

Chapter 2

Scientific Foundation, Trends, and Modeling Results

2013 Plan for the Revoked 1-Hour Ozone Standard
SJVUAPCD

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CHAPTER 2: SCIENTIFIC FOUNDATION, TRENDS, AND MODELING RESULTS

Ozone (O₃), a molecule of three oxygen atoms, is a product of atmospheric reactions involving volatile organic compounds (VOCs), oxides of nitrogen (NO_x), the hydroxyl radical (HO), other radicals, and sunlight. As such, ozone is not emitted directly but, rather, is formed secondarily. Ozone is found in two regions of the Earth's atmosphere: the upper regions of the atmosphere (the stratosphere), where the ozone layer is effective in absorbing the Sun's ultraviolet (UV) radiation; and ground-level (or tropospheric) ozone. At high concentrations, this ground-level ozone can be harmful to public health and can degrade the environment.

As a pollutant, ozone has been measured in the San Joaquin Valley air basin (Valley) and across the nation for decades. The District, ARB, EPA, and private partners have invested millions of dollars into Study Agency field study, analysis, and modeling over the last several decades to build a strong scientific foundation for the Valley's ozone attainment plans.

This chapter summarizes the contributions to the Valley's 1-hour ozone levels, ozone research, trends in the Valley's 1-hour ozone concentrations, and projections of 1-hour ozone that show attainment of the 1979 standard by 2017. For more information, see Appendix A (Ambient 1-Hour Ozone Data Analysis), Appendix B (Emissions Inventory), and Appendix F (Modeling Approach and Results).

2.1 CONTRIBUTIONS TO THE VALLEY'S 1-HOUR OZONE LEVELS

Contributions to the Valley's ozone levels are a function of geography and natural environment (including meteorology), the production and presence of ozone precursors (e.g. NO_x and VOCs), the atmospheric chemistry that controls the ozone life cycle, and the import of non-Valley emissions into the Valley. All of these factors, except geography, vary throughout the year, but during the summer months they combine to account for the Valley's highest annual ozone concentrations.

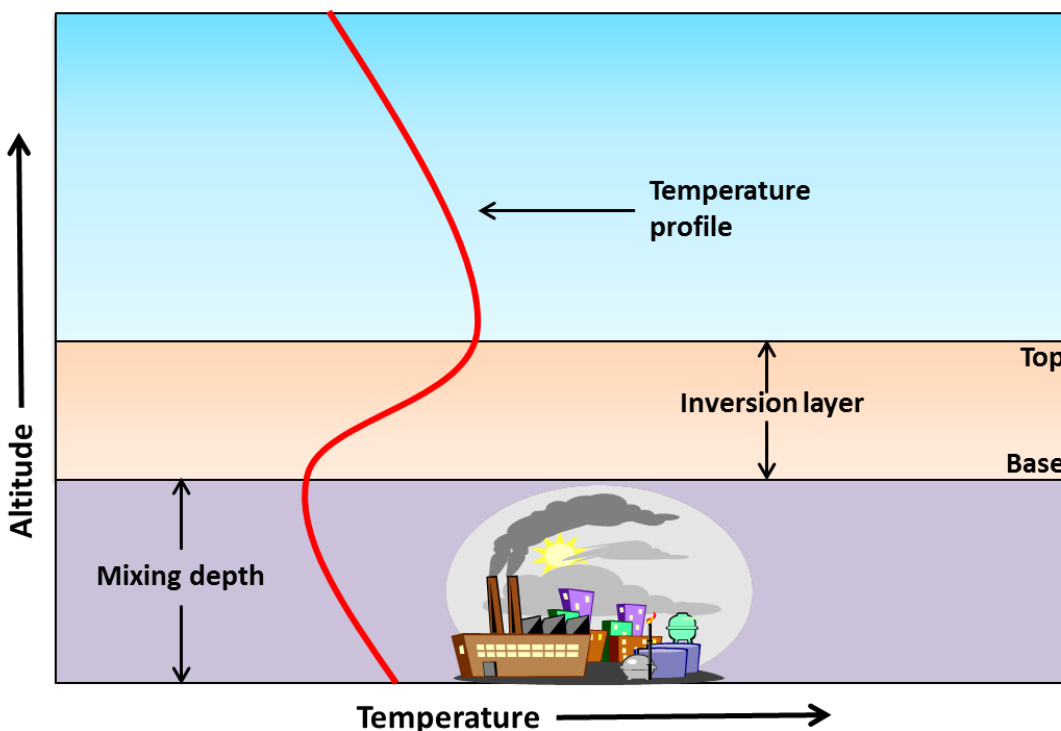
2.1.1 The Valley's Natural Environment

The topography and climate in the Valley create ideal conditions for generating and trapping ozone precursors, and then creating and retaining ozone air pollution. Comprising nearly 25,000 square miles, the Valley is a continuous intermountain basin (Figure 2-1).

Figure 2-1 San Joaquin Valley Air Basin

During the summer months, low precipitation levels, high temperatures, light winds, and afternoon northwesterly winds in the Valley are conducive to forming and transporting elevated ozone levels from the northern to southern region of the Valley. The Valley averages over 260 sunny days per year. Nearly 90% of the annual precipitation in the Valley falls between the months of November through April, with little to none occurring during the summer months.

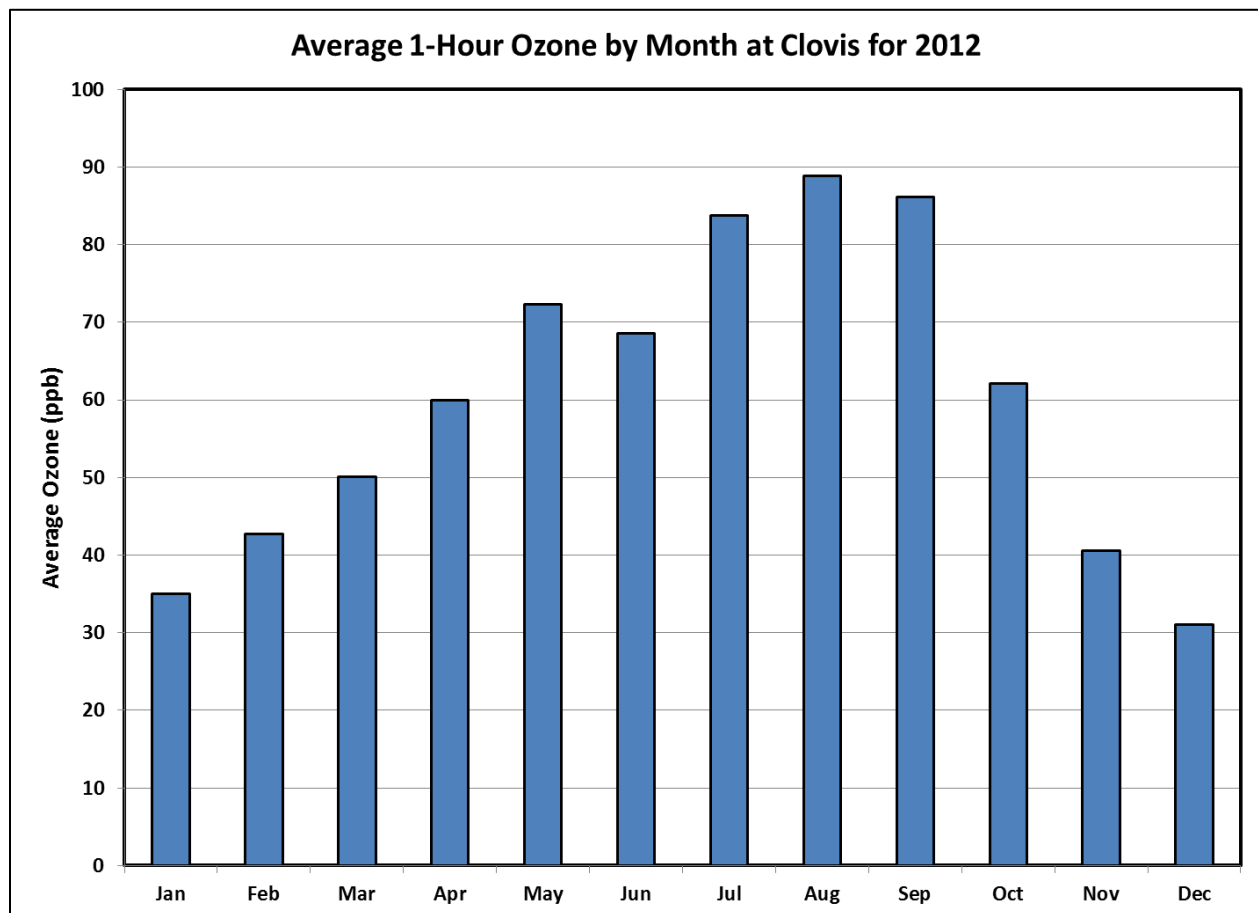
Inversion layers and vertical mixing can influence ambient air quality. A temperature inversion, or increasing temperature with increasing height (Figure 2-2), can shut down the vertical mixing of an air mass, thus creating a situation in which pollutants are trapped near the earth's surface. Temperature inversions are common in the Valley throughout the year. The base of the inversion acts as a lid on the atmosphere, trapping pollution by limiting vertical dispersion. During the summer, inversion events caused by high pressure systems cause air pollutant emissions to build up. Ozone precursors then react to form ozone, which can in turn build in concentrations from day to day under a prolonged period of atmospheric stagnation.

Figure 2-2 Effect of Temperature Inversion on Pollutant Dispersion

Winds, at ground level or at higher altitudes, transport pollutants from other regions into the Valley, within the Valley to areas downwind, and from the Valley into other regions. The amount of pollution transported from other areas into the Valley varies. Typically during an average summer day, surface winds pick up ozone precursors emitted in regions to the north of the Valley and transports them southeast toward the central and southern end of the basin where ozone levels have the potential to form at their highest concentrations. Air flow also moves upslope along the Sierra Nevada Mountains during the day as the air heats up, and then moves downslope as the air cools in the evening.

Because of frequent high pressure systems influencing Valley meteorological and dispersion conditions during the summer months, ozone concentrations tend to be the highest from June to September. As an example, Figure 2-3 shows the average 1-hour ozone concentration per month during 2012 for the Clovis air monitoring site. Ozone concentrations rise from the beginning of the year toward the summer where levels reach their peak by August when temperatures are usually the warmest and when high pressure and stagnation over the Valley are most common.

California's summer wildfires can also affect ozone air quality. These fires emit ozone precursors and particulates that can be transported by wind to the Valley. The precursors react to form ozone, although particulates in the smoke plume can sometimes reduce ozone formation rates by blocking sunlight. During the summer of 2008, California experienced a record number of wildfires. The resulting emissions caused serious public health impacts and unprecedented levels of PM_{2.5} and ozone in the Valley and other regions throughout the state.

Figure 2-3 2012 Monthly Average Ozone at Clovis

2.1.2 Emissions of Ozone Precursors

The District and the California Air Resources Board (ARB) maintain an accounting of ozone precursor emissions for the Valley. This emissions inventory represents an estimate of how much direct pollution is being emitted from various pollutant-generating activities and sources. The emissions inventory is used to develop control strategies, to determine the effectiveness of permitting and control programs, to provide input into air quality modeling, to fulfill rate-of-progress (ROP) requirements, and to address other planning needs.

Appendix B contains NO_x and VOC emissions inventories for anthropogenic (emissions generated from human activities) sources for the years 2007 through 2022. As shown in Figure 2-4, NO_x emissions will steadily decline through 2017 as current control strategies continue to be implemented. Figure 2-5 shows that VOC emissions are projected to be relatively stable from 2014 forward; however, VOC emissions decreased 28% between 2000 (not shown) and 2014. These emissions inventory trends show the progress made through progressive regulatory and non-regulatory activities. As rules are adopted or amended with tighter emission limits, or as emission reduction control technologies improve, overall emissions decrease. In light of the Valley's projected

increase in population over this time period, the projected emissions reductions highlight the success of the control measures adopted and enforced by the District, ARB, and other regulatory agencies.

Figure 2-4 Summer NOx Trends in the Valley

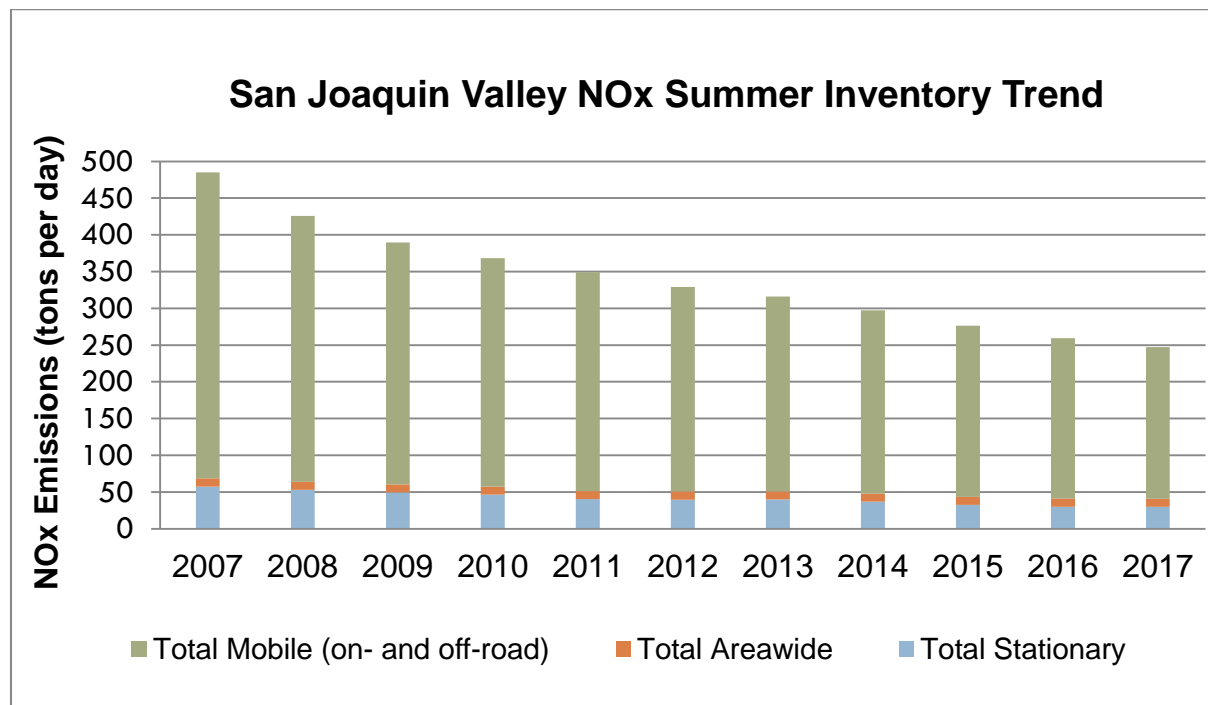
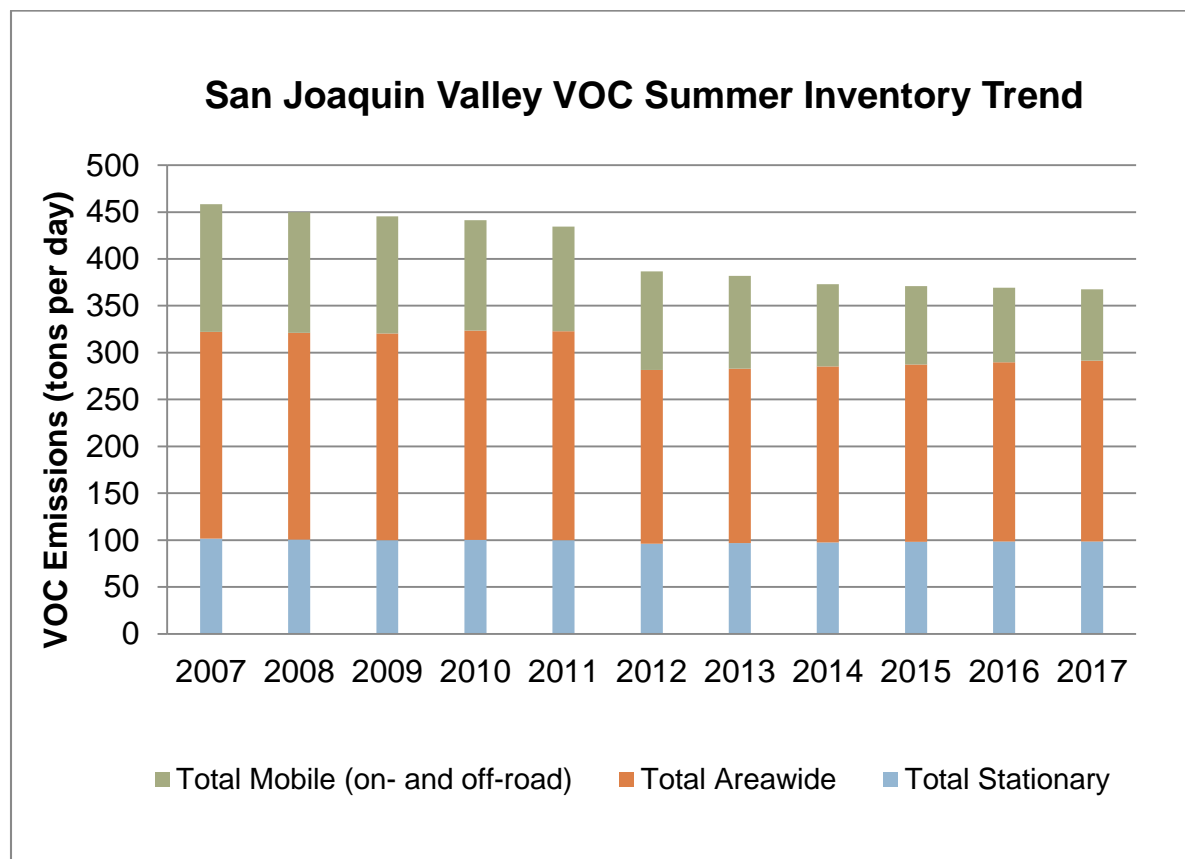


Figure 2-5 Summer VOC Trends in the Valley



Only anthropogenic emissions are subject to regulatory requirements. However, biogenic emissions from vegetation, which are estimated and included in photochemical modeling analyses, can overwhelm anthropogenic VOC emissions, particularly during the Valley's ozone season (see Appendix E (Modeling Protocol) for more information).

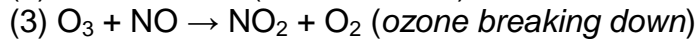
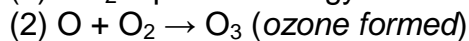
2.1.3 The Nature and Formation of Ozone

Ozone is a product of intricate atmospheric reactions involving VOCs, NO_x (such as NO₂ and NO), the hydroxyl radical (HO), other radicals, and sunlight (photon energy). The concentration of ambient ozone at any given location in the Valley is a function of the natural environment, ozone precursor emissions, and atmospheric chemistry.

2.1.3.1 The Ozone Life Cycle

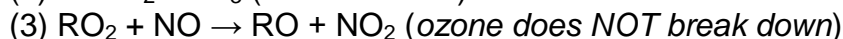
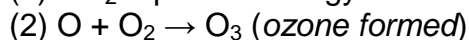
In a balanced atmosphere, where precursor emissions of VOC and NO_x levels are relatively low, ozone is both created and destroyed at a pace to keep ozone at acceptable background levels. This ozone life cycle occurs continuously while sunlight is present, but ends at nightfall.

The following reactions summarize the ozone life cycle process:



The O_3 molecule is a very strong oxidizing agent. It is very willing to give away the additional oxygen atom to another molecule and become the more stable O_2 .

The ozone life cycle becomes unbalanced in the presence of elevated precursor emissions. As noted in Section 2.1.2, biogenic VOC emissions are especially high during the Valley's summer ozone season. The same photon energy that reacts with NO_2 in the balanced reaction set also reacts with ozone in the presence of water (humidity) to form hydroxyl radicals (HO) that quickly oxidize VOCs to produce peroxy radicals (RO_2), which in turn react quickly with dissociated NO to form NO_2 , bypassing the ozone consumption process. The following set of reactions summarizes this alternate chain of events:

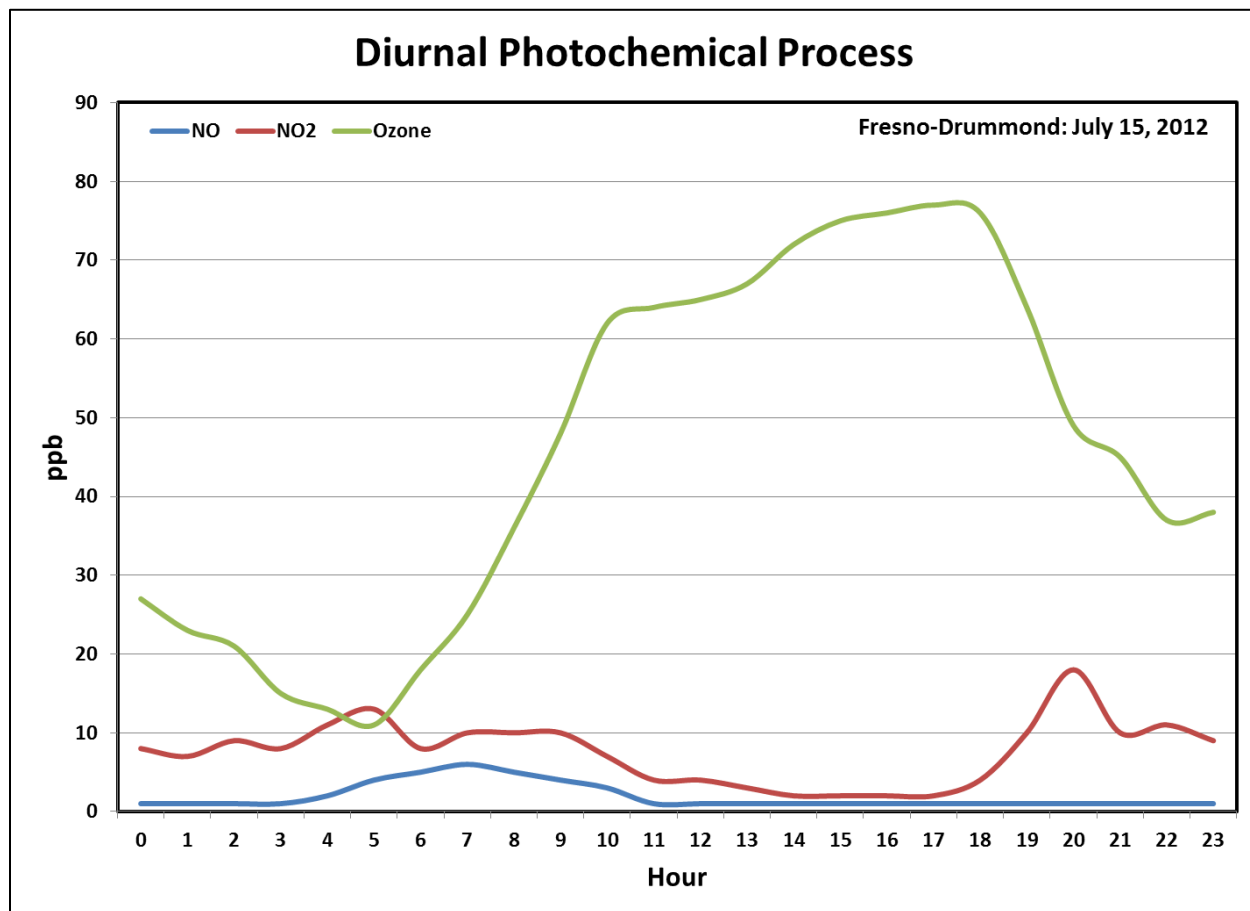


The multi-step breakdown of VOCs (mostly biogenic) regenerates radicals, which work as the fuel, or catalyst, consuming the dissociated NO and driving the ozone production cycle (without ozone break down).

This catalytic process is cut off as night falls, or with the removal of the photon energy input. Once the sun sets, ozone levels fall. Figure 2-6 is an example of the diurnal photochemical ozone formation process under unbalanced conditions and shows the concentration of NO, NO_2 , and ozone throughout the hours of a common summer day. The day begins with low ambient levels of NO_x (NO and NO_2) and ozone. As the morning commute begins, NO_x emissions increase as these pollutants are emitted directly from motor vehicle traffic. The influx of NO_x emissions between hours four and seven provide the initial startup of the rapid, unchecked photochemical production of ozone beginning at hour five and increasing into the late afternoon. As ozone production increases, NO and NO_2 concentrations fall quickly to almost zero (being consumed by VOC reactions). In the early evening, with waning sunlight and decreasing photon energy, ozone production ceases and its concentration rapidly diminishes as NO and NO_2 levels return to normal ambient levels.

While biogenic VOC emissions are prevalent throughout the Valley, additional VOC emissions from the combustion of fossil fuels combined with NO_x emissions from the same mobile and stationary sources found in metropolitan areas give rise to the highest concentrations of ground level ozone in the Valley.

Figure 2-6 Photochemical Process for a Valley Summer Ozone Day



2.1.3.2 Relative Roles of VOCs and NO_x in Ozone Formation

Both VOC and NO_x emissions contribute to the formation of ozone. However, although the breakdown of VOCs provides the fuel for unchecked ozone production throughout a summer day in the Valley, ozone production is more sensitive to the amount of NO_x under high-VOC and relatively lower-NO_x conditions. For most of the summer ozone season, the Valley is characterized by this *NO_x-limited regime*.

Determination of an ozone chemical regime is not a straight-forward task. As described below, the District, ARB, EPA, and private partners have invested millions of dollars into Study Agency field study, analysis, and modeling over the last several decades to build a strong scientific foundation for the Valley's ozone attainment plans. To date, grid-based photochemical models remain the best available tool to determination relative precursor limitations. Modeling for the *2013 Plan for the Revoked 1-Hour Ozone Standard* and other ozone SIPs shows that the Valley is a *NO_x-limited regime*, especially in projections of future years. For this reason, the District focuses its emissions reductions efforts on NO_x reductions, as they are most effective in reducing Valley ozone concentrations.

Other ozone chemical regimes include a *NOx-rich* regime, in which ozone formation is more sensitive to the amount of VOCs, and a regime in which VOC and NOx equally contribute to ozone formation. As proven through extensive modeling and successful reduced ambient ozone levels based on NOx-centric strategies, developing reduction strategies based on these regimes would not be effective in the Valley.

2.1.3.3 The Propensities of Different VOCs to Form Ozone

The potential of VOCs to form ozone is specific to the type of VOC. VOCs include many different compounds, each with different properties that contribute differently to ozone formation. These differences in ozone forming potential, or *propensities*, of VOCs are quantified as ozone *reactivities*.

VOC *reactivity scales* have been developed to measure the ozone forming potential of individual VOCs,^{1,2,3} of which the most frequently used is the *maximum incremental reactivity* (MIR) scale.^{4,5} Incremental reactivity is defined as the amount of additional ozone formation, under optimal NOx conditions, resulting from an addition of a small amount of the given VOC to the system in which ozone is formed, divided by the amount of VOC added. See Section 2.2.3 for recent research results on Valley VOC reactivity trends. While understanding VOC reactivity is an important component of ozone plan analysis, research and modeling have shown the Valley to be NOx-limited; therefore, NOx reductions are the most effective strategy for reducing Valley ozone concentrations.

2.1.4 SJV Trans-Boundary Emissions and Policy-Relevant Background Ozone

As ozone research continues, evidence is mounting that ozone formation is not only affected by precursor emissions originating within the Valley, but is in part affected by trans-boundary emissions; in other words, pollutants are migrating from sources outside the Valley and settling within the Valley. This issue has given rise to the term *policy relevant background* (PRB) ozone, which is defined as the surface ozone concentration that would be present over the U.S. in the absence of North American anthropogenic (human caused) emissions. PRB ozone includes emissions from both biogenic (plant life) and trans-boundary sources.

The 1990 amendments to the Clean Air Act (CAA) recognize the potential threat of trans-boundary ozone flow to attainment. While not absolved from implementing reasonably available controls to reduce emission from sources under their control, CAA §179B (International Border Areas), mandates that state, local, and regional authorities

¹ Bowman, F. M. & Seinfeld, J. H. (1994). Ozone Productivity of Atmospheric Organics. *Journal of Geophysical Research*, 99, 5309–5324.

² Bowman, F. M. & Seinfeld, J. H. (1994). Fundamental Basis of Incremental Reactivities of Organics in Ozone Formation in VOC/NOx Mixtures. *Atmospheric Environment*, 28, 3359–3368.

³ Carter, W.P.L (1994). Development of Ozone Reactivity Scales for Volatile Organic Compounds. *Journal of the Air & Waste Management Association*, 44, 881–899.

⁴ Ibid.

⁵ Carter, W.P.L., Pierce, J.A., Luo, D., & Malkina, I.L. (1995). Environmental Chamber Study of Maximum Incremental Reactivities of Volatile Organic Compounds. *Atmospheric Environment*, 29, 2499–2511.

will not be penalized or otherwise burdened and held responsible for the impact of pollution emissions from foreign sources:⁶

Notwithstanding any other provision of law, any State that establishes to the satisfaction of the Administrator that, with respect to an ozone nonattainment area in such State, such State would have attained the national ambient air quality standard for ozone by the applicable attainment date, but for emissions emanating from outside of the United States, shall not be subject to the provisions of section 181(a)(2) or (5) or section 185.⁷

As emissions in many other parts of the world increase, both the relative and absolute contributions of international transport to U.S. air quality problems have increased, especially in the western continental United States (U.S.). Evidence collected to date suggests that the incremental contributions of these flows into U.S. regions will affect air quality degradation on the same order of magnitude as the incremental air quality improvements that are expected to result from the recent strengthening of the 2008 8-hour ozone standard.⁸ As air districts, especially those along the west coast and in higher elevations in the western U.S., plan for attainment of the 2008 standard, and perhaps more stringent standards in the future, the understanding of such trans-boundary ozone flow will be of great importance.

The volume of research on trans-boundary ozone has grown considerably in the past 10 years. Transport of ozone to North America from Asia along prevailing air currents is now well-established in the scientific literature.⁹ Driven by increasing fossil fuel combustion, tropospheric ozone concentrations entering the west coast of the U.S. have increased by about 10 parts per billion (ppb) from the mid-1980s to the mid-2000s.¹⁰ Closely related to this trend, NO_x emissions from southern and eastern Asia increased 44% during the 2001 to 2006 timeframe. During the same period, NO_x emissions in China rose 55%.¹¹ In contrast, European ozone precursor emissions decreased by more than 33% from 1990 to 2005 and by a comparable level in the U.S. from 1985 to 2008. Furthermore, a recent study of trans-boundary ozone flows into western North America from 1995 to 2008 found a comparable upward annual trend in ozone (0.80

⁶ Clean Air Act, U.S.C. § 7509a.

⁷ *Ibid* 5. Note: The U.S. Chamber of Commerce and other interested parties have complained that EPA has provided no clear, consistent guidance to state, local, and regional authorities seeking to account for the impact of foreign emissions in calculating attainment of CAA standards.

⁸ National Research Council. (2009). *Global Sources of Local Pollution: An Assessment of Long-Range Transport of Key Air Pollutants to and from the United States*. Washington, DC: The National Academies Press, p. 31. Retrieved from http://www.nap.edu/catalog.php?record_id=12743#toc

⁹ Hudman, R. C., Jacob, D. J., Cooper, O. R., Heald, C.L., Park, R.J. ... Ryerson, T. (2004) Ozone Production in Transpacific Asian Pollution Plumes and Implications for Ozone Air Quality in California. *Journal of Geophysical Research: Atmospheres*, 109, D23S10.

¹⁰ Oltmans, S. J., Lefohn, A. S., Harris, J. M., & Shadwick, D. S. (2008). Background Ozone Levels of Air Entering the West Coast of the U.S. and Assessment of Longer-Term Changes. *Atmospheric Environment*, 42, 6020–6038.

¹¹ Zhang, Q., Streets, D.G., Carmichael, G.R., He, K.B., Huo, H., Kannari, A. ... Yao, Z.L.. (2009). Asian Emissions in 2006 for the NASA INTEX-B Mission. *Atmospheric Chemistry and Physics*, 9, 5131–5153. Retrieved from <http://www.atmos-chem-phys.net/9/5131/2009/acp-9-5131-2009.pdf>

ppb per year) on those days when air masses transported across the Pacific Ocean had originated in China, India, and Southeast Asia.¹²

Such understanding of trans-boundary flow has direct implications for establishing reasonably accurate PRB levels. Air quality agencies will use the PRB level to create accurate emission and transport models that form the foundation for cost-effective control measures. For example, if the Valley PRB ozone level is underestimated, subsequent emission controls put on local, regional, or state precursor sources will fail to achieve expected ozone reductions.

This mounting evidence of an escalating PRB in the western U.S. is now impacting EPA's ongoing policy deliberations regarding a new 8-hour ozone standard. In establishing the 2008 8-hour ozone standard of 75 ppb, the EPA assumed a PRB ozone range of 15–35 ppb. In its current reassessment of this standard, members of the EPA's Clean Air Scientific Advisory Committee (CASAC) assert that this range seriously underestimates PRB ozone, particularly in the western U.S. Ongoing research on trans-boundary and PRB ozone will be key in future policy decisions and the establishment of subsequent federal ozone standards.

2.2 AIR QUALITY RESEARCH FOCUSED ON OZONE

Because of its unique combination of geography, meteorology, and chemistry, the Valley continues to be one of the most studied airsheds in the world. On a number of academic and professional fronts, including the efforts of the San Joaquin Valleywide Air Pollution Study Agency (Study Agency), a substantial amount of research has focused on ozone in the Valley. In addition to Study Agency and District sponsored research, many academic groups, independent from the District, regularly study the air quality dynamics of Valley and contribute to the body of shared knowledge. It is this shared knowledge that informs the District's planning process and guides the ultimate success and implementation of its attainment plans.

2.2.1 Central California Ozone Study

The Study Agency has developed and funded extensive ozone research specific to the Valley. The Study Agency was established in 1985 under a joint-powers agreement between local counties and includes input from districts, the State, EPA, public and private industry representatives, and other governmental agencies to create a cooperative and unbiased research program. The Study Agency's main purpose is to further the scientific understanding of regional air quality issues to assist regulatory agencies in attainment strategy and policy development.

The Central California Ozone Study (CCOS) is the most recent major Study Agency field program to study ozone in the Valley. This study was conducted during the summer of 2000 and included extensive monitoring throughout the Valley and

¹² Cooper, O.R., Parrish, D.D., Stohl, A., Trainer, M., Nédélec, P., Thouret, V. ... Avery, M.A. (2010). Increasing Springtime Ozone Mixing Ratios in the Free Troposphere over Western North America. *Nature*, 463, 344–348.

surrounding regions to provide a robust and spatially dense dataset for a large portion of California. Many subsequent research projects have taken advantage of CCOS data to provide a better understanding of ozone in the Valley. The results from these studies have given academics and air quality regulators alike a more robust understanding of Valley ozone formation and have aided in the development of the most effective control strategies.

2.2.2 PAMS monitoring

The District participates in EPA's enhanced Photochemical Assessment Monitoring Stations (PAMS) program. PAMS sites measure ozone precursors, including NOx and VOC, in addition to a variety of meteorological parameters in serious, severe, or extreme ozone nonattainment areas. The District's current PAMS monitoring network is comprised of two smaller networks focused on the Fresno and Bakersfield metropolitan statistical areas (MSAs). Each of these MSAs include three PAMS sites, with each site filling the role of either a Type 1, Type 2, or Type 3 site:

- Type 1 PAMS sites monitor morning upwind ozone and ozone precursor concentrations
- Type 2 PAMS sites monitor morning ozone and ozone precursor concentrations at the downwind edge of the central business district
- Type 3 PAMS sites monitor peak afternoon ozone concentration downwind of the MSA

PAMS monitoring sites are usually established at existing state and local air monitoring stations (SLAMSS). Table 2-1 summarizes the sites that make up the Valley's PAMS network. There is currently no Type 3 PAMS monitor in the Bakersfield MSA because the Arvin-Bear Mountain air monitoring site was closed in 2010 (see Section 2.2.5). PAMS monitoring will eventually be transitioned to the permanent Arvin-Bear Mountain replacement site.

Table 2-1 San Joaquin Valley PAMS Monitoring Network

MSA	Type 1	Type 2	Type 3
Fresno	Madera-Pump	Clovis	Parlier
Bakersfield	Shafter	Bakersfield-Muni	--

Valley PAMS monitoring typically occurs each summer from June to August, when ozone concentrations tend to reach annual maximums. Through Valley PAMS monitoring, over 50 VOCs are measured and analyzed. Table 2-2 lists the targeted and measured compounds for the PAMS program.

Table 2-2 PAMS VOC Target Species

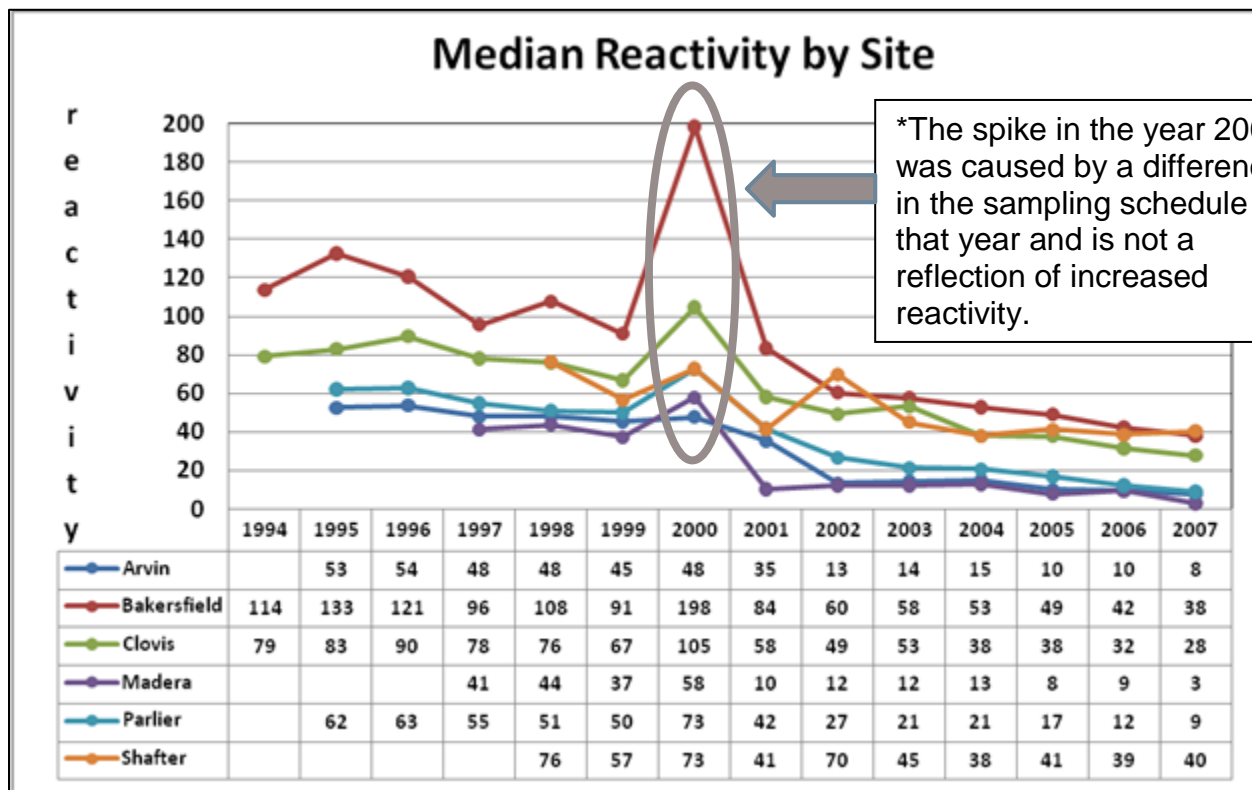
Type	Compound	Type	Compound
Hydrocarbon	Ethylene	Hydrocarbon	3-methylhexane
Hydrocarbon	Acetylene	Hydrocarbon	2,2,4-trimethylpentane
Hydrocarbon	Ethane	Hydrocarbon	n-Heptane
Hydrocarbon	Propylene	Hydrocarbon	Methylcyclohexane
Hydrocarbon	Propane	Hydrocarbon	2,3,4-trimethylpentane
Hydrocarbon	Isobutane	Hydrocarbon	Toluene
Hydrocarbon	1-Butene	Hydrocarbon	2-methylheptane
Hydrocarbon	n-Butane	Hydrocarbon	3-methylheptane
Hydrocarbon	t-2-Butene	Hydrocarbon	n-Octane
Hydrocarbon	c-2-Butene	Hydrocarbon	Ethylbenzene
Hydrocarbon	Isopentane	Hydrocarbon	m&p-Xylenes
Hydrocarbon	1-Pentene	Hydrocarbon	Styrene
Hydrocarbon	n-Pentane	Hydrocarbon	o-Xylene
Hydrocarbon	Isoprene	Hydrocarbon	n-Nonane
Hydrocarbon	t-2-pentene	Hydrocarbon	Isopropylbenzene
Hydrocarbon	c-2-pentene	Hydrocarbon	n-Propylbenzene
Hydrocarbon	2,2-Dimethylbutane	Hydrocarbon	m-Ethyltoluene
Hydrocarbon	Cyclopentane	Hydrocarbon	p-Ethyltoluene
Hydrocarbon	2,3-dimethylbutane	Hydrocarbon	1,3,5-Trimethylbenzene
Hydrocarbon	2-methylpentane	Hydrocarbon	o-Ethyltoluene
Hydrocarbon	3-Methylpentane	Hydrocarbon	1,2,4-trimethylbenzene
Hydrocarbon	2-Methyl-1-Pentene	Hydrocarbon	n-Decane
Hydrocarbon	n-hexane	Hydrocarbon	1,2,3-trimethylbenzene
Hydrocarbon	Methylcyclopentane	Hydrocarbon	m-Diethylbenzene
Hydrocarbon	2,4-dimethylpentane	Hydrocarbon	p-Diethylbenzene
Hydrocarbon	Benzene	Hydrocarbon	n-Undecane
Hydrocarbon	Cyclohexane	Carbonyl	Formaldehyde
Hydrocarbon	2-methylhexane	Carbonyl	Acetone
Hydrocarbon	2,3-dimethylpentane	Carbonyl	Acetaldehyde

2.2.3 VOC Reactivity Trends

In 2010, a study was conducted to analyze trends historical PAMS data recorded for the Valley focusing on the 1994 through 2007 time frame.¹³ Within this study, the Maximum Incremental Reactivity (MIR) scale was used to quantify the strength of the ozone forming potential for each VOC. The compounds found to be the most conducive to ozone formation throughout all of the PAMS sites were toluene, two xylenes, ethylene, propylene, isopentane, and 1,2,4-trimethylbenzene. Figure 2-7, taken from the study's final report, shows the median reactivity trend among all compounds for each site over the 1994–2007 time period.

¹³ Providence Engineering and Environmental Group (2010). *Analysis of PAMS Data 1994–2007*.

Figure 2-7 VOC Reactivity Trends by PAMS Site



Generally, the report noted that the Bakersfield PAMS site had the highest reactivity, exceeding the reactivity levels among all of the PAMS sites in the Fresno MSA. The report also noted that the Arvin PAMS site had low reactivity coupled with high ozone concentrations. This observation supports the assessment that the high ozone concentrations in the Arvin area are not formed locally, but are transported from upwind areas.

Overall, the trend in median VOC reactivity among all of the PAMS sites in the Valley is declining, meaning that over time, and as emissions reductions have occurred, more VOC is required than in the past to form an equal amount of ozone.

2.2.4 Trans-Boundary Ozone Research

Recent research by the National Oceanic and Atmospheric Administration (NOAA) found evidence that trans-boundary ozone flow from Asia was significantly impacting ground-level ozone monitors in the northern Sacramento Valley. Additionally, daily flows of trans-boundary ozone were found to be highly correlated with ozone exceedance events in Butte County, CA.

Based on these results, in 2011 the District awarded the University of California at Davis \$130,000 for the installation of a trans-boundary ozone and PM2.5 monitoring station on Chews Ridge, east of Big Sur. The site sits at an elevation of 5,200 feet and is the home of Monterey Institute for Research in Astronomy Observatory. The goal of this

work is to investigate whether trans-boundary ozone is mixing downward into the boundary layer of the Valley and subsequently transported to ambient monitors. The project includes bimonthly air flights over the Valley and the marine boundary layer during peak ozone season. Monitoring and data collection is slated to continue through September 2013.

In addition, in June, 2013 the District awarded a grant of \$100,000 to the same UC Davis research team to conduct an intensive flight campaign over the course of the 2013 ozone season consisting of four three-day flights during periods of ozone buildup. Data collection includes north to south Valley transects in the Valley boundary layer and free troposphere as well as spiral transects in the south Valley around Bakersfield. The research design builds on previously published research by NOAA scientists in the 2010 CalNEX campaign that estimated Bakersfield ozone enhancements from trans-boundary flows of 12-23% on peak days.

2.2.5 Arvin Ozone Saturation Study

Since 1989, ARB had maintained an air quality monitoring station at 20401 Bear Mountain Boulevard in Arvin, at the Arvin-Edison Water Storage District facility. In December 2010, ARB discontinued monitoring at that station, but prior to closure, established a new site at Di Giorgio Elementary School (19405 Buena Vista Blvd), also in Arvin, just 2.2 miles away from the Bear Mountain site. ARB operated both stations in parallel for the approximately one year (including the summer of 2010).

Results of the parallel monitoring indicated that the new site at Arvin-Di Giorgio measured concentrations approximately 10% lower than the levels historically recorded at the Arvin-Bear Mountain site. While this relative difference may be due to accuracy levels inherent to air quality monitoring equipment, EPA has indicated that this difference may impact their ability to find the Valley in attainment of federal ozone standards. The data also suggests that ozone concentrations measured at the Di Giorgio Elementary School are more representative of residents' exposure.

Understandably, residents and others have concerns about the different measurements at the two sites. In response to those concerns, the District is sponsoring an Arvin Saturation Study to further evaluate the relative differences in ozone concentrations in the Arvin area. Through this study, the District will measure ozone levels in multiple locations in and around Arvin to develop relationships between measurements at the new air monitoring location (Arvin-Di Giorgio), City of Arvin, and other points in the area during the summer ozone season, in particular, August through September of 2013.

2.3 1-HOUR OZONE AIR QUALITY IN THE VALLEY

Past records of Valley 1-hour ozone concentrations show many days in which all Valley monitoring sites recorded values well over the standard, accounting for many exceedance days and many hours over the standard per exceedance day. The record also shows that 1-hour ozone exceedances occurred in many months throughout the year. In contrast, during 2011 and 2012, very few days exceeded the 1-hour ozone standard, with peak values on those days only slightly above the standard. Not only were there significantly fewer exceedance days, but the number of hours of each exceedance dropped to one or two hours per event, and only a couple of months experienced 1-hour ozone exceedances. Appendix A presents detailed analyses of these trends. Some of these analyses are summarized below.

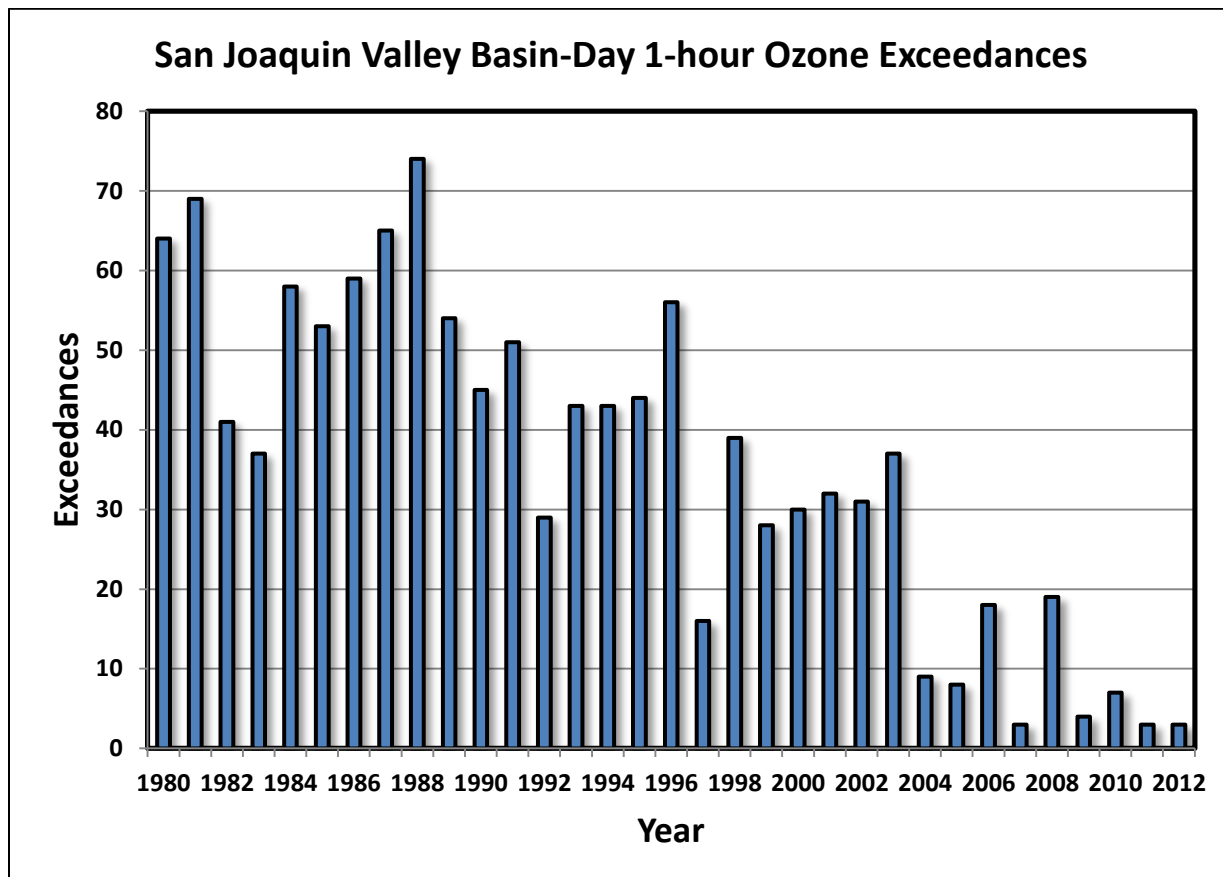
2.3.1 Number of Exceedance Days as the Attainment Test

The attainment test for the 1-hour ozone standard is based on the number of exceedance days per year, averaged over a three-year period. The 1-hour ozone standard is 0.12 parts per million (ppm) rounded to the closest on hundredth. Thus, 1-hour ozone concentrations at or greater than 0.125 ppm exceed the standard, and 1-hour ozone concentrations at or lower than 0.124 ppm meet the standard. If any hour in a day is above the standard, then that day is an exceedance day. The highest hourly concentration on a given day is recorded as the 1-hour ozone concentration for that day; although, all hourly concentrations are kept on record and analyzed.

A site with an average of 1.0 or fewer exceedance days per year, as averaged over a three-year period, meets the standard. In other words, if the site has 3.0 or fewer exceedance days in a three-year period, it meets the standard; if that site has more than 3.0 exceedance days in a three-year period, then it does not meet the standard.

As Figure 2-8 shows, in the 1980s the number of annual exceedance days during the 1980s was near or above 60 days, even exceeding 70 days in 1988. Since that time, the number of exceedances per year has decreased, even becoming rare in the last few years. Comparing the years 2012 to 1980, the number of annual exceedances has decreased by over 95%.

Figure 2-8 Basin-Day Exceedances per Year from 1980–2012

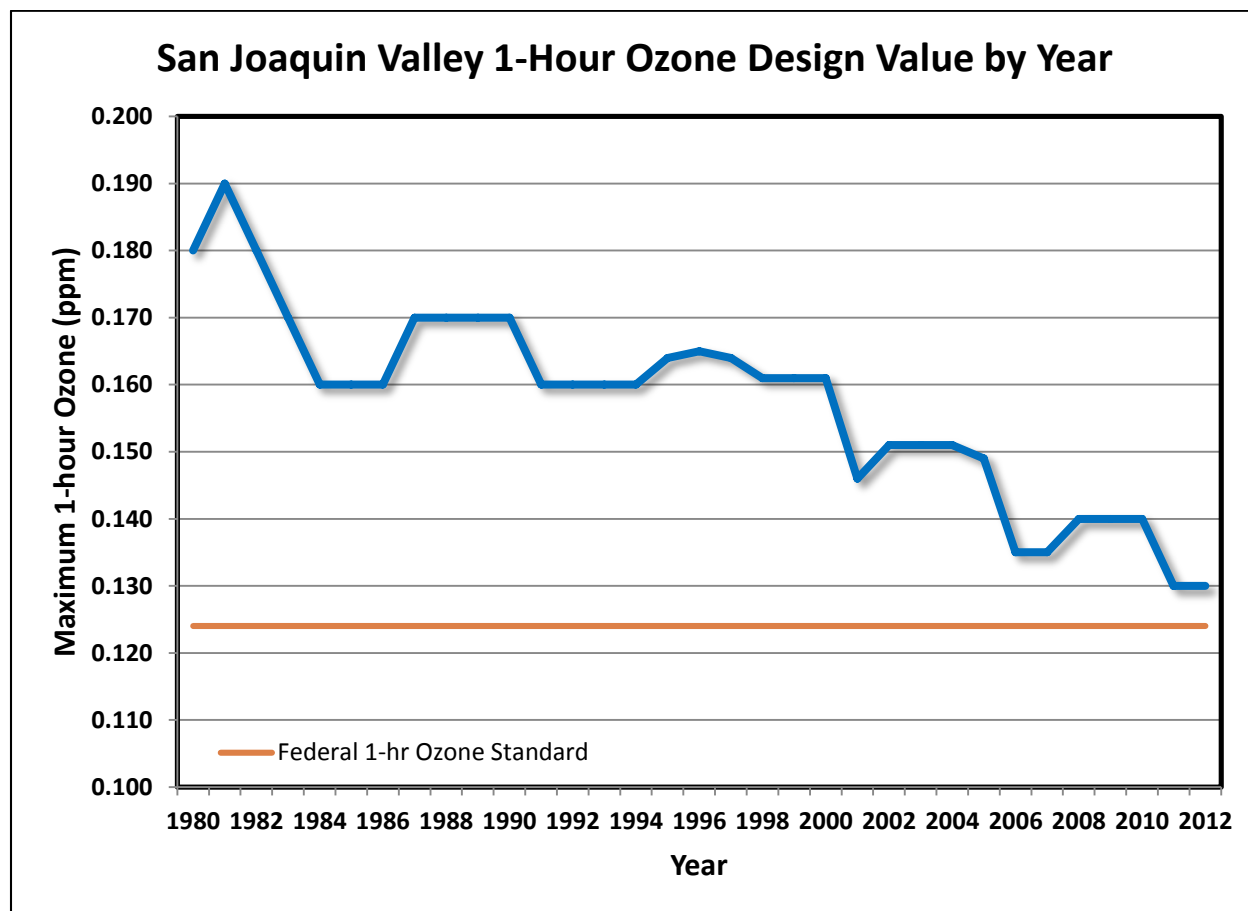


2.3.2 1-Hour Ozone Design Value Trend

The fourth highest 1-hour ozone value for the three-year period, also referred to as the *design value*, indicates how close an area is to attainment. Design value calculations follow EPA protocols for rounding, averaging conventions, data completeness, sampling frequency, data substitutions, and data validity. A 1-hour ozone design value at or greater than 0.125 ppm indicates nonattainment for that monitor (if the fourth highest value over the three-year period is an exceedance day, then there were more than the 3.0 allowed exceedance days over that three-year period). Because of this connection between design values and the exceedance-day-based attainment test, future year design values are modeled to determine when the region will reach attainment, as discussed later in this chapter.

The trend of the maximum 1-hour ozone design values among the ozone sites in the Valley has also changed dramatically over the monitoring history of the region. Figure 2-9 shows the change in the basin maximum design value from 1980 (0.18 ppm) through 2012 (0.13 ppm). The change represents a 27% reduction in the ozone design value.

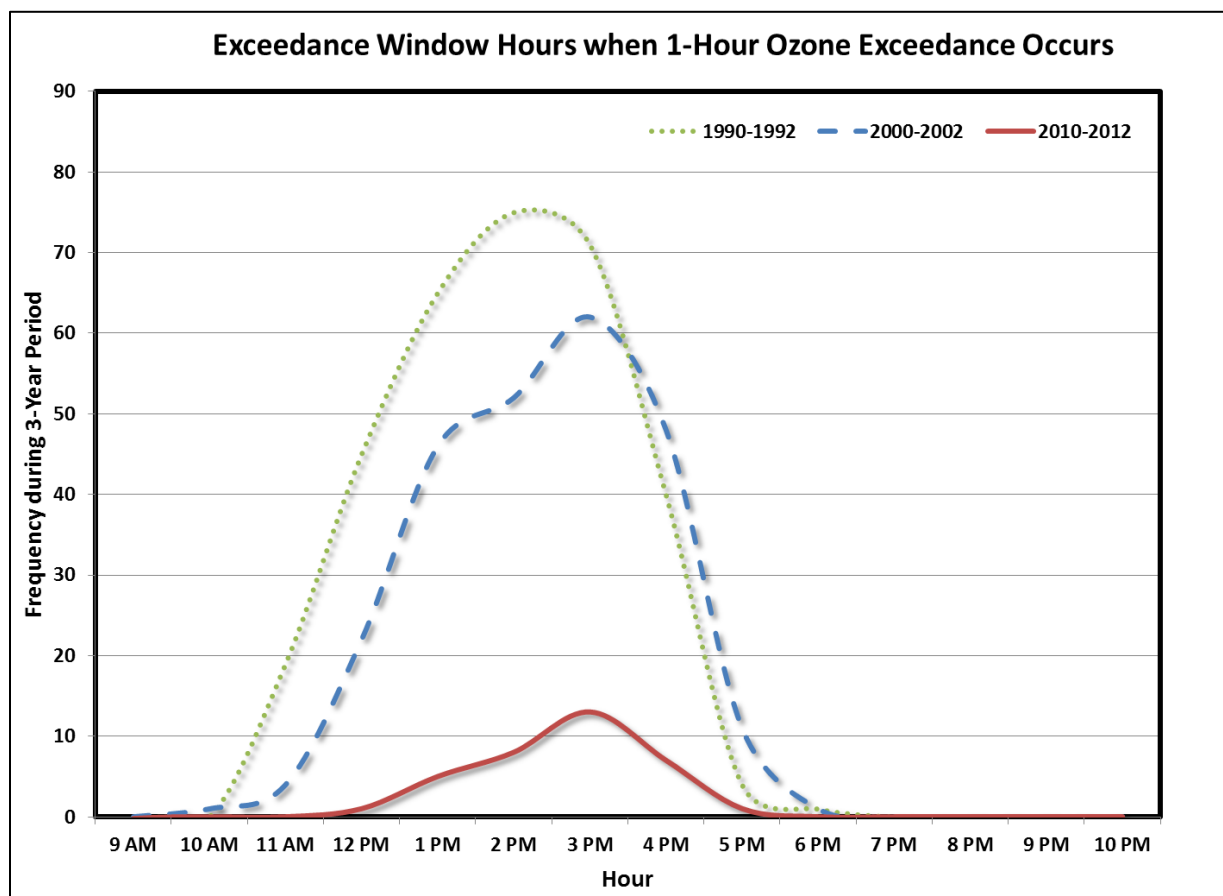
Figure 2-9 Valley Maximum 1-Hour Ozone Design Value Trend



2.3.3 Exceedance Window

The number of hours over which a 1-hour ozone exceedance occurs is also decreasing over time. Figure 2-10 shows this 1-hour ozone exceedance window as a frequency of exceedances measured at a particular hour, from 9 a.m. to 10 p.m., for the three-year time periods of 1990–1992, 2000–2002, and 2010–2012. In the most recent three-year period, the 1-hour ozone exceedance window is significantly narrower compared to the earlier periods, and the frequency of 1-hour exceedances has significantly decreased as illustrated in Figure 2-10.

Figure 2-10 1-Hour Ozone Exceedance Window Trend



2.4 MODELING APPROACH AND RESULTS

Consistent with EPA guidelines, ARB used a modeled attainment test to predict future 1-hour ozone concentrations at each monitoring site in the Valley to demonstrate attainment of the revoked 1-hour ozone standard. A photochemical model simulates the observed ozone levels using precursor emissions and meteorology in the region. The model also simulates future ozone levels based on projected changes in emissions, while keeping the meteorology constant. This modeling is used to identify the relative benefits of controlling different ozone precursor pollutants, as well as to determine the most expeditious attainment date. The modeling protocol is presented as Appendix E to this plan, and a summary of the modeling process and results is included as Appendix F to this plan.

In summary, the modeling shows that the Valley will attain the 1-hour ozone standard by 2017 based on implementation of the ongoing control program (Table 2-3). The air quality monitoring site with the highest predicted 1-hour ozone concentration is Edison, which is 4.7 ppb below the 124.0 ppb standard. Other Valley air monitoring sites, which have historically registered above the standard, are predicted to be measured at 15 to 30 ppb below the standard. Therefore, the air quality simulations predict that the entire Valley will attain the standard by 2017.

This is not to say that attainment before 2017 is not possible. In fact, the Valley's 1-hour ozone air quality has greatly improved over the past several years through the implementation of already-adopted control measures. As of the posting of this plan, attainment could be possible as early as 2013. On the other hand, it takes as little as four hours over a three-year period (where those four hours occur on four separate days at a single air monitoring site) to keep an area out of attainment. A single episode of ozone build up could prolong nonattainment past 2013, or even past 2017, depending on the circumstances.

With this challenging nature of the 1-hour ozone standard in mind, based on the modeling and other analysis conducted as part of this planning effort, 2017 is the official attainment year for this plan. The 2017 attainment year is consistent with the five-year attainment timeframe of CAA §172(a)(2)(A); in addition, this plan is not using the full 10-year attainment timeframe allowed under CAA §172(a)(2), nor does it rely on yet-to-be-identified "black box" emission reductions under CAA §182(e)(5).

Table 2-3 Base Year and Future Year 1-Hour Ozone Design Values

Monitoring Station	DV (2005-07)	DV (2015-17)
Edison	135	119.3
Arvin-Bear_Mountain_Bldv	131	107.4
Fresno-1st_Street	130	103.7
Clovis-N_Villa_Avenue	125	104.1
Fresno-Sierra_Skypark_#2	124	98.8
Parlier	121	97.4
Sequoia_and_Kings_Canyon	118	102.4
Bakersfield-5558_California	117	98.0
Sequoia_Natl_Park-Lower	113	98.5
Visalia-N_Church_Street	112	94.5
Oildale-3311_Manor_Street	112	95.2
Fresno-Drummond_Street	110	93.0
Hanford-S_Irwin_Street	110	92.6
Modesto-14th_Street	109	95.9
Shafter-Walker_Street	105	87.7
Turlock-S_Minaret_Street	104	91.8
Merced-S_Coffee_Avenue	102	85.4
Stockton-Hazelton_Street	101	86.3
Maricopa-Stanislaus_Street	100	83.5
Madera-Pump_Yard	95	82.4