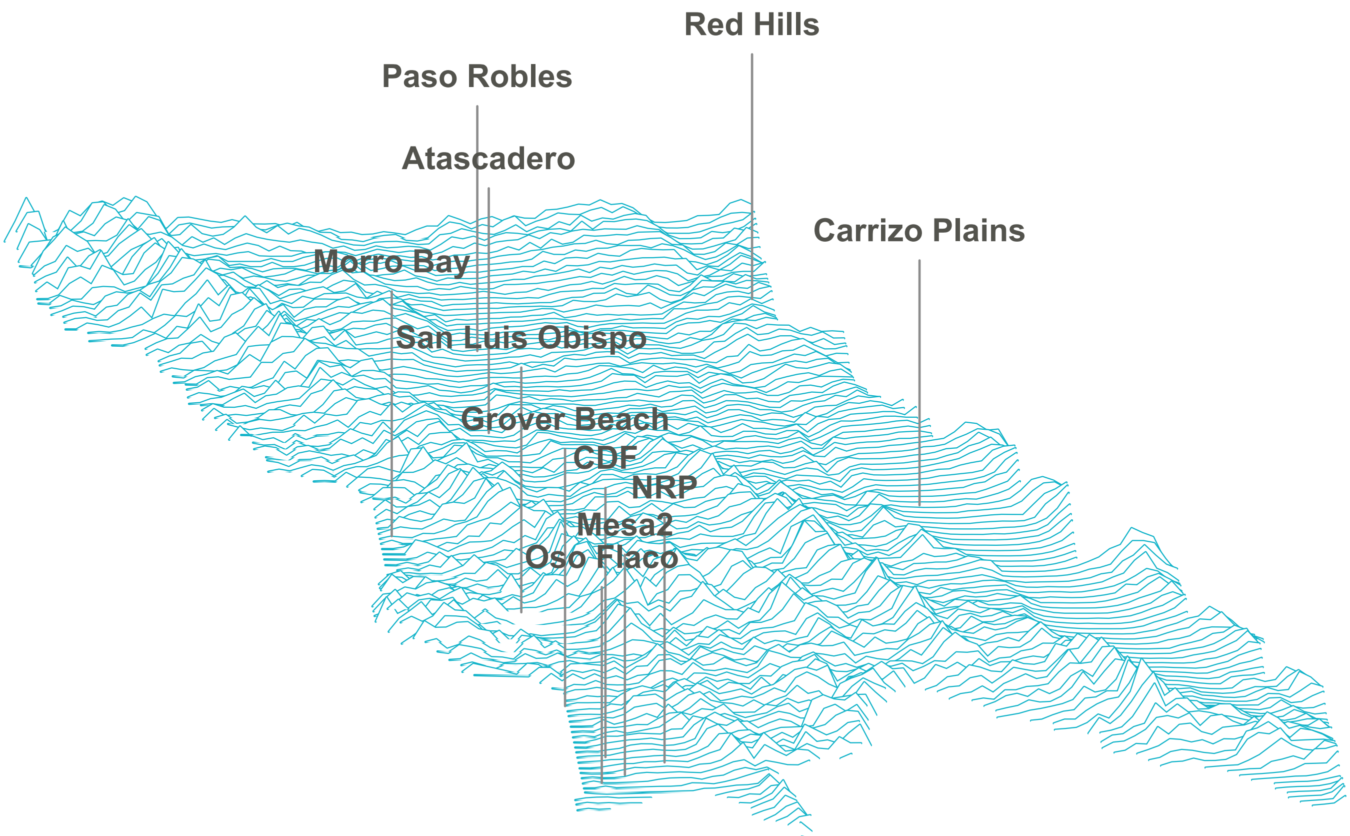
ANNUAL AIR QUALITY REPORT | 2016



SLO COUNTY apcd | Air Pollution Control District
San Luis Obispo County

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2016 Annual Air Quality Report
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Executive Summary

Continuing the pattern of the last several years, the majority of San Luis Obispo County experienced low levels of ozone pollution in 2016, but occasional exceedances of state and federal standards occurred in the rural eastern portion of the county. This area (Figure 1) was designated as a nonattainment zone for the federal ozone standard in May 2012, but air quality in the region has been steadily improving (Figures 7 & 8). Despite several large wildfires in 2016, the state and federal 8-hour standard (70 ppb) was exceeded only 7 times, making the year almost as clean as 2015 (4 exceedances), which was the cleanest year since monitoring began.

Smoke from the Soberanes and Chimney wildfires had major impacts on air quality throughout the county in 2016. The Soberanes Fire started on July 22nd and burned over 130,000 acres in and around the Los Padres National Forest in Monterey County. The fire smoldered into October. The Chimney Fire burned more than 46,000 acres around Lake Nacimiento from August 13th into September. The District issued Air Quality Alerts related to these fires on July 26th and August 17th. The year's highest ozone concentrations at Paso Robles, Atascadero, Red Hills, and Carrizo Plains—including 6 of the 7 exceedances of the 8-hour standard—all occurred during this period (Table 3).

South County air quality continues to be impacted by dust blown from the Oceano Dunes State Vehicular Recreation Area (ODSVRA) along the coast. While the federal PM_{10} standard was not exceeded at any site in 2016, the more stringent state standard was exceeded more than 20% of the time on the Nipomo Mesa, which is a slight increase from the previous year. In addition, the Rule 1001 performance standard was violated 56 times. As discussed in the Appendix, this year's ODSVRA dust control projects did not result in clear-cut reductions of PM_{10} at CDF. With regard to $PM_{2.5}$, neither 24-hour nor the annual average standards were exceeded anywhere in the county this year.

While windblown dust was the predominant source of high particulate matter levels in the South County, smoke from the Soberanes and Chimney Fires was the main contributor to particulate matter events in the North County. As shown in Table 4, the 3 highest PM_{10} days at Paso Robles and 2 out of 3 of the highest PM_{10} and $PM_{2.5}$ days at Atascadero all occurred during these fires.

There were no exceedances of the standards for nitrogen dioxide or sulfur dioxide at any stations this year.

Finally, there were a few notable network changes in 2016 that affect the data in this report:

- The nitrogen dioxide monitor at Morro Bay was permanently shut down on March 31, 2016.
- The Oso Flaco site was temporarily shut down by the California Department of Parks and Recreation on December 15, 2016. The site was reopened in March 2017.
- Due to a safety issue, the California Air Resources Board temporarily shut down the PM_{10} and $PM_{2.5}$ monitors at the San Luis Obispo Site in September of 2015. The monitors came back online in June of 2016. The ozone and meteorological monitors at the site were not affected.

The air quality database for San Luis Obispo County is a public record and is available from the District office in various forms, including comprehensive records of all hourly or other sample values acquired anywhere in the county. Data summaries are published in Annual Air Quality Reports, like this one. Summary data appear weekly in the Saturday edition of The Tribune, a local newspaper. Ambient monitoring data is added to separate archives maintained by EPA and ARB. Summary data from San Luis Obispo County can be found in EPA and ARB publications and on the world wide web at the following websites:

www.slocleanair.org
APCD website
www.arb.ca.gov
ARB website
www.epa.gov
US EPA website
www.airnow.gov
Air Quality Index site

Air Quality Monitoring and Data

Air quality in San Luis Obispo County was measured by a network of 11 ambient air monitoring stations in 2016; their locations are depicted in Figure 1. The San Luis Obispo County Air Pollution Control District (District) owns and operates seven permanent stations: Nipomo Regional Park (NRP), Grover Beach, Morro Bay, Atascadero, Red Hills, Carrizo Plain, and the CDF fire station on the Nipomo Mesa. The California Air Resources Board (ARB) operates stations in San Luis Obispo and Paso Robles. Two stations are owned by third parties but operated by the District: Mesa2, located on the Nipomo Mesa and owned by the Phillips 66 refinery, and Oso Flaco, located within the ODSVRA and owned by the California Department of Parks and Recreation. See Table 2 for a summary of the pollutants monitored at each station.

Air quality monitoring is subject to rigorous federal and state quality assurance and quality control requirements, and equipment and data are audited periodically to ensure data validity. Gaseous pollutant levels are measured every few seconds and averaged to yield hourly values. Particulate matter ($PM_{2.5}$ and PM_{10}) is sampled hourly using Beta Attenuation Monitors (BAMs). All monitoring instruments are Environmental Protection Agency (EPA)-approved Federal Equivalent Methods (FEMs) or Federal Reference Methods (FRMs).

The dataset for 2016 reviewed in this report was downloaded from the EPA's Air Quality System (AQS) database in May and October 2017. Prior to being uploaded to AQS, all data were thoroughly reviewed and validated by the collecting agency (i.e., ARB for data from Paso Robles and San Luis Obispo and the District for all other sites). The raw data and the R-code used to compile the statistics and generate the graphs in this report are available online at https://github.com/sloapcdkt/2016aqrptR.

Figure 1: Map of Monitoring Stations in San Luis Obispo County

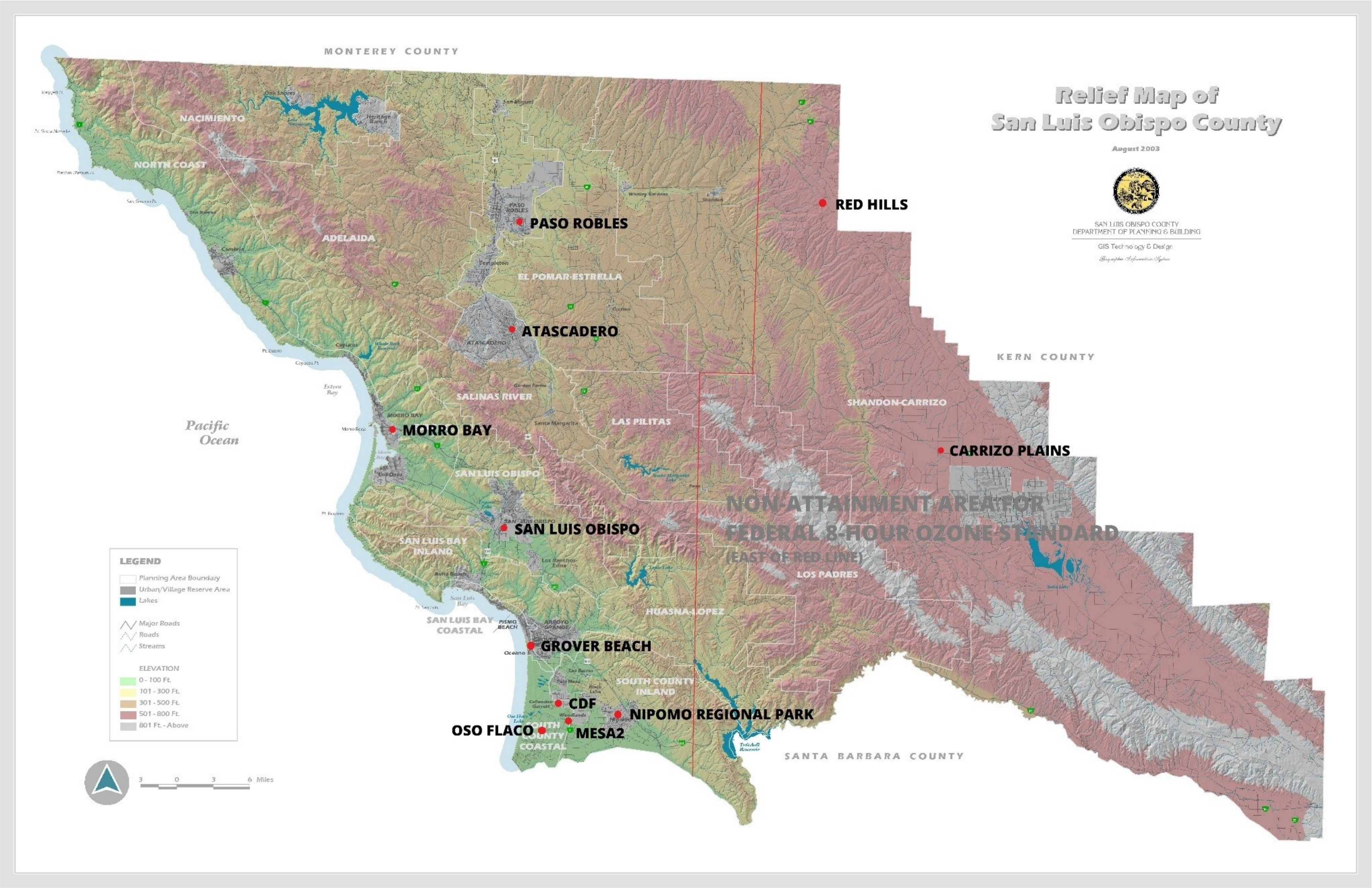

Table 1: Ambient Air Quality Parameters Monitored in San Luis Obispo County in 2016

	O_3	NO	NO_2	NO_x	SO_2	CO	PM_{10}	$PM_{2.5}$	WS	WD	ATM
APCD Permanent Stations											
Atascadero	X	X	X	X			X	X	X	X	X
Morro Bay	X	X	X	X					X	X	
Nipomo Regional Park	X	X	X	X			X		X	X	X
Red Hills	X								X	X	X
Carrizo Plain	X								X	X	X
CDF							X	X	X	X	
Grover Beach									X	X	
ARB Stations											
San Luis Obispo	X						X	X	X	X	X
Paso Robles	X						X		X	X	X
Operated by APCD											
Mesa2					X		X	X	X	X	X
Oso Flaco							X		X	X	X

Acronyms:

O_3	Ozone	SO_2	Sulfur Dioxide	PM_{10}	Particulates < 10 microns	WS	Wind Speed
NO	Nitric Oxide	CO	Carbon Monoxide	$PM_{2.5}$	Particulates < 2.5 microns	WD	Wind Direction
NO_2	Nitrogen Dioxide					ATM	Ambient Temp
NO_x	Oxides of Nitrogen						

Ambient Air Pollutants Of Local Concern

Ozone

Ozone (O_3) is a gas that is naturally found near the earth's surface at low concentrations, typically 10 to 40 parts per billion (ppb). It is also a principle component of photochemical smog, produced when precursor pollutants such as volatile organic compounds and nitrogen oxides react under the influence of sunlight. Ozone precursors are emitted by many human activities, but industrial processes and the wide use of motor vehicles are primary sources. The chemistry of atmospheric ozone is complex, and in the absence of sunlight, ozone is destroyed by reaction with the same precursor molecules that fuel its formation during the day. As a result, ozone concentrations typically increase as sunlight intensity increases, peaking midday or in the afternoon and gradually declining from there, typically reaching their lowest levels in the early morning hours and just before sunrise, as shown in Figure 2, below.

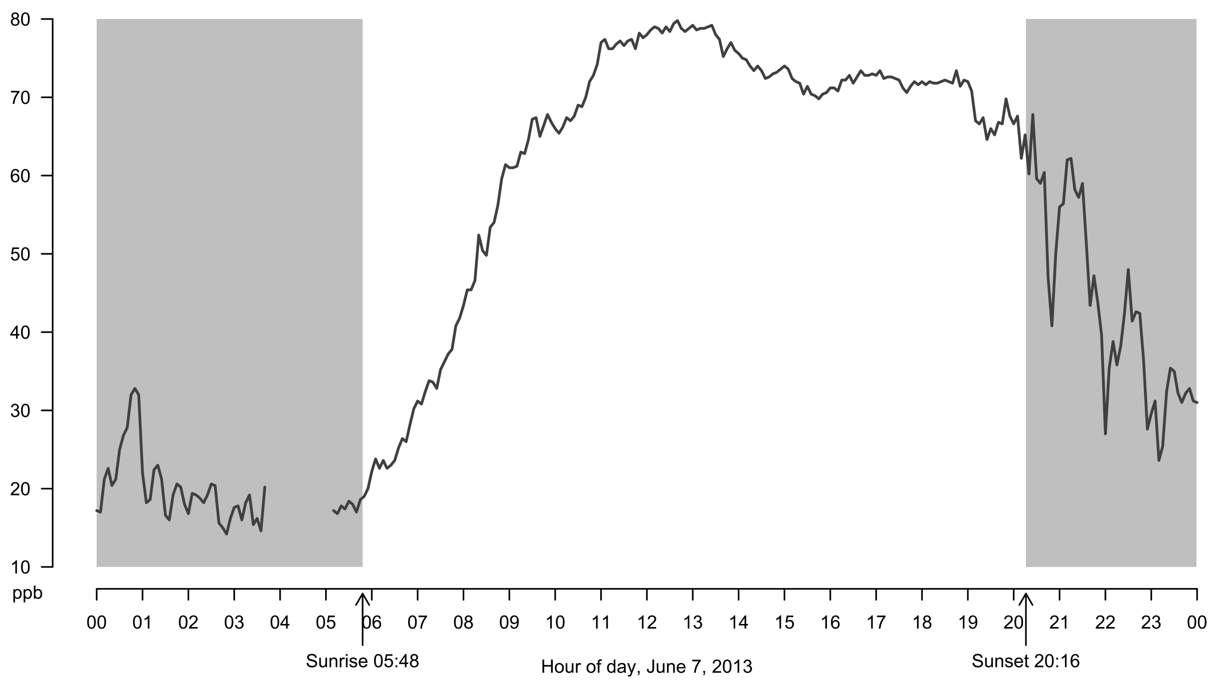

Figure 2: Example of Diurnal Ozone Pattern from Carrizo Plain

As a pollutant, ozone is a strong oxidant gas that attacks plant and animal tissues. It can cause impaired breathing and reduced lung capacity, especially among children, athletes and persons with compromised respiratory systems; it can also cause significant crop and forest damage. Ozone is a pollutant of particular concern in California where geography, climate and emissions from industrial and commercial sources and millions of vehicles contribute to frequent violations of health-based air quality standards.

While ground level ozone is harmful to plants and animals and is considered a pollutant, upper level (stratospheric) ozone occurs naturally and protects the earth from harmful ultra-violet energy from the sun.

Particulate Matter

Ambient air quality standards have been established for two classes of particulate matter: PM_{10} (respirable particulate matter less than 10 microns in aerodynamic diameter), and $PM_{2.5}$ (fine particulate matter 2.5 microns or less in aerodynamic diameter). Both consist of many different types of particles that vary in their composition and toxicity. $PM_{2.5}$ tends to be a greater health risk since these particles can get lodged deep in the lungs or enter the blood stream, causing both short and long-term damage. Sources of particulate pollution include diesel exhaust; mineral extraction and production; combustion products from industry and motor vehicles; smoke from open burning; paved and unpaved roads; condensation of gaseous pollutants into liquid or solid particles; and wind-blown dust from soils disturbed by demolition and construction, agricultural operations, off-road vehicle recreation, and other activities.

In addition to its harmful health effects, particulate matter can also greatly reduce visibility.

Nitrogen Dioxide, Sulfur Dioxide, and Carbon Monoxide

Nitrogen dioxide (NO_2) is the brownish-colored component of smog. NO_2 irritates the eyes, nose and throat and can damage lung tissues. Sulfur dioxide (SO_2) is a colorless gas with health effects similar to NO_2. Both pollutants are generated by fossil fuel combustion from mobile sources such as vehicles, ships, and aircraft and at stationary sources such as industry, homes and businesses. SO_2 is also emitted by petroleum production and refining operations. These pollutants can create aerosols, which may fall as acid rain causing damage to crops, forests, and lakes. They can also exacerbate asthma and harm the human respiratory system.

Carbon monoxide (CO) is a colorless and odorless gas that can interfere with the ability of red blood cells to transport oxygen. Exposure to CO can cause headaches, fatigue, and even death. CO results from fuel combustion of all types, but motor vehicles are by far the chief contributor of CO in outdoor air.

State and National Ambient Air Quality Standards

California ARB and the U.S. EPA have adopted ambient air quality standards for six common air pollutants of primary public health concern: ozone, particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide, sulfur dioxide, carbon monoxide, and lead. These are called "criteria pollutants" because the standards establish permissible airborne pollutant levels based on criteria developed after careful review of all medical and scientific studies of the effects of each pollutant on public health and welfare.

The National Ambient Air Quality Standards (NAAQS; see Table 2) are used by EPA to designate a region as either "attainment" or "nonattainment" for each criteria pollutant. A nonattainment designation can trigger additional regulations for the region aimed at reducing pollution levels and bringing the region into attainment. For most pollutants, the NAAQS allow a standard to be exceeded a certain number of times each calendar year without resulting in a nonattainment designation. Additionally, exceedances caused by exceptional events (see below) may be excluded from attainment/nonattainment determinations at the discretion of the EPA.

In May 2012, the EPA designated the eastern portion of San Luis Obispo County as marginally nonattainment for the 8-hour ozone standard. This was based on data from enhanced monitoring over the previous decade that revealed previously unrecognized elevated ozone levels in that region; the western portion of the county retained its federal ozone attainment status. (See Figure 1 for the boundary between the attainment and nonattainment areas.) In October 2015, the standard was lowered from 75 to 70 ppb; the EPA has yet to designate the county with regard to the new standard. The county is currently designated as attainment for all other NAAQS.

The California Ambient Air Quality Standards are generally more restrictive (i.e. lower) than the NAAQS, and typically are specified as not to be exceeded. Thus, a single exceedance is a violation of the applicable standard and triggers a nonattainment designation. As a result, San Luis Obispo County is designated as a nonattainment area for the state one-hour and 8-hour ozone standards, as well as the state 24-hour and annual PM_{10} standards. The county is designated as attaining the state annual $PM_{2.5}$ standard.

State and national standards for NO_2 have never been exceeded here. The state standard for SO_2 was exceeded periodically on the Nipomo Mesa until 1993. Equipment and processes at the facilities responsible for the emissions were upgraded as a result, and the state SO_2 standard has not been exceeded since that time. Exceedances of the federal SO_2 standard had never been recorded here until 2014, when maintenance activities at these facilities resulted in emissions exceeding the 1-hour standard of 75 ppb that was established in 2011. State CO standards have not been exceeded in the county since 1975.

Exceptional Events

Exceptional events are unusual or naturally occurring events that can affect air quality but are not reasonably controllable or preventable and are unlikely to reoccur at a particular location. Examples include wildfires and haboobs. Air quality monitoring data influenced by exceptional events can sometimes be excluded from regulatory determinations related to violations of the NAAQS, if recommended by the APCD and approved by the EPA. The APCD has not submitted any exceptional event documentation for 2016 and does not expect any data compiled in this report to be excluded from future attainment determinations.

Table 2: Ambient Air Quality Standards for 2016 and Attainment Status*

A standard exceedance *occurs when a measured pollutant concentration exceeds (or in some cases, equals) the applicable standard prescribed by state or federal agencies. It does not necessarily constitute a violation.*

A standard violation *may occur following a single or cumulative series of standard exceedances. Criteria constituting a violation are unique for each pollutant.*

A nonattainment designation *occurs when a state or federal agency formally declares an area in violation of a standard. Typically, ARB performs designations annually. Several years often pass between EPA designations.*

	Averaging Time	California Standard†	National Standard†
Ozone (O_3)	8 Hours	**70 ppb**	**70 ppb** §
	1 Hour	**90 ppb**	
Respirable Particulate Matter (PM_{10})	24 Hours	**50 μg/m³**	150 μg/m³
	1 Year‡	**20 μg/m³**	
Fine Particulate Matter ($PM_{2.5}$)	24 Hours		35 μg/m³
	1 Year‡	12 μg/m³	12 μg/m³
Carbon Monoxide (CO)	8 Hours	9.0 ppm	9 ppm
	1 Hours	20 ppm	35 ppm
Nitrogen Dioxide (NO_2)	1 Year‡	30 ppb	53 ppb
	1 Hour	180 ppb	100 ppb
Sulfur Dioxide (SO_2)	3 Hours		500 ppb (secondary)
	1 Hour	250 ppb	75 ppb (primary)
Hydrogen Sulfide (H_2S)	1 Hour	0.03 ppm	
Visibility	8 Hours	Sufficient amount to reduce the prevailing visibility to less than ten miles when the relative humidity is less than 70 %.	

* San Luis Obispo County (in whole or in part) is designated as nonattainment for the standards in **boldface print** as of November 2017.

† For clarity, the ozone, SO_2, and NO_2 standards are expressed in parts per billion (ppb), however most of these standards were promulgated in parts per million (ppm).

‡ This standard is calculated as a weighted annual arithmetic mean.

§ The national 8-hour ozone standard was lowered from 75 to 70 ppb on October 1, 2015. Eastern San Luis Obispo County is still designated as nonattainment for the old standard. The EPA has yet to designate the county with regard to the new standard.

Ozone and Gaseous Pollutant Summary

In 2015, the federal 8-hour ozone standard was lowered from 75 to 70 parts ppb, which is the same level as the state 8-hour standard. The old 75 ppb standard was exceeded on two days: July 28th at Red Hills and Carrizo Plain and August 4th at Carrizo Plain. Exceedances of the new standard occurred on 7 days countywide, with 6 days at Red Hills and 3 days at Carrizo Plain. The state 1-hour standard for ozone (90 ppb) was exceeded on 2 days this year: July 28th at Red Hills, Carrizo Plain and Paso Robles and August 4th at Red Hills and Carrizo Plain.

Both exceedances of the 1-hour standard and 6 of the 7 exceedances of the 8-hour standard were associated with the Soberanes and/or Chimney Fires. The Soberanes Fire burned from July 22nd into October and charred over 130,000 acres in Monterey County. The Chimney Fire burned more than 46,000 acres around Lake Nacimiento from August 13th into September.

Standards for nitrogen dioxide and sulfur dioxide were not exceeded this year; note that the nitrogen dioxide monitor at Morro Bay was discontinued on March 31.

First, Second and Third Highest Hourly Averages

Table 3 lists the highest hourly (and for ozone, 8-hour) values recorded in 2016 for ozone, sulfur dioxide, and nitrogen dioxide at the stations where they are monitored. Concentrations are in parts per billion (ppb). Sampling date and hour appear under each pollutant value in the format "month/day: hour." All times are Pacific Standard Time; for 8-hour averages, the hour noted is the beginning hour. Values that exceed federal standards are shown in **bold,** and those exceeding state standards are underlined.

Table 3: Highest Measurements for Gaseous Pollutants in 2016

Station	O_3 1-hour			O_3 8-hour			SO_2 1-hour			NO_2 1-hour		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Paso Robles	91 07/28:14	89 08/16:14	81 07/27:11	66 09/17:10	64 09/27:10	63 06/21:10						
Atascadero	84 09/19:14	79 07/28:13	77 07/22:17	65 09/19:10	64 08/29:11	63 07/28:09				34 11/08:17	33 11/08:18	32 11/09:18
Morro Bay*	60 04/17:17	60 10/08:13	59 04/06:14	57 10/08:10	54 04/06:10	53 04/17:10				36 03/01:07	29 02/16:18	28 01/12:17
San Luis Obispo	69 10/08:15	62 09/27:12	61 09/18:15	62 10/08:10	57 04/18:10	56 09/27:09						
Red Hills	111 07/28:12	93 08/04:16	84 07/29:16	**86** 07/28:10	**75** 07/29:09	**75** 08/13:09						
Carrizo Plain	102 07/28:15	101 08/04:16	80 07/29:14	**88** 07/28:09	**76** 08/04:11	**74** 07/29:09						
Nipomo Regional Park	70 09/27:11	70 10/08:14	68 04/18:18	64 09/27:08	63 04/18:11	63 10/08:10				27 12/29:18	24 11/10:18	24 11/10:19
Mesa2, Nipomo							11 08/01:21	2 05/28:01	2 05/29:01			

* Partial year only for NO_2 data from this site.

Visual Ozone Summary

Figures 3 and 4 depict the measured ozone values at each of the stations where it is monitored in 2016. The maximum 8-hour average for each day is shown for each site; exceedances of the 70-ppb standard are shown in red with the day of month printed beside them. The heavy "stair step" line marks the monthly median. The vertical axis extends to the annual maximum; units are ppb.

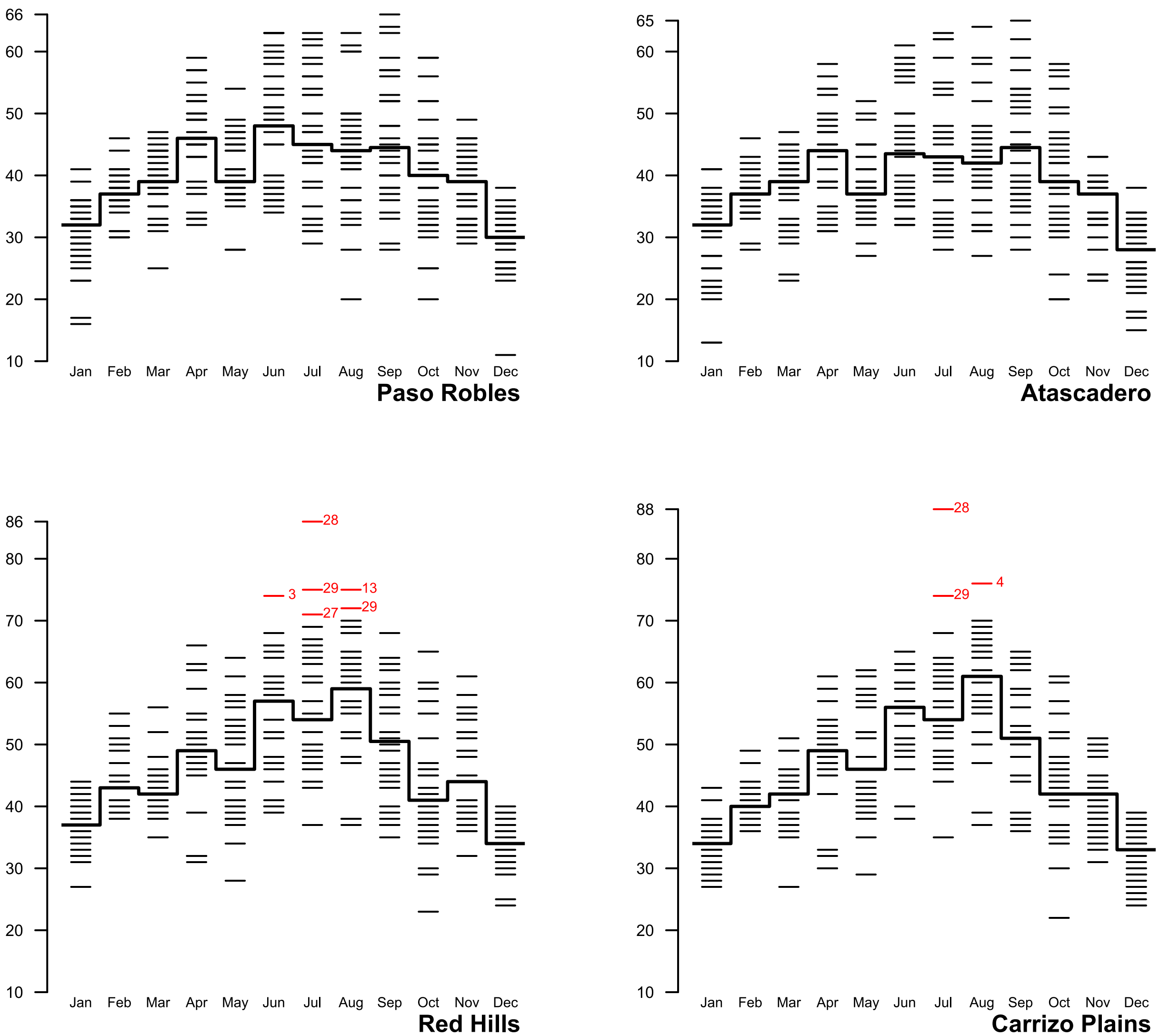

Figure 3: Daily Maximum 8-Hour Average for 2016

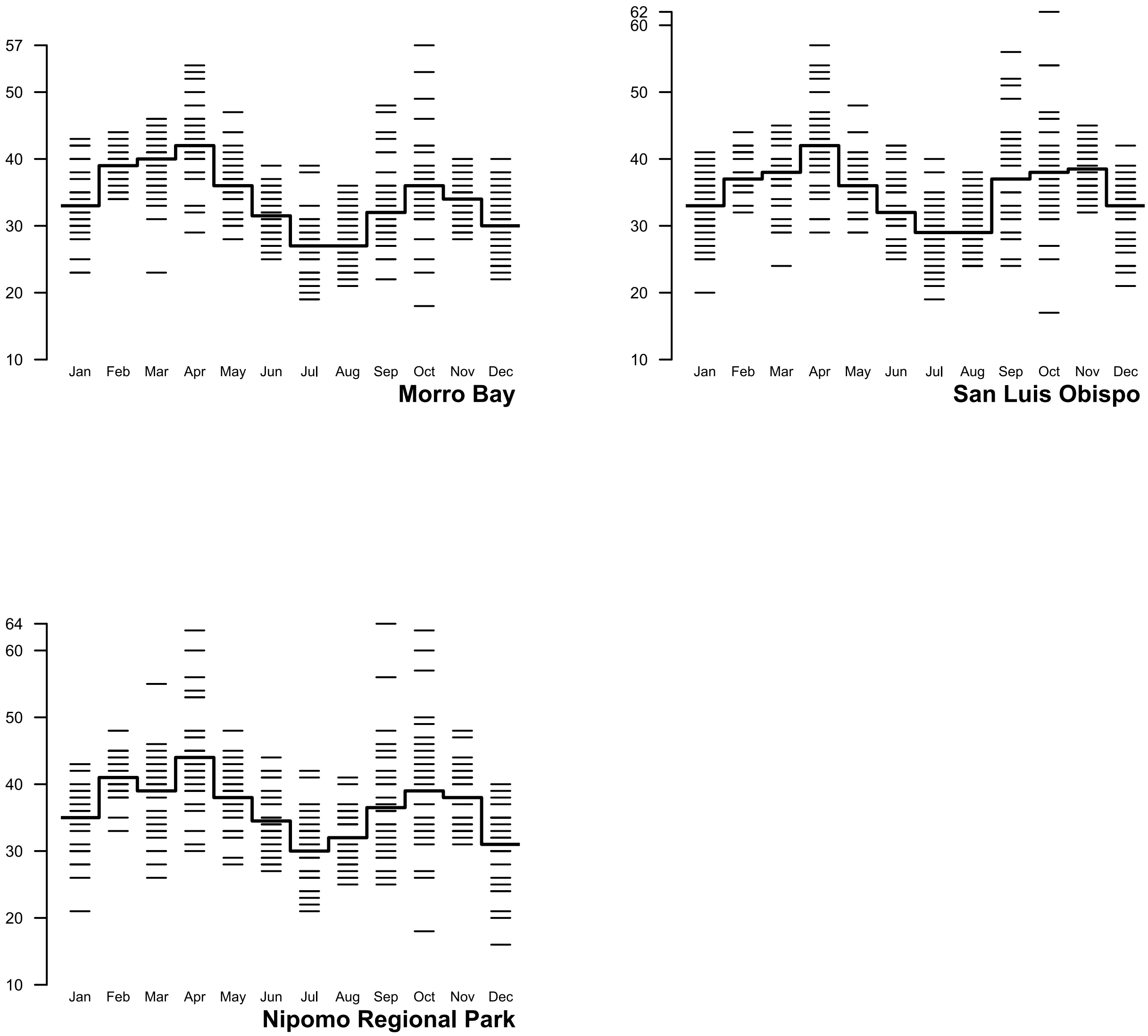

Figure 4: Daily Maximum 8-Hour Average for 2016

Particulate Matter Summary

In 2016, there were no exceedances of the federal 24-hour PM_{10} standard (150 μg/m^3) anywhere in the county. Exceedances of the state 24-hour PM_{10} standard (50 μg/m^3) were observed on 74 different days: 71 at CDF, 43 at Mesa2, 13 at NRP, 10 at Oso Flaco, and 1 at Atascadero.[1] This year, San Luis Obispo, NRP, CDF, and Mesa2 exceeded the state annual average PM_{10} standard of 20 μg/m^3. The federal 24-hour $PM_{2.5}$ standard (35 μg/m^3) and the federal and state annual average standards (both 12 μg/m^3) were not exceeded anywhere in the county this year.

Local Rule 1001, which is intended to address windblown dust emissions and downwind air quality impacts from the Oceano Dunes State Vehicular Recreation Area (ODSVRA), states that the park operator "shall ensure that if the 24-hour average PM_{10} concentration at the [riding area] Monitor is more than 20% above the 24-hour average PM_{10} concentration at the Control Site Monitor, the 24-hour average PM_{10} concentration at the [riding area] Monitor shall not exceed 55 μg/m^3." For determining compliance with this standard, the CDF and Oso Flaco monitors have been designated as the riding area and control site monitors, respectively. This year there were 56 days that violated the Rule 1001 standard, as well as 3 possible violation days when the CDF 24-hour average exceeded 55 μg/m^3 but Oso Flaco was offline.

Note that the PM_{10} and $PM_{2.5}$ monitors at San Luis Obispo operated for only part of the year (mid-June through December), and do not meet state and federal completeness requirements for computing annual averages. While the Oso Flaco PM_{10} monitor operated for most of the year, including the windy seasons when high PM_{10} levels are expected, it similarly does not meet completeness requirements.

Highest 24-hr Concentrations and Annual Averages

Table 4 lists the highest 24-hour concentrations recorded in 2016 and the dates on which they occurred, as well as the annual means for PM_{10} and $PM_{2.5}$ for all stations where these pollutants were monitored. Concentrations are in μg/m^3. Values exceeding federal standards are shown in **bold**; those exceeding state standards are underlined.

Table 4: PM_{10} and $PM_{2.5}$ Summary for 2016

Station	24-hour PM_{10}			Annual Average PM_{10}‡	24-hour $PM_{2.5}$			Annual Average $PM_{2.5}$‡
	1st	2nd	3rd		1st	2nd	3rd	
Paso Robles	44 07/26	44 07/28	43 07/27	18.0				
Atascadero	56 06/19	47 07/28	46 08/16	18.1	28.6 12/21	26.2 09/19	24.6 08/16	6.3
San Luis Obispo *	42 06/26	40 07/23	39 06/27	*	21.0 08/03	20.9 08/04	20.5 08/13	*
CDF, Arroyo Grande	144 07/10	143 06/14	142 10/01	33.9	32.5 10/01	30.2 06/14	29.3 07/10	8.2
Nipomo Regional Park	78 08/30	71 06/25	70 07/23	22.4				
Oso Flaco *	62 11/16	56 04/25	55 03/28	*				
Mesa2, Nipomo	111 07/10	104 06/14	100 03/25	26.6	23.0 07/10	21.4 10/01	21.2 03/25	5.8

* Incomplete year, see text for details.

‡ Weighted arithmetic mean as calculated by an AMP450 AQS report.

[1] ARB and EPA apply different conventions to the handling of significant digits. The ARB website (http://www.arb.ca.gov/adam/topfour/topfour1.php) thus counts 75 exceedances of the state PM_{10} standard at CDF, 48 at Mesa2 and 11 at Oso Flaco. The database used by the ARB website may also contain erroneous values.

Visual $PM_{2.5}$ and PM_{10} Summaries

Figures 5 and 6, below, show the 24-hour $PM_{2.5}$ and PM_{10} values from the stations where these pollutants were measured in 2016. As with the ozone plots in the previous section, these plots show daily concentrations by month for each site; exceedances of state and federal standards are shown in red with the day of month printed beside them. The heavy "stair step" line marks the monthly median. The vertical axis extends the annual maximum; units are $\mu g/m^3$.

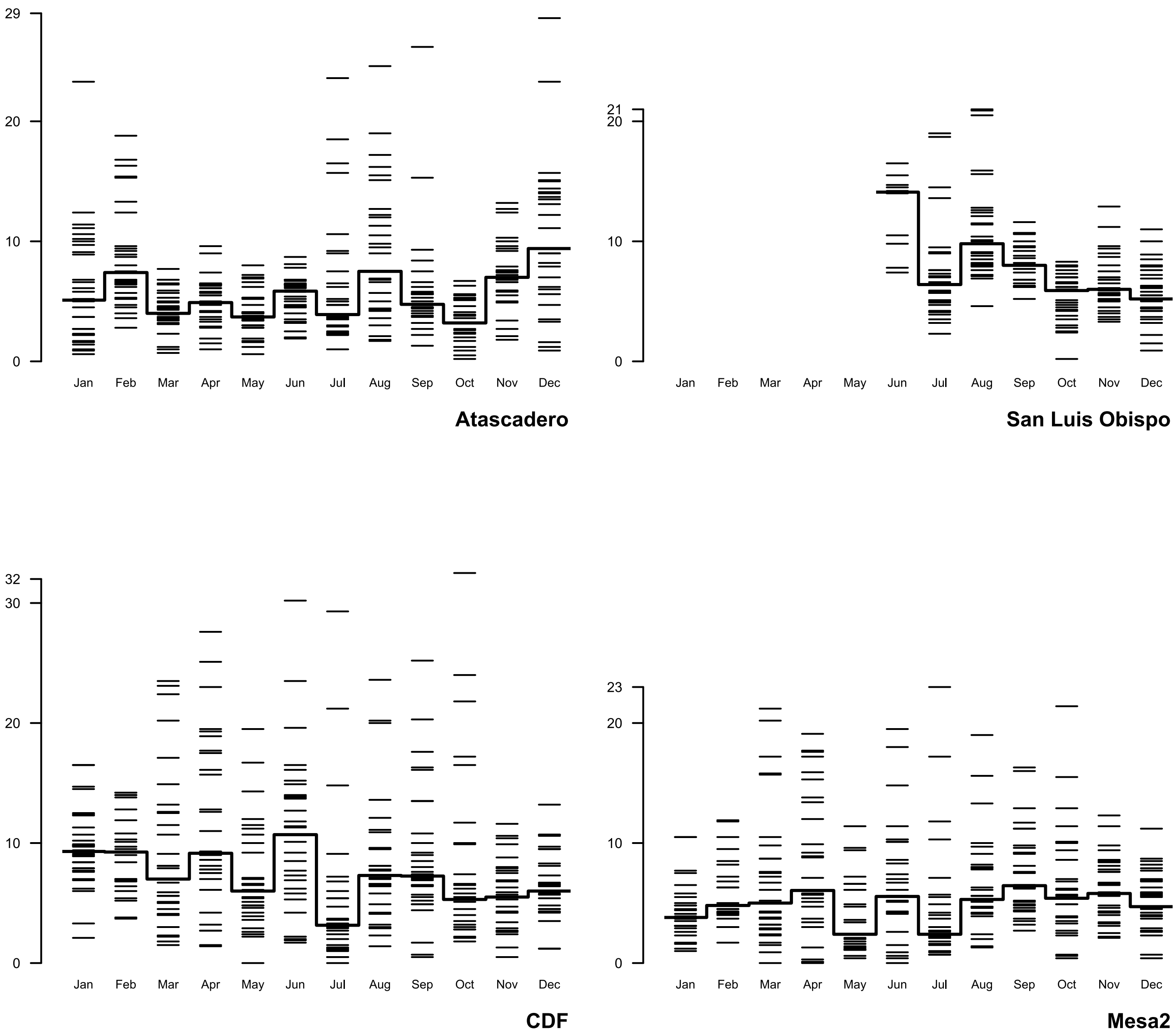

Figure 5: Daily $PM_{2.5}$ Values for 2016

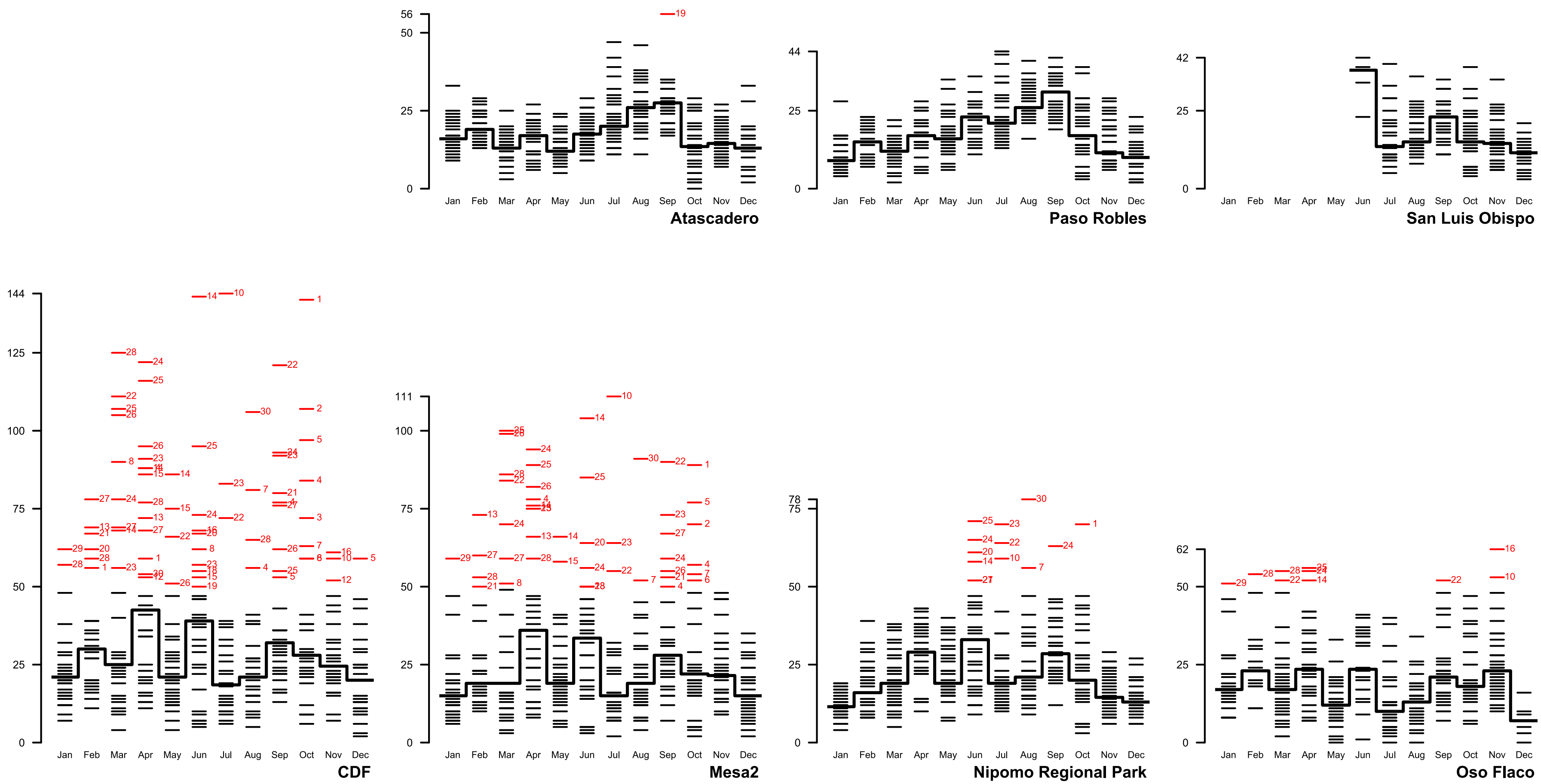

Figure 6: Daily PM$_{10}$ Values for 2016

10-Year Trends

Ozone

Figure 7, below, depicts the total number of hours each year at each site during which the ozone concentration was at or above 65 ppb. This is a useful indicator for trends, even though there are no health standards for single-hour exposure to this level of ozone. Figure 8 shows ozone design values over the same period. Design values are used by EPA to determine whether an area attains a federal standard. For ozone, the design value is calculated by averaging the 4th highest annual 8-hour average over three consecutive years. For example, a 2016 design value is the average of the 4th highest 8-hour averages from 2014, 2015, and 2016. Only design values meeting data completeness requirements are included; the dashed red line indicates the federal 8-hour standard which changed from 75 ppb to 70 in 2015.

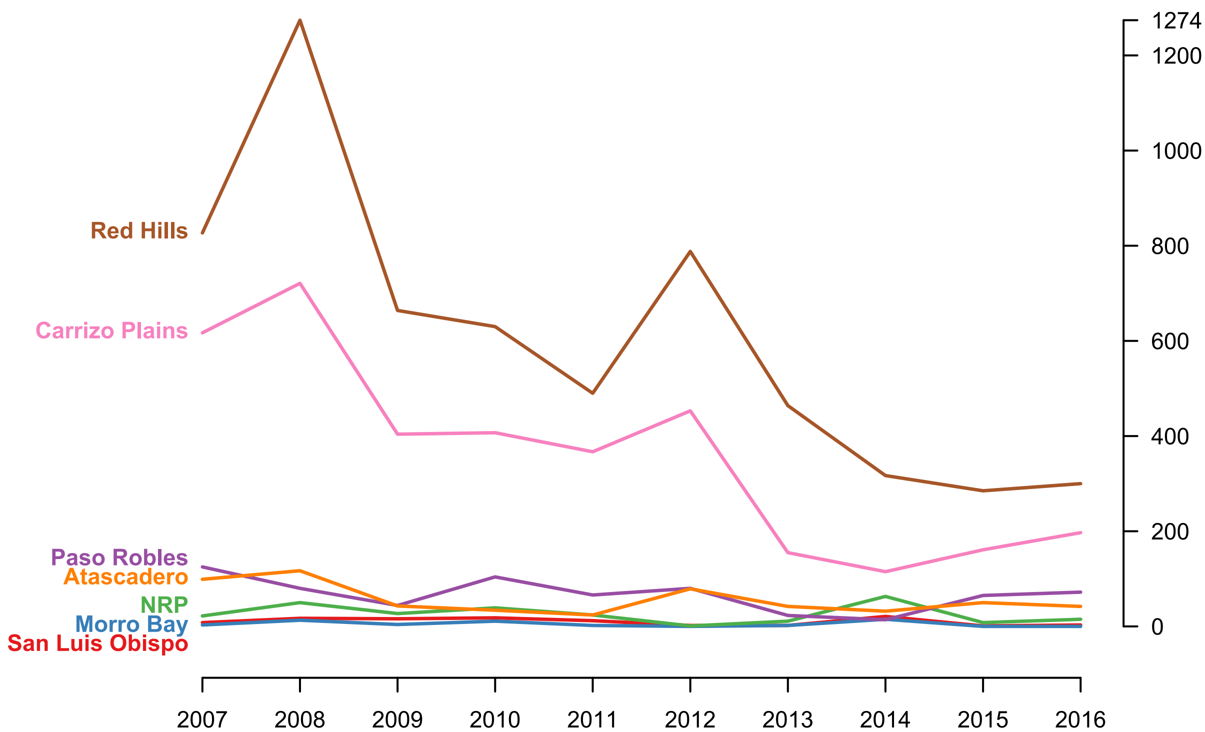

Figure 7: Hours At or Above 65 ppb Ozone, 2007-2016

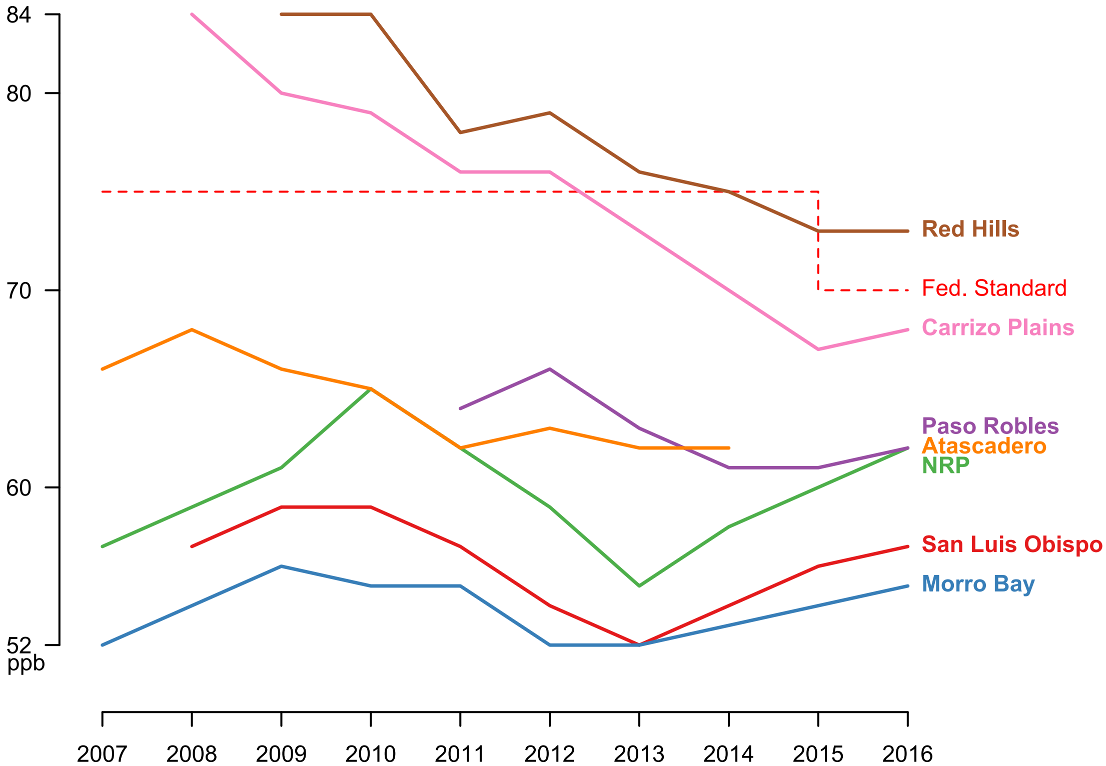

Figure 8: Ozone Design Value Trends, 2007-2016

Particulate Matter

Figure 9, below, shows for each site the total number of hours each year when PM_{10} was at or above 50 μg/m^3 during the hours when people are most likely to be active (10 am to 4 pm). Collection of hourly data began in mid–2009 for some sites and later for others; years with less than 90% valid hourly data are omitted. This metric is intended to illustrate trends in population exposure, even though there are no health standards for single-hour exposure to this level of PM_{10}.

Figure 10 depicts annual average PM_{10} concentrations over the past 10 years;[2] years with partial data are omitted. The red dashed line marks the state PM_{10} standard for the annual mean of 20 μg/m^3. While occasional exceedances of the standard occur at most sites, the monitors on the Nipomo Mesa at Nipomo Regional Park, Mesa2, and CDF are consistently higher than elsewhere in the county.

Trends in the annual average $PM_{2.5}$ levels are depicted in Figure 11 for the four sites in the county where it is measured. Data for the past 10 years are shown, and years with partial data are omitted. The red dashed line marks the 12 μg/m^3 state and federal $PM_{2.5}$ standard for the annual mean. As with PM_{10}, the stations on the Nipomo Mesa tend to record higher levels than those elsewhere in the county.

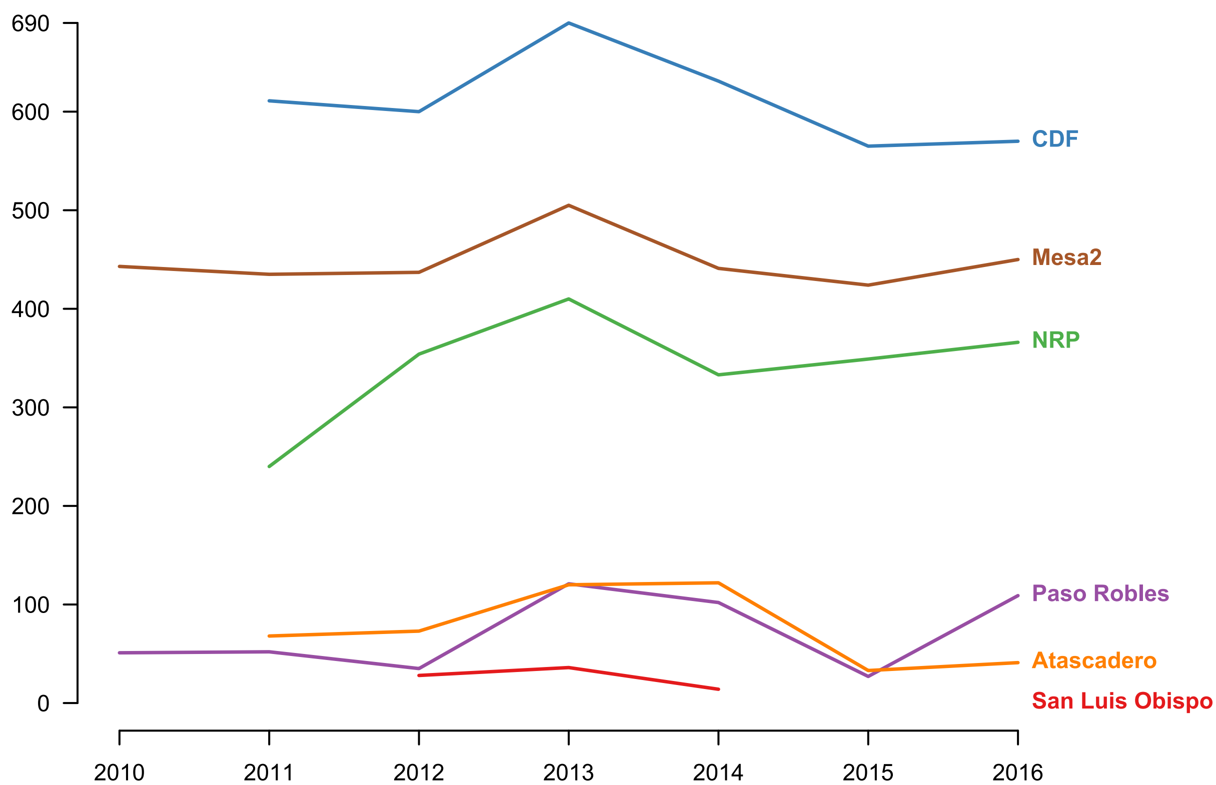

Figure 9: Hours At or Above 50 g/m^3 PM_{10}, 2010-2016

[2] In general, these are seasonally weighted averages as calculated by AQS. For years when sampling methodology changed or a site was moved, the average depicted is the time-weighted average of the methodologies or locations.

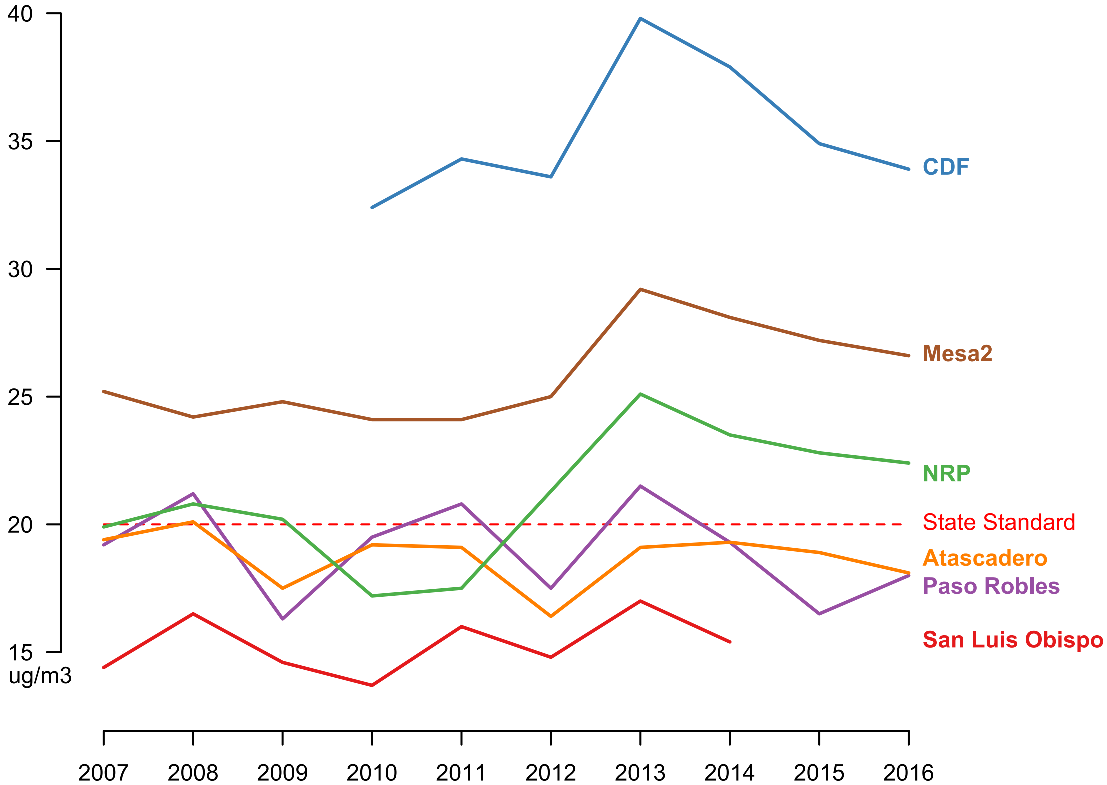

Figure 10: PM_{10} Annual Average, 2007-2016

Figure 11: $PM_{2.5}$ Annual Averages, 2007-2016

Ambient Air Monitoring Network Plans

Each year, the District prepares an Ambient Air Monitoring Network Plan. This document is an annual examination and evaluation of the network of air pollution monitoring stations in the county. The annual review is required by 40 CFR 58.10 and helps ensure continued consistency with the monitoring objectives defined in federal regulations.

Each report is a directory of existing and proposed monitors in the county network and serves as a progress report on the recommendations and issues raised in earlier network reviews. Reports also address ongoing network design issues. The most recent Ambient Air Monitoring Network Plan is available online at http://www.slocleanair.org/airquality/monitoringstations.php.

As highlighted in the 2016 and 2017 reports, the following major changes were made to the APCD network in 2016:

- The oxides of nitrogen monitor at Morro Bay was permanently shut down on March 31, 2016.
- The Oso Flaco site was temporarily shut down by the California Department of Parks and Recreation on December 15, 2016. The site was reopened in March 2017.
- Due to a safety issue, the California Air Resources Board temporarily shut down the PM_{10} and $PM_{2.5}$ monitors at the San Luis Obispo Site in September of 2015. The monitors came back online in June of 2016. The ozone and meteorological monitors at the site were not affected.

Appendix: Recent Trends in South County Particulate Matter

Introduction

Last year's Annual Air Quality Report[3] contained an appendix which analyzed recent trends in particulate matter at CDF and Mesa2. It concluded that the mitigation measures deployed by the ODSVRA operator (California Department of Parks and Recreation) in 2015 did not have a measurable effect on PM_{10} levels at CDF. This section updates that analysis with 2016 data.

Background

Enacted by the District Board in 2011, Local Rule 1001 requires the operator of the ODSVRA to implement dust mitigation measures with the goal of reducing PM_{10} emissions from the riding area of the park to the level of emissions from non-riding areas. Table A1, below, summarizes the mitigation efforts through 2016. These efforts have included temporary fencing arrays and engineered roughness elements installed in the riding area during the windy season (April through July), straw bale arrays in the non-riding area, and permanent revegetation in non-riding areas. All project elements were located upwind of the CDF monitoring station.[4]

Table A1: Dust Mitigations on the ODSVRA

Year	Mitigation Measures		
	Fencing Array	Straw Bale Array	Other
2014	15 acres	30 acres	
2015	40 acres	"refresh" 2014's array	Revegetation: 6 acres
2016	40 acres		Engineered roughness element array: < 1 acre

[3] San Luis Obispo County Air Pollution Control District, September 2016. "2015 Annual Air Quality Report." http://www.slocleanair.org/images/cms/upload/files/2015aqrt-FINAL.pdf

[4] See District webpage, "Oceano Dunes Dust," at http://www.slocleanair.org/air-quality/oceano-dunes.php for the text of Rule 1001, summaries of mitigation measure enacted thus far, and related documents.

Trend Analysis
PM_{10} levels at CDF and Mesa2 have fluctuated over the years. No large-scale dust control projects were in place from 2010 through 2013,[5] so for this period the trends in annual average PM_{10} values for these sites (Figure 10, above) and in the number of state standard exceedances (Figure A1, below) likely reflect year-to-year differences in meteorology. With varying levels of seasonal dust mitigations in place in 2014–2016, annual averages decreased year over year; the number of exceedances of the 24-hour average PM_{10} standard also decreased from 2013 to 2014 and again from 2014 to 2015, but increased in 2016. Are these trends the result of the mitigations deployed on the ODSVRA, or do they continue to simply reflect difference in meteorology from year to year?

The dust control projects were sited upwind of CDF and appear to have been designed specifically to reduce the PM_{10} levels at that monitor. These mitigation projects would thus not be expected to have much of an impact, if any, on PM_{10} levels at Mesa2. Yet, as shown in Figures 10 and A1, the trends in the annual average and in exceedances at CDF and Mesa2 track each other. This suggests that factors other than the dust control projects are responsible for the observed trends.

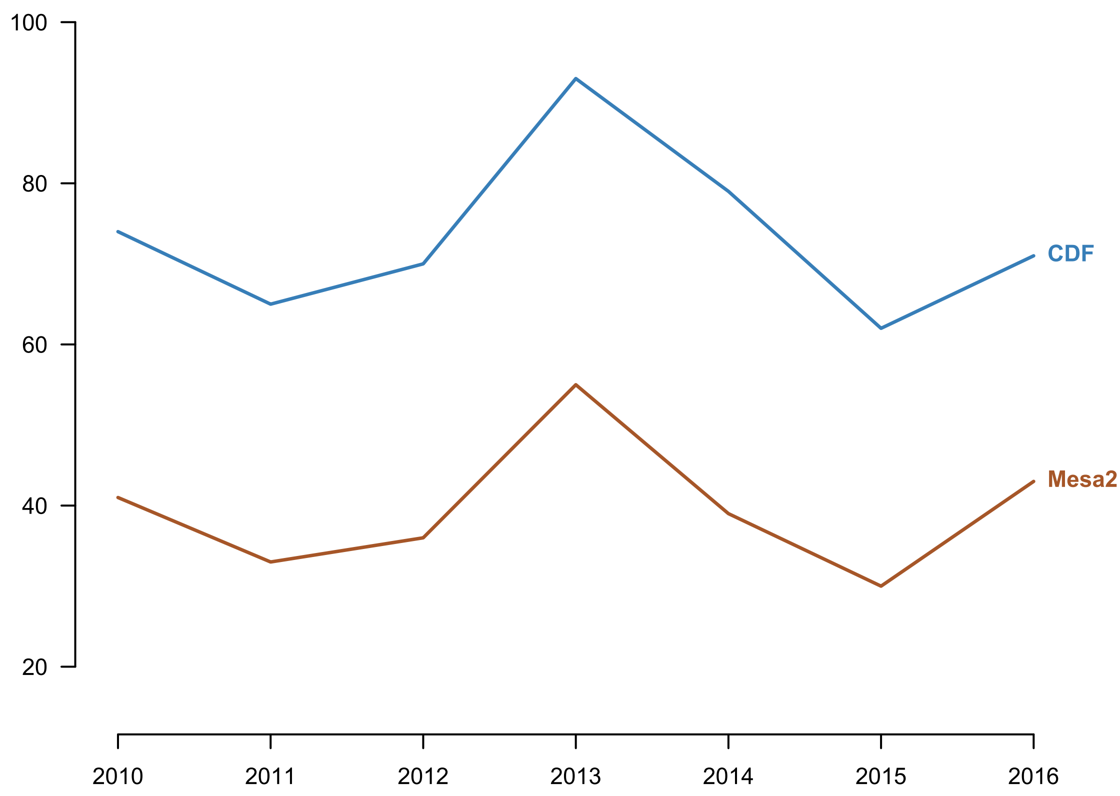

Figure A1: Annual Number of Exceedances of the State 24-hr PM_{10} Standard

[5] Pilot mitigation projects were conducted during this period, but these were small in scale, and designed to test the efficiency of saltation control within a project's area. They were not designed nor expected to impact PM_{10} concentrations at CDF.

Trends in wind speed and direction can be visualized using wind roses. Examining wind roses for CDF shows that 2014 and 2015 were indeed less windy than previous years and that winds increased in 2016. More specifically, during the season when most standard exceedances tend to occur, the frequency of high winds out of the northwest deceased from 2013 to 2014 and from 2014 to 2015 but then increased in 2016. Figure A2, below, shows wind roses for the month of April for each year from 2010 to 2016. Note that in 2015, the frequency of winds from 285 to 315-degree sector is only about 20%, while in previous years it is typically 25 to 30%. In 2016, the frequency returned to about the previous level. Note also that the proportion of winds in this sector greater than 12 mph (shown in red) decreased from 2013 to 2014 and from 2014 to 2015 but increased from 2015 to 2016. Wind roses for May and June (Figures A3 and A4, below) show similar year-to-year changes. These trends parallel the trends in annual number of standard exceedances (Figure A1), at least qualitatively.

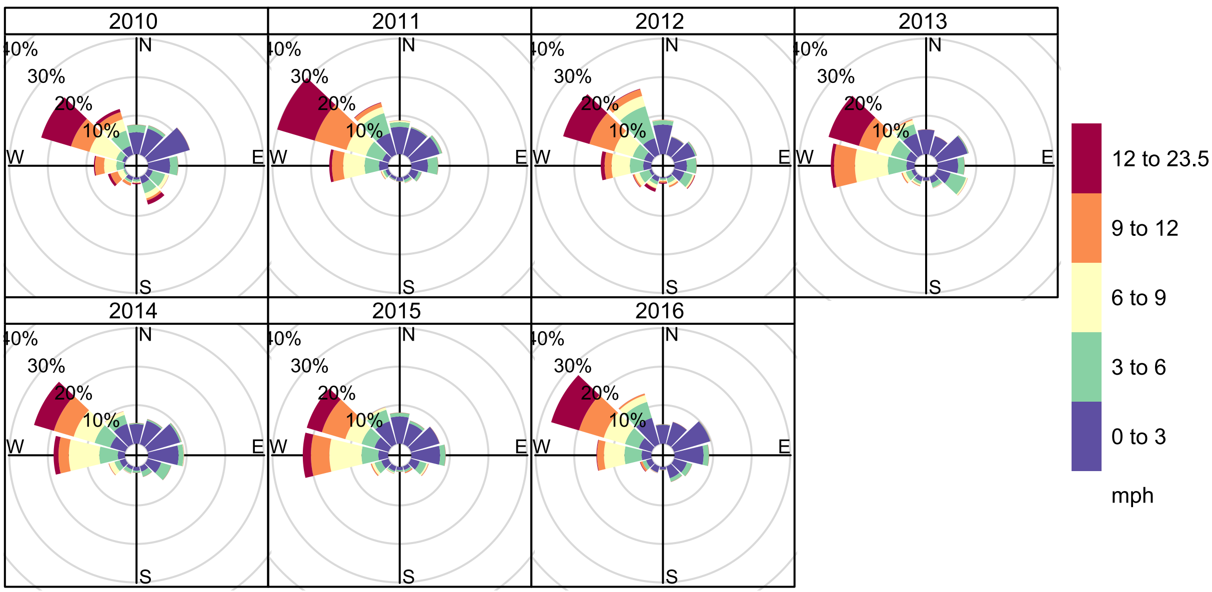

Figure A2: Wind Roses for CDF in April 2010 to 2016

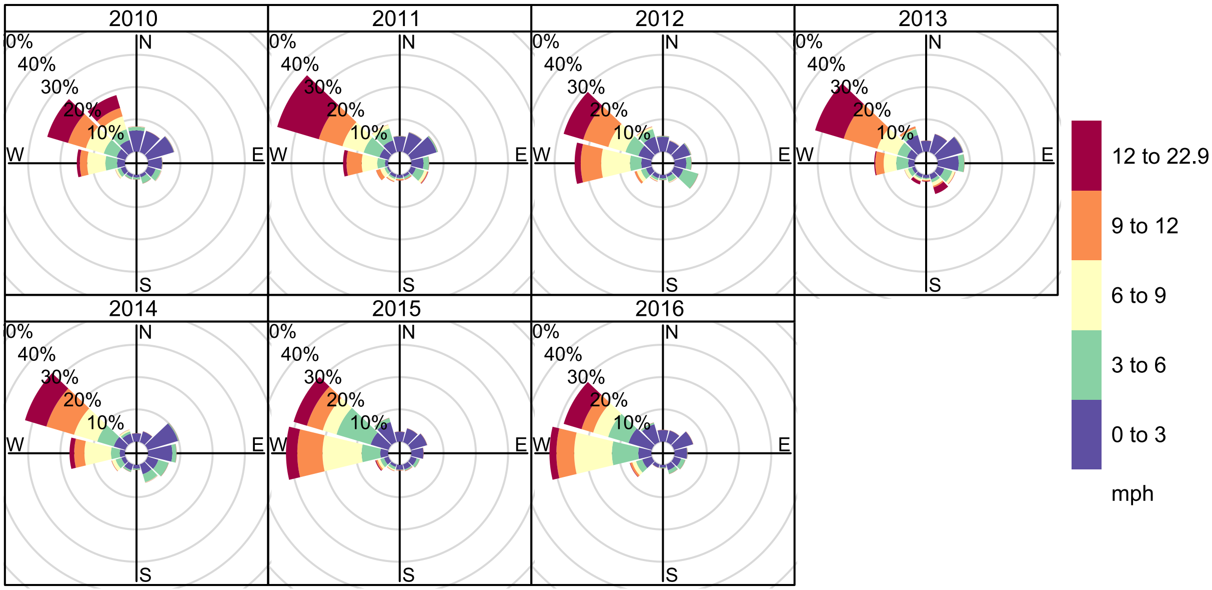

Figure A3: Wind Roses for CDF in May 2010 to 2016

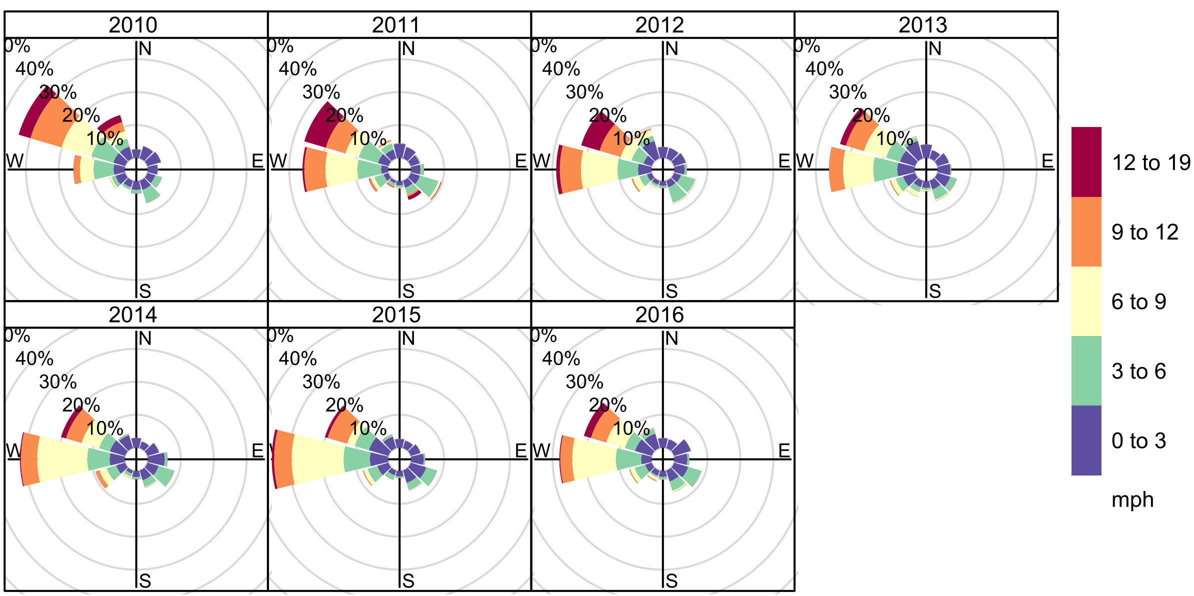

Figure A4: Wind Roses for CDF in June 2010 to 2016

Filter Days Analysis

This section is by Mel Zeldin, Consultant to the District, and Karl Tupper, Air Quality Specialist with the District

The previous section made a qualitative assessment of the dust control effectiveness; this section provides a quantitative approach.

In its most general form, the observed concentration of a non-reactive pollutant, such as crustal-originating PM_{10}, is a function of both emissions and meteorological conditions. On the Nipomo Mesa, wind conditions can transport PM_{10} from the ODSVRA such that exceedances of the federal ambient air quality standards are occasionally measured at the CDF monitoring site, and the more stringent California PM_{10} standard is exceeded on a regular basis. Emissions can occur from sufficiently strong wind conditions or from activities occurring within the ODSVRA. Since both emissions and meteorology vary from day to day, it can be very difficult to determine the effectiveness of mitigation efforts intended to reduce the severity of PM_{10} transported inland from the dunes.

Fundamentally, measured PM_{10} concentrations are a function of both emissions and meteorology:

$$\mathbf{C} = f(\mathbf{Em}, \mathbf{Met})$$

where **C** is the measured concentration, and *f*(**Em**, **Met**) is a function related to emissions and meteorological conditions. Without accounting for changes in **Met**, the assumption that a change in **C** at CDF is due to some mitigation of **Em** could lead to erroneous conclusions about the effectiveness of the mitigation efforts.

One way to better relate changes in **Em** to changes in **C** is to examine a subset of the available data chosen such that, to the degree possible, **Me**t is held constant, and thus any change in **C** is actually reflective of changes in **Em**. The challenge is to devise a set of appropriate “filters” stringent enough to create quasi-fixed meteorological conditions, yet not so restrictive as to limit the number of occurrences to too few to be statistically meaningful.

The meteorological filter was developed using data from years 2011 through 2014. In essence, this four-year period represents a baseline of pre-mitigation conditions, since the first major mitigations occurred in 2015. (While mitigations were in place in 2014, they were less extensive and further away from CDF, and thus less likely have a discernable effect on measured PM_{10} levels.) The filter uses data from CDF and the S1 meteorological tower within the ODSVRA[6] to select days with *approximately* constant meteorological conditions that are likely to have high 24-hr average PM_{10} concentrations.

The specific criteria for defining a “filter day” are as follows:

During the six-hour period from 10 am to 3:59 pm:

1. *All S1 and CDF PM_{10}, wind speed, and wind direction measurements must be valid;*
2. *The S1 vector average wind direction must be between 285 and 300 degrees for the six-hour period;*
3. *The S1 site must have <u>all</u> hourly wind speeds greater than or equal to 5 m/s;*
4. *The S1 site must have at least 3 of the 6 hourly wind speed greater than 10 m/s;*
5. *The S1 site must <u>not</u> have any hourly wind direction > 310 degrees;*

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[6] The S1 tower is located with the ODSVRA and owned and maintained by the California Department of Parks Recreation. The District plays no role in the collection or validation of these data, which are available at http://ohv.parks.ca.gov/?page_id=26819.

6. *The CDF site must not have any hourly wind direction < 285 degrees.*

As noted above, these criteria were developed using data from 2011-2014, and then applied to 2015 and 2016. (Data from 2010 was not used because the S1 tower was not yet operational.)

Statistical Estimates for the Baseline Period

For the 2011-2014 baseline period, there were 61 days meeting the filter day criteria. The following analysis uses the data from the six-hour period from 10 am to 3:59 PM for these filter days. Data were aggregated for each year, and because average wind speeds varied slightly year to year, the PM_{10} concentrations were normalized to wind speed to get an average concentration per m/s for each year. From these annual values, a pooled average and standard deviation were determined, as follows:

YEAR	# FILTER DAYS	CDF PM_{10} (μg/m^3)	S1 WIND (m/s)	PM_{10} per m/s
2011	10	270	10.3	26.8
2012	16	357	11.8	30.5
2013	21	325	11.5	28.1
2014	14	317	10.7	29.1
Average		317	11.1	28.6
SD				1.6

Note that the normalized values for all four years are remarkably similar. Year 2011 has the fewest number of data filter days with an annual total of 10.

As a double check of the average normalized value as shown in the above table, all 366 hourly data points for the 61 days over the four years were averaged and then normalized. The resulting value was 28.7, identical (as rounded) to the average of the four annual values.

Evaluation of 2015 and 2016

The filter day results for 2015 are shown below:

YEAR	# FILTER DAYS	CDF PM_{10} (μg/m^3)	S1 WIND (m/s)	PM_{10} per m/s
2015	5	336	10.2	32.3
2016	12	261	10.4	24.3

As discussed more fully in last year's Annual Air Quality Report, 2015 was a meteorologically anomalous year, with far fewer filter days than other years. The normalized value of 32.3 μg/m^3 per m/s, is 2.4 standard deviations *greater* than the value for the baseline years, which runs contrary to the expected result, which would be a normalized value that is *lower* than the baseline if the mitigations were effective at reducing downwind PM_{10} levels.

With 12 days meeting the filter criteria, 2016 was a more typical year in terms of meteorology, and with a normalized value of 24.3 μg/m^3 per m/s, the result is 2.8 standard deviations below the baseline. In contrast to 2015, this is a change in the expected direction.

Figure A5, below, plots S1 wind speed versus CDF PM_{10} for filter days, aggregated by year. The data are from the tables, above, and include only values from 10 am to 3:59 PM. While this approach attempts to hold meteorology constant, in practice this can be done approximately, and the annual average S1 wind speeds on filter days ranges from 10.2 to 11.8 m/s. For the baseline years (2011-2014) and 2016, the figure shows that CDF PM_{10} follows the expected trend: as S1 wind speed increases, so does CDF PM_{10}, even over this narrow range. Note that 2015 is anomalous to this trend.

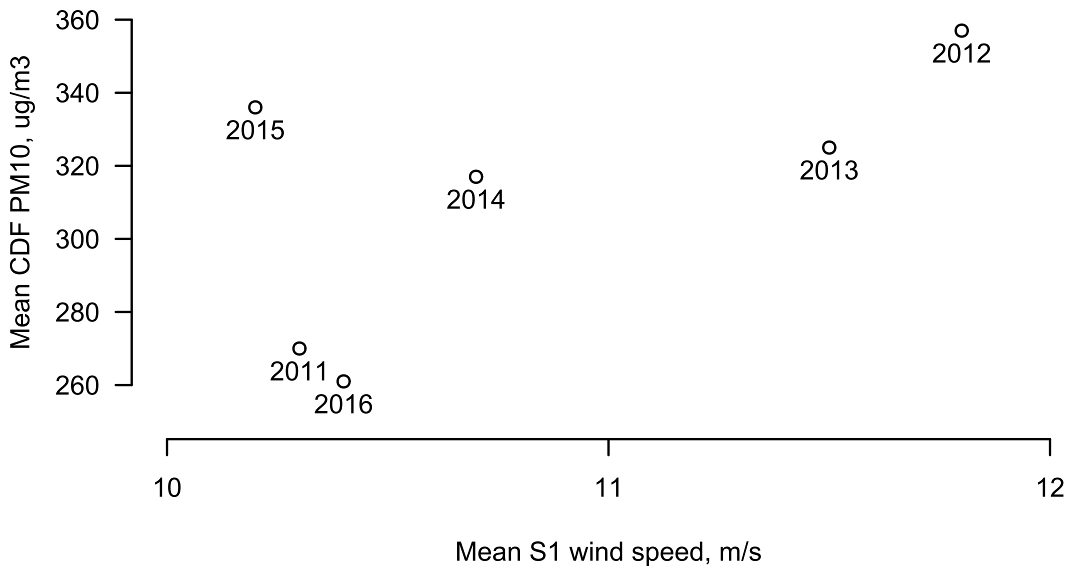

Figure A5: CDF PM_{10} versus per m/s S1 wind speed on "filter days"

Statistical Analysis

The analysis indicates that 2015 and 2016 differ from the baseline, with one above the baseline and the other below. But are these differences statistically significant?

Analysis of variance (ANOVA) was used to explore between-year variance versus within-year variance. First, the PM_{10}/wind speed ratios for the filter days from the baseline years (2011-2014) were analyzed by one-way ANOVA to determine whether these years differed significantly from one another. The resulting p-value of 0.095 is not statistically significant, indicating that within-year variance is much greater than any between-year variance. In other words, the PM_{10}/wind speed ratios for the different baseline years are not significantly different from each other, so it is appropriate to pool them.

These years were therefore pooled together, and then the data for 2015 was compared to this baseline, again using one-way ANOVA. The resulting p-value was 0.049, which is marginally significant at the 95% confidence level, indicating that 2015 is different from the other years, albeit just barely.

Since the PM_{10}/wind speed ratio for 2015 is higher than for the baseline years, the inference is that 2015 is worse than the previous years. Note that this approach is equivalent to performing a T-test comparing 2015 to the pooled baseline years. This assumes equal variances, and an F-test suggests that the assumption of equal variances is valid (p-value = 0.39). ANOVA and T-tests both assume that the data is normally distributed, and a histogram of the ratios looks normal (not shown). Nonetheless, the analysis was repeated using the non-parametric Kruskal-Wallis rank sum test. This test also showed that the ratio for 2015 was slightly statistically significant higher than the baseline years (p-value = 0.031).

Applying these same tests to the 2016 results suggests that the difference between this year and is baseline is also statistically significant. The p-value of the one-way ANOVA comparison is 0.0005 with an F-test also suggesting the assumption of equal variances is valid (p-value = 0.06), and the Kruskal-Wallis rank sum test yields a p-value of 0.0001.

Interestingly, 3 of the 12 filter days in 2016 occurred in September and October, after the temporary fencing array was removed.[7] Splitting the 2016 filter days data set into during- and post-mitigation subsets (i.e. March through July vs August through October) yields the following results:

Months	Mitigations in Place?	# FILTER DAYS	CDF PM_{10} ($\mu g/m^3$)	S1 WIND (m/s)	PM_{10} per m/s
March – July	YES	9	244	10.4	22.8
Aug – Oct	NO	3	311	10.4	28.9

Comparing the 3 post-mitigation filter days to the 9 "peri"-mitigation days using one-way ANOVA suggests that the mitigation effect is statistically significant (p-value = 0.042) albeit just barely. It should be noted, however, that applying the same analysis to the baseline years also shows a lower PM_{10}/wind speed ratio for March through July period, although the difference of 3.3 $\mu g/m^3$ per m/s is not statistically significant (p-value: 0.096).

Decision Tree Analysis

In this approach, first the meteorological conditions associated with exceedances of the state PM_{10} standard at CDF were identified. Next, the number of days each year with these conditions was determined and compared to the number of exceedances actually observed. As with the first approach, data from 2011 to 2014 was treated as a baseline, and 2015 and 2016 as test years.

Meteorological Conditions Associated with Exceeding the State PM_{10} Standard

In order to identify the conditions associated with exceedances of the state standard, a decision tree for predicting exceedances was developed using hourly wind speed and wind direction data from CDF and the S1 tower from 2011-2014. The decision tree was "grown" and "pruned" using the "tree" package in R (version 3.4.0).[8] The optimized decision tree is very simple and predicts an exceedance of the standard at CDF when:

- S1 wind speed at 3 pm exceeds 9.445 m/s **and** CDF wind direction at 1 pm is greater than 289.5 degrees.

This simple rule accurately classifies 90.6% (95% confidence interval: 89.0 to 92.2%) of days in 2011-2014 as exceedances or not. By comparison, a naïve method which ignores meteorology and always classifies days as not exceeding the standard would have an accuracy of 78.2%.

[7] For 2015, all 5 filter days occurred when the mitigation measures were in place.

[8] Brian Ripley (2016). tree: Classification and Regression Trees. R package version 1.0-37. CRAN.R-project.org/package=tree.

Trends in the Annual Number of Days with Meteorological Conditions Associated with Exceeding the State PM_{10} Standard

Figure A6, below, plots the number of days each year with the wind characteristics identified above. Also depicted are the number of exceedances observed at CDF each year. Qualitatively, the trends track each other closely, even though there are many more observed exceedances than the rule predicts. (This downward bias in the number of predicted exceedances is an artifact of the skewed distribution of the 24-hour average PM_{10} values.)

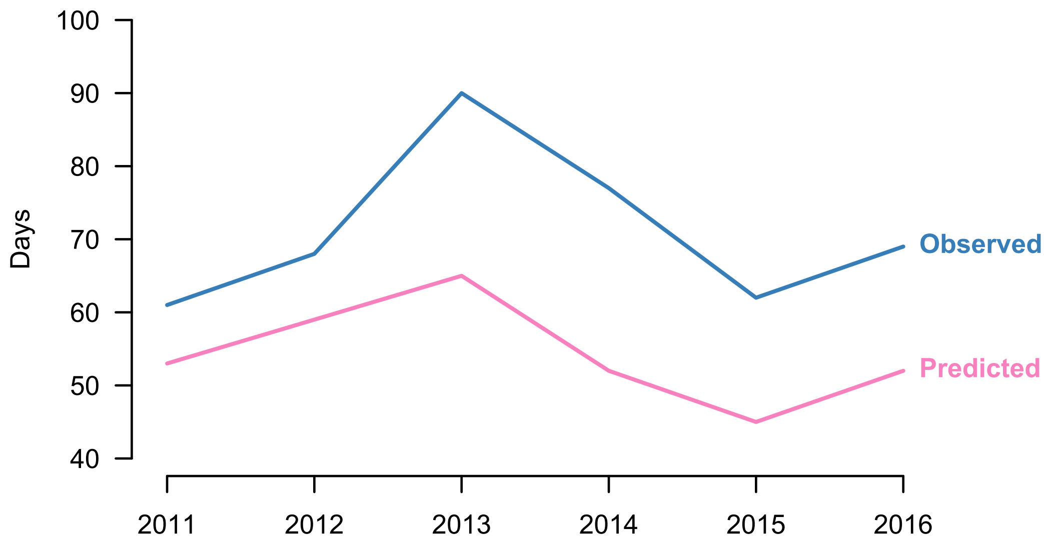

Figure A6: Predicted and Observed Exceedances of the state standard at CDF by Year

Conclusions

Last year's Annual Air Quality Report concluded that 2015 dust control projects did not measurably reduce PM_{10} levels at CDF. The trend analysis and the decision tree analysis both indicated that PM_{10} levels tracked annual variations in meteorology. The filter days analysis suggested that ODSVRA was actually more emissive than meteorological conditions would predict. This increase was statistically significant, albeit only slightly.

For 2016, it is a bit of a "split decision": the trend and decision tree analyses again suggest that PM_{10} at CDF simply tracks meteorology, while the filter day analysis suggests a statistically significant decrease in the emissivity of the ODSVRA.

There are number possible explanations for these results. It is possible that the 2016 dust control projects were indeed somewhat effective in reducing PM_{10} at CDF, but only the filter days methodology is sensitive enough to capture the effect. However, the fence arrays in 2015 and 2016 were very similar: both were 40 acres (nominally) and they were deployed in approximately the same location. It seems unlikely that the small differences between the arrays could have resulted in a statistically significant increase in emissivity one year and then a statistically significant decrease the next.

More likely is the possibility that are inter-annual differences in meteorology that are not captured by the analyses employed. For the filter days approach, perhaps the filtering criteria are not stringent enough—an upper bound on wind speed might result in more homogenous meteorological conditions. In calculating the ratio of PM_{10} to wind speed, the filter days approach makes an implicit assumption of a linear relationship between PM_{10} and wind speed; however, the real relationship is more likely to be a power law.[9] Accounting for this non-linear relationship may improve the analysis. For the decision tree approach, allowing additional variables to be considered—e.g. pressure, boundary layer height, precipitation—might generate a more complex but more accurate algorithm, and this could make any departure from baseline conditions more apparent. Accuracy might also be improved by using more flexible prediction techniques instead of decision trees, such as neural networks or support vector machines.

Overall, it appears that ODSVRA dust control projects have not resulted in decreases in PM_{10} levels large enough to be unambiguously detected by the analytical approaches employed to date. More effective mitigations and/or more sensitive analytical methodology will be needed in order to demonstrate real reductions of PM_{10} at CDF.

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[9] J.A. Gillies and V. Etyemezian (2014). "Wind and PM_{10} Characteristics at the ODSVRA from the 2013 Assessment Monitoring Network." http://www.slocleanair.org/images/cms/upload/files/DRI_Oceano-Dune-Wind%20-PM-Conditions_09-22-2014%281%29.pdf