value, with the exception of a few sites with lower design values that showed a small increase of 1 ppb.

Table 12. Preliminary Look: 2014-2015 Design Values

	County	Site	2014	2015
Northern	Merced	Merced-S Coffee Avenue	0.081	0.082
	San Joaquin	Stockton-Hazelton Street	0.069	0.068
	San Joaquin	Tracy-Airport	0.079	0.076
	Stanislaus	Modesto-14th Street	0.078	0.079
	Stanislaus	Turlock-S Minaret Street	0.084	0.082
Central	Fresno	Clovis-N Villa Avenue	0.095	0.093
	Fresno	Fresno-1st Street/Fresno-Garland	0.089	0.087
	Fresno	Fresno-Drummond Street	0.088	0.086
	Fresno	Fresno-Sierra Skypark #2	0.087	0.087
	Fresno	Parlier	0.092	0.091
	Fresno	Tranquility-32650 West Adams Avenue	0.075	0.075
	Kings	Hanford-S Irwin Street	0.084	0.085
	Madera	Madera-28261 Avenue 14	0.084	0.083
	Madera	Madera-Pump Yard	0.081	0.082
Southern	Kern	Arvin-Di Giorgio	0.088	0.087
	Kern	Bakersfield-5558 California Avenue	0.085	0.085
	Kern	Bakersfield-Municipal Airport	0.091	0.090
	Kern	Edison	0.084	0.084
	Kern	Maricopa-Stanislaus Street	0.079	0.079
	Kern	Oildale-3311 Manor Street	0.081	0.079
	Kern	Shafter-Walker Street	0.081	0.080
	Tulare	Porterville-1839 Newcomb Street	0.081	0.082
	Tulare	Sequoia and Kings Canyon Natl Park	0.091	0.089
	Tulare	Sequoia Natl Park-Lower Kaweah	0.086	0.085
	Tulare	Visalia-N Church Street	0.080	0.079

The preliminary 2015 data are consistent with the conclusions of the WOE assessment demonstrating that the Valley continues to show a trend toward lower ozone.

11 Summary

Photochemical modeling performed in support of the Valley's 8-hour ozone attainment plan shows that with current emissions reductions programs, the San Joaquin Valley will attain the 0.075 ppm 8-hour ozone standard by 2031. This is consistent with additional analyses using observed ozone levels, meteorology, and precursor emissions. While the southern portion of the Valley transitioned to a NOx-sensitive regime first, other regions are now undergoing the same transition.

This WOE package comprises a set of complementary analyses that supplement the SIP-required modeling, providing additional support for the attainment demonstration based on the following factors:

- Trends for multiple indicators of ozone air quality have shown progress in the Valley, with a decrease in basinwide design value of 20 percent from 1990 to 2014 (22 percent when including 2015 data), with an 18 percent reduction in design value since 2004.

- From 2000-2012, ambient NOx concentrations have decreased in the central and southern regions by an average of 40 percent.

- Exceedance days have decreased by 40 percent in the past decade, and the severity of ozone has significantly decreased throughout the Valley.

- Sites in the northern region are already close to the level of the standard. The highest site in 2014, Turlock-S Minaret Street, has shown a decrease in design value of 0.010 ppm (0.094 to 0.084 ppm) since 2004, and is now within 11 percent of the standard.

- The central region has exhibited progress at most sites, with a declining trend in design values over the past decade, especially in recent years. The design site, Clovis-N Villa Avenue, showed limited progress prior to 2010; however, since then ozone concentrations have been decreasing. The other high sites in the central region on average have seen a 14 percent drop in design value and approximately 27 percent drop in exceedance days in the past decade.

- Sites in the southern region have shown the most progress, with the highest design value in the region decreasing by 22 percent (0.116 to 0.091 ppm) since 2004, and exceedance days decreasing by 73 percent.

- Accounting for meteorological variability, season average ozone levels declined from 2007-2014 in the southern and northern regions of the Valley. Similarly adjusted design value trends could be expected to show a greater response to emission reductions and decline at a faster rate throughout the Valley.

- From the emission inventory, there has been a basinwide reduction of 46 percent (288 tons/day) in NOx and a reduction of 33 percent (166 tons/day) in VOC from 2000 to 2012. These reductions have driven the VOC/NOx ratio in the Valley towards and into the NOx limited regime. Within that time frame, the central and southern regions had on average a 47 percent reduction in NOx, corroborated by the 40 percent decrease in ambient NOx concentrations in those regions.

- The ozone weekday-weekend analysis supports that the central and southern regions are already in a NOx-limited regime and the northern region will soon be transitioning into one.

- Recent studies conducted by researchers at UC Berkeley have analyzed the effects of NOx and VOCs on high ozone days in the Valley. They concluded that the northern region has not yet transitioned to a NOx-limited regime. However, as of 2010, NOx reductions were already effective or poised to become so in the southern region and central regions.

- Based on all available ambient precursor trends, emissions inventory, weekday-weekend analyses, and field-based studies, it is expected that the Valley will be increasingly responsive to NOx reductions.

- Between 2012 and 2031, current control programs are expected to reduce NOx emissions by approximately 60 percent (around 200 tons/day).

- The modeled ozone reductions in the Valley also demonstrate increasing responsiveness to NOx reductions. The substantial NOx reductions that will occur though ongoing implementation of current control programs are consistent with the demonstration that the Valley will attain the 0.075 ppm ozone standard in 2031.

Taken together, all of these factors indicate that all sites in the San Joaquin Valley can be expected to attain the national 8-hour ozone standard by 2031 with current ARB and District control programs.