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Breathing Hazard

AIR POLLUTION IN THE SALTON SEA REGION

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SUGGESTED CITATION

Cohen, Michael J., and Katherine A. Halama. 2025. Breathing Hazard: Air Pollution in the Salton Sea Region. Pacific Institute, Oakland, CA, https://pacinst.org/publication/breathing-hazard/.

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A Haboob traveling northward across the Salton Sea on October 6, 2022.
Photograph courtesy of Rodney Pentoney from Michigan, UPS Airlines Pilot

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ABOUT THE PROJECT TEAM

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Michael Cohen is a Senior Fellow at the Pacific Institute, where he has worked since 1998 to promote the management and revitalization of the Salton Sea ecosystem. He is the author of several articles and previous Pacific Institute Salton Sea reports (available at https://pacinst.org/issues/salton-sea/) and has served on various Salton Sea advisory committees. He holds a bachelor's degree in government from Cornell University and a master's degree in geography, with a concentration in Resources and Environmental Quality, from San Diego State University.

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Katherine Halama was a research intern at the Pacific Institute and a recent graduate of the University of Colorado Boulder's Masters of the Environment program, where she focused on environmental and natural resources policy. She is primarily interested in water policy and management in the Western U.S. and the Colorado River Basin, as well as air quality and sustainable land use. Katherine holds a bachelor's degree in environmental studies from the University of Colorado Boulder.

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Emilio Mateo joined the Pacific Institute in 2024. He produced the maps in this report and the interactive webtool at pacinst.org/issues/salton-sea. His prior projects were related to mountain hydrology, climate resilience and adaptation, and communicating the findings from these projects to the broader scientific community and the public to inform actions. His research interests include water resource management, hydrometeorological processes in alpine regions, and science communication and outreach. He holds a Bachelor of Science in Environmental Science and Statistics from University of Michigan, a Master of Arts in Geography from University of Denver, and a doctorate in Geography from The Ohio State University.

ACKNOWLEDGEMENTS

We gratefully acknowledge the insights and time of Isabella Arzeno-Soltero, Ann Cheney, Eric Connally, Heather Cooley, Amato Evan, Linton Freund, Mara Frielich, Mario Llanos, Aydee Palomino, Will Porter, and Lily Wu, who provided valuable comments, recommendations, and suggestions on earlier versions of this report. We also thank the Imperial Irrigation District (IID) and its consultant for reviewing our use of their Air Quality Management Program data. New and remaining errors are solely our own.

This report could not have been completed without the assistance and support of many people, including Damon Barta, Dana Beigel, Jeremy Brooks, the California Air Resources Board (CARB) ADAM/ADMIS team, David Ceballos, Brian Cohen, Melinda Dorin, Kai Dunn, Jose Figueroa Acevedo, Steven Garcia, Nathan Gogna, Chris Hancock, Karen Henderson, Miguel Hernandez, Israel Hernandez, Simon Hook, Jessica Humes, Tiffany Khoury, Rob Jensen, Sara Lockett, Daniel Macedo Mora, Nareeya Nalivka, Derek Nguyen, Ismael Ramirez, Maria Rivas Huerta, Andrea Schmid, Brian Schmid, Ryan Sinclair, Monica Soucier, Juliana Taboada, Linda Tate, Leslie Walker, Evon Wilhoff, and Yohannes Yimam. We thank them for their time and guidance and help acquiring data.

The U.S. Bureau of Reclamation funded the research in this report under Agreement No. R24AC00145. The Regional Access Project Foundation funded outreach efforts for the report. We gratefully acknowledge their support. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Bureau of Reclamation or the Regional Access Project (RAP) Foundation.

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Figures and Tables

Abbreviations & Glossary

AB 617	Assembly Bill 617 (2017) requires local air districts and CARB to reduce air pollution in select environmental justice communities 1
aeolian	windblown
AF	Acre-feet (1 acre-foot = 325,851 gallons)
alluvial	deposited by water
AQMP	IID's Air Quality Mitigation Program
BLM	Bureau of Land Management
CARB	California Air Resources Board
CSC	Community Steering Committee
CERP	Community Emissions Reduction Plan
CNRA	California Natural Resources Agency
CVWD	Coachella Valley Water District
DFW	California Department of Fish & Wildlife
DWR	California Department of Water Resources
ECV	Eastern Coachella Valley
EIR	Environmental Impact Report
EPA	U.S. Environmental Protection Agency
fugitive	dust emissions that are difficult to locate and control (as opposed to "significant" or concentrated dust emissions that are easier to identify and regulate)
g/L TDS	grams per liter, total dissolved solids
H_2S	hydrogen sulfide
ICAPCD	Imperial County Air Pollution Control District
IID	Imperial Irrigation District
JPA	Joint Powers Authority
km/hr	kilometers per hour
$\mu g/m^3$	micrograms per cubic meter
mph	miles per hour
NAAQS	National Ambient Air Quality Standards — established by the EPA as required by the Clean Air Act

1 See https://ww2.arb.ca.gov/capp/mdc/bp2/community-air-protection-program-blueprint-20 for additional information on AB 617 programs.

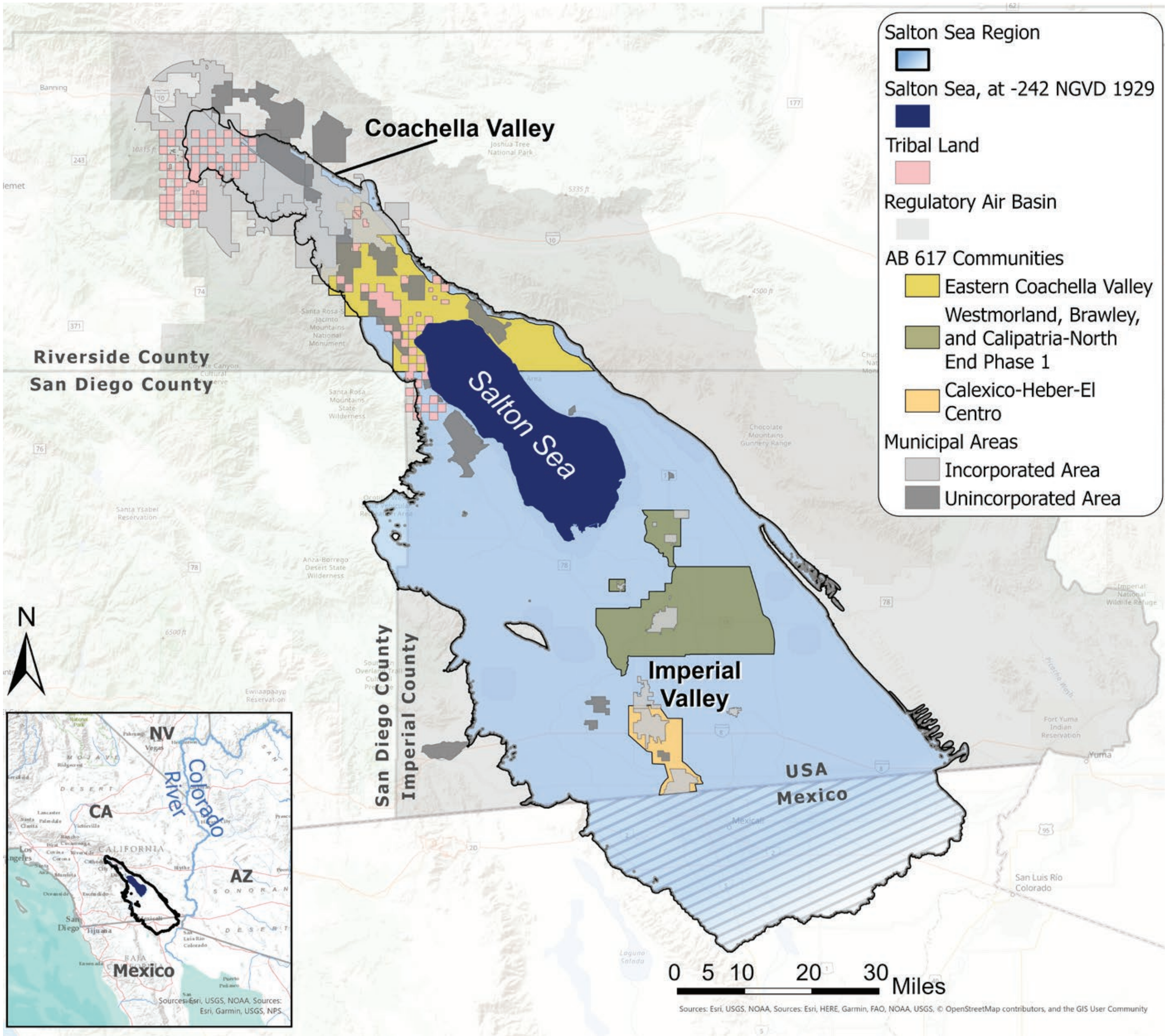
NAVD	"North American Vertical Datum" — a vertical reference standard used by USGS
NGVD	"National Geodetic Vertical Datum" — a vertical reference standard used by USGS
NRCS	Natural Resources Conservation Service
NOx	nitrogen oxides
OHV	Off-highway vehicle, a motorized vehicle typically used on unimproved roads and trails
O&M	operations and maintenance
ppb	parts per billion
ppm	parts per million
PEIR	Salton Sea Ecosystem Restoration Program Programmatic Environmental Impact Report
PM_{10}	particulate matter less than 10 microns in diameter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
QSA	Quantification Settlement Agreement
Reclamation	Bureau of Reclamation, U.S. Department of the Interior
SCAQMD	South Coast Air Quality Management District
SDCWA	San Diego County Water Authority
SOx	sulfur oxides
SS SRA	Salton Sea State Recreational Area
SSMP	California's Salton Sea Management Program
SWRCB	California State Water Resources Control Board
USACE	U.S. Army Corps of Engineers
US FWS	U.S. Fish & Wildlife Service
USGS	U.S. Geological Survey
VOCs	volatile organic compounds

Executive Summary

The Salton Sea, California's largest lake, has shrunk by more than 70 square miles (19%) in the past 30 years. Colorado River water irrigates more than half a million acres of productive farmland in the Imperial and Coachella valleys, in southeastern California (Figure ES-1). Runoff from these fields sustains the lake but has decreased by almost 20% since the 1990s (Figure ES-2) as a result of agreements transferring water out of the region. Continuing efforts to protect Lake Mead and Lake Powell have incentivized farmers to further reduce their use of Colorado River water, accelerating the decline of the Salton Sea and exposing additional lakebed (known as "playa"). More playa means more dust in an area already suffering from bad air quality and some of the highest respiratory hospitalization rates in the state. Expected additional water use reductions will accelerate the Salton Sea's decline and increase the amount of playa exposed, affecting the health of the 560,000 people in the region.

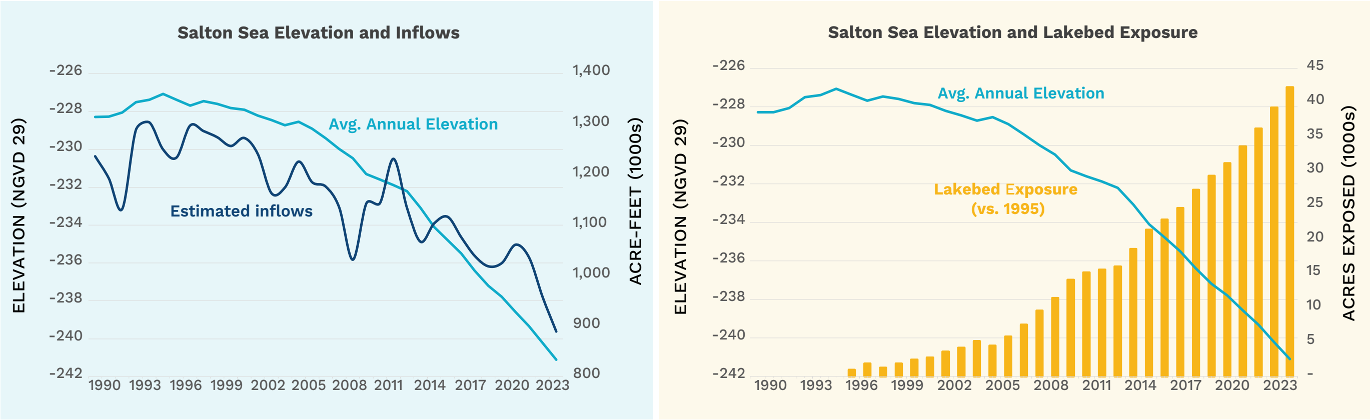
Expected additional water use reductions will accelerate the Salton Sea's decline and increase the amount of playa exposed, affecting the health of the 560,000 people in the region.

FIGURE ES-1. The Salton Sea Region and Air Basin



Sources: USGS, ICAPCD, SCAQMD.

FIGURE ES-2. Salton Sea Inflows, Elevation, and Size Reduction, 1990–2024



Sources: USGS, Tetra Tech elevation/area/capacity table.

Research on playa exposure, air quality, and the public health impacts of additional lakebed exposure has generated more information on these topics since the publication of the Pacific Institute's *Hazard* in 2006 and *Hazard's Toll* in 2014. New research suggests that the biological and chemical properties of the pollutants emitted from the playa and from the lake itself, in addition to the size of the dust particles, may disproportionately impair the health of people living in the area.

Air quality research on the Salton Sea region tends to focus on the harmful impacts of the sea itself, minimizing the broader context in which people live, work, and play. This broader context is important. The surrounding desert contributes massive amounts of dust to the region, as do unpaved roads and certain farming practices. Particulates from burning fields and fires further degrade local air quality, as do diesel emissions from truck traffic on freeways north and south of the region. Confined animal feedlots in the Imperial Valley contribute to local emissions, while nitrogen and phosphorus fertilizers may generate additional pollutants. These and other factors, combined with limited local healthcare availability, contribute to high levels of air pollution and poor public health in the area.

The objective of this report is to inform the planning and implementation of dust suppression measures and air quality projects intended to protect public health in the Salton Sea region. We seek to guide local and state efforts by assessing the relative contributions of Salton Sea playa dust to the overall air quality in the region. We did not perform any new measurements or surveys for this report. Instead, we obtained data from a variety of existing sources, including published reports and information on file with various local, state, and federal agencies.

STUDY AREA

Located in southeastern California, the Salton Sea stretches 35 miles between the lower Coachella Valley in Riverside County and the Imperial Valley in Imperial County (Figure ES-1) and currently covers about 300 square miles. The mountain ranges bordering the study area tend to funnel winds from the northwest across the Coachella Valley toward the Salton Sea. Stronger prevailing winds blow from the western desert across the southern portion of the Salton Sea.

We define the Salton Sea study region as the area extending to 200 feet above the valley floor, where emissions tend to stay when the winds don't blow, from slightly northwest of Palm Springs to the international border. The study area is largely open desert (31% barren land and 15% shrub/scrub), 29% intensely irrigated farmland, 12% open water (mainly the Salton Sea itself), and cities and towns.

Median income for households within 10 miles of the Salton Sea shoreline was less than half the state average in 2013 (Singh et al. 2018). As of 2016, 65% of residents of the Eastern Coachella Valley (ECV), north of the Salton Sea, lived below the poverty line (Pick 2017), while the US Census Bureau reports that 17% of Imperial County residents lived in poverty in 2024. A 2010 study found there was only one doctor per 8,407 ECV residents, versus one per 1,090 in California as a whole. Limited access to healthcare, combined with high poverty rates and the presence of undocumented individuals, suggest that asthma and emergency department visits may be underreported.

POLLUTANT DYNAMICS

Dust particles can linger in the atmosphere for hours, days, or even weeks. Wet soils of any type are typically non-emissive, while disturbed dry soils tend to be more emissive than undisturbed dry soils. Fifteen miles-per-hour (mph) winds are often sufficient to generate emissions from dry, unstable or disturbed Salton Sea playa, while 25 mph winds are typically required to generate emissions from stable, undisturbed playa (CNRA 2006). At Mecca, four miles north of the Salton Sea in Riverside County, winds carry materials from the Coachella Valley and, infrequently, California's Inland Empire, west of San Gorgonio pass. Niland, in Imperial County, about five miles east of the current Salton Sea shoreline and about four miles from the former shoreline, is directly downwind from a mile of partially vegetated playa. In 2024, Mecca experienced about 60 hours of winds at or above 15 mph and zero hours at or above 25 mph while Niland experienced about 545 hours of winds at or above 15 mph and about 75 hours of winds at or above 25 mph.

The chemical components of some PM, such as black carbon emitted by fuel combustion and other sources, pose threats beyond the physical size of the particles themselves.

POLLUTANTS AND EMISSIONS

Ozone and dust particles, known as particulate matter (PM), are regulated as "criteria air pollutants" in the region. Roughly 70% of the PM in the region comes from "fugitive emissions," diffuse sources that are difficult to locate or control, typically generated by strong winds. Dust from unpaved roads operations accounts for another 20% of regional PM. In addition, almost 200 toxic air contaminants have been identified in the region.

The chemical components of some PM, such as black carbon emitted by fuel combustion and other sources, pose threats beyond the physical size of the particles themselves. Pesticides, off-road driving, and fires — including agricultural burning, wildfires, incinerators, and landfill fires — all add to the toxic air contaminant mix afflicting the region. Recent research suggests that biological contaminants and hydrogen sulfide (Centeno et al. 2025) are also pollutants of concern. Hydrogen sulfide, a gas people can notice in concentrations as low as one part per billion, has a characteristic rotten egg smell (Batterman et al. 2023). In September 2012, people in the San Fernando Valley complained about the smell after a storm blew the gas 150 miles from the Salton Sea (James 2016). Communities in the Eastern Coachella Valley have also expressed concern about chronic exposure to low concentrations of hydrogen sulfide (Centeno et al. 2023).

The high quantities of nutrients entering the Salton Sea have fed harmful algal blooms. Nutrient loadings have been an issue for more than 25 years (Cohen et al. 1999). On April 23, 2021, a local agency issued a news advisory warning people to avoid contact with the Salton Sea due to an algal bloom with toxic cyanobacteria. Ongoing research at UC Riverside has identified biological elements in aerosols from the lake itself and in some dust as an additional threat. A recent study found a strong correlation between Salton Sea algal blooms and increased hospitalization rates for people in downwind communities (Miao et al. 2025).

> The various physical, chemical, and biological components of air pollution combine to create a multi-pollutant burden on communities in the study region.

This report describes the many forms, phases, and sources of pollutants impairing air quality in the region. These factors vary across time and place. The only existing multi-year estimates of Salton Sea lakebed emissions suggest that they account for less than 1% of total PM emissions in the region. Lakebed emissions also vary: more than 70% come from about 20% of the exposed lakebed, and almost 90% of the total comes from the western and southern parts of the lakebed. There is also a notable difference in dust sources in communities north of the Salton Sea versus those to the south. Dust blown over the Salton Sea accounted for only 0.5% of the total at a monitoring station north of the lake, but nearly five times that amount (2.3%) at a station south of the lake (Miao et al. 2025).

AIR QUALITY

Air pollution is regulated at local, state, and federal levels — with local air districts having jurisdiction mainly over stationary sources, the state air board having jurisdiction mainly over mobile sources, and the U.S. Environmental Protection Agency (EPA) having jurisdiction over specific air pollutants. Both the Coachella and Imperial valleys exceed (are in “nonattainment” of) federal ozone standards more than 10% of the year on average. The Salton Sea Air Basin exceeds the state dust standard about 120 days per year.

REMEDIATION

Local and state agencies have implemented projects and control measures in the study region, reducing emissions and improving air quality. To date, California has constructed more than 3,000 acres of dust suppression projects on exposed Salton Sea playa at an estimated cost of about $49 million. Preliminary estimates suggest that these projects reduce dust emissions from the project sites by more than 75%. The irrigation district in the Imperial Valley has constructed almost 3,000 additional acres of dust suppression projects and has spent about $55 million on its air quality program overall.

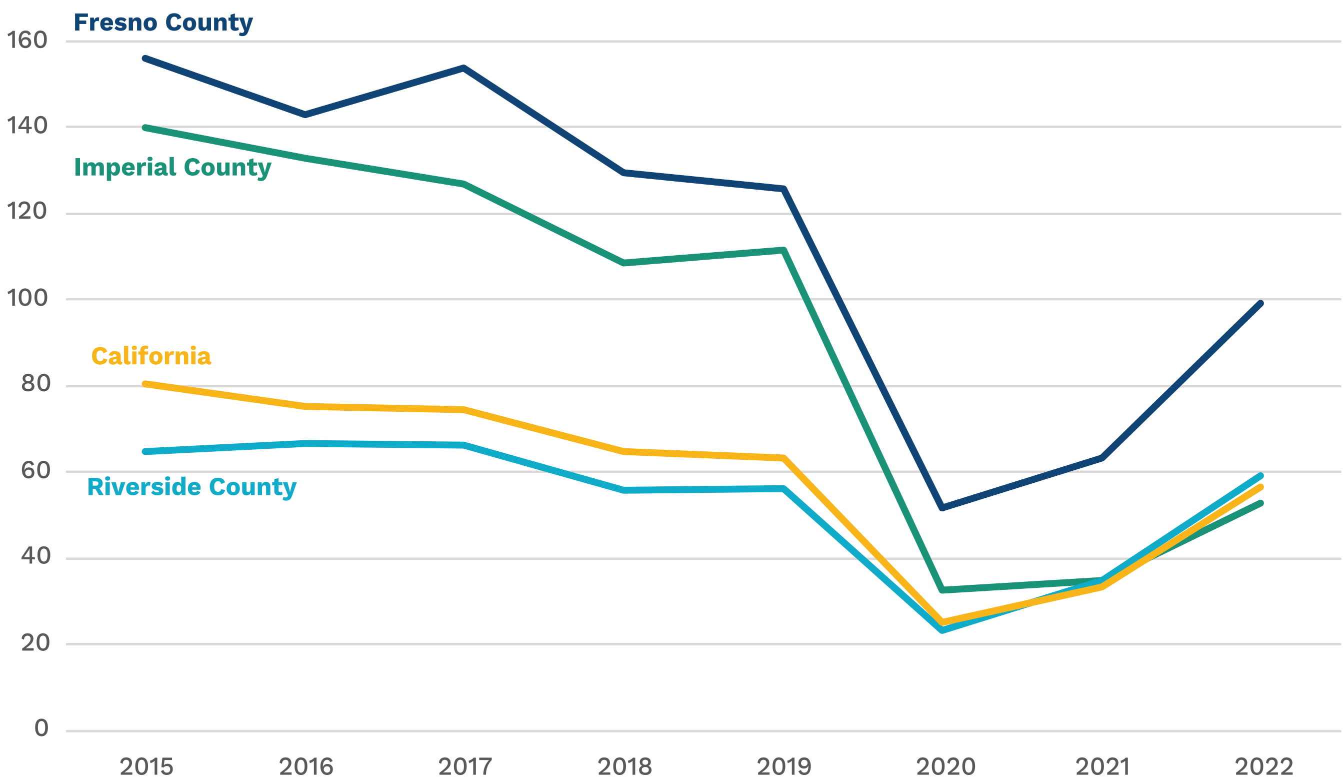
PUBLIC HEALTH

Both short- and long-term exposure to air pollution have been found to increase rates of disease and death. For example, ozone exposure can lead to lung problems and chest pain, while hydrogen sulfide can irritate the eyes, nose, and lungs. Fine dust can lodge deep in the lungs, causing many respiratory issues. Pesticides can affect the nervous system, irritate the eyes or skin, affect the hormone or endocrine systems, and can be carcinogenic (EPA 2015). Recent surveys in the Salton Sea region have found a high incidence of nosebleeds, allergies, and asthma among children, ascribed by caregivers to the Salton Sea, pesticides, and burning trash (Cheney et al. 2023). Black carbon can carry a host of toxic chemicals (Cassee et al. 2013; Costa 2011) and is a major air pollutant in the ECV. Dust storms, composed of larger dust particles, can reduce visibility, increasing the risk of traffic accidents, injuries, and fatalities.

The various physical, chemical, and biological components of air pollution combine to create a multi-pollutant burden on communities in the study region. The impacts from occupational-related exposure, combined with limited medical services and high costs of healthcare, further burden low-income communities in the region.

Figure ES-3 shows relative rates of children's emergency department visits for asthma among children under 18 years of age in Imperial and Riverside counties, as compared to Fresno County and California as a whole. (Fresno County typically experiences the highest such rates in the state.) Although the Imperial County rate includes children outside the study area, the figure suggests that, prior to the COVID-19 pandemic, the rate for children in the study area was about 75% higher than the state average. Children's rates of hospitalization for asthma-related conditions show a similar pattern. Counties in California's Central Valley — which share many agricultural practices with the study region but lack the Salton Sea's influence — regularly have the state's highest average annual concentrations of fine dust. Imperial County does not make the list of the worst 25, according to the American Lung Association's *State of the Air* report.

FIGURE ES-3. Age-Adjusted Pediatric Asthma Emergency Department Visit Rates, 2015–2022



Source: California Department of Public Health

DISCUSSION AND RECOMMENDATIONS

Over the past decade, our understanding of the many factors contributing to air pollution in the Salton Sea region has increased dramatically. State and local governments have increased their efforts to prevent and remediate threats to public health. These efforts include new rules and regulations, dust suppression projects, and the installation of air filters and weatherization of homes. Hospitalization rates for childhood asthma in the Salton Sea region have recently fallen to about the state average, though the reasons for this decline are not clear. Even so, air quality in the region regularly continues to exceed state and federal standards for ozone, particulates, and hydrogen sulfide. Moreover, the Salton Sea will continue to shrink, exposing more emissive playa and exacerbating existing conditions.

Many researchers have noted that high nutrient loadings into the Salton Sea drive the chemical and biological processes generating emissions (Centeno et al. 2023, 2025, Hung et al. 2024). Given the massive amounts of nutrients already in the Salton Sea and its sediments, meaningfully reducing the lake's overly productive biological processes would require a 70-90% reduction in external nutrient loadings (Hung et al. 2024). To date, the pace of regulatory change, together with the associated large-scale political and economic challenges, suggests that **biological and chemical emissions are likely to persist for the foreseeable future**.

Annually, more than 70,000 tons of dust from barren land, and more than 20,000+ tons from unpaved roads, pollute the air in the Salton Sea region. **The magnitude, persistence, and dispersed sources of dust emissions make efforts to control them very challenging and very expensive** (UC Dust 2024). Mobile sources generate thousands of additional tons of harmful diesel particulate matter; though federal, state, and local rules have decreased these emissions, they continue to pose a measurable threat to area residents.

Taken together, the broad range of pollutants in the region, the diffuse and dynamic range of their sources, the expected persistence of factors driving emissions, powerful local stakeholders, and climate-intensified droughts and storms, all suggest that **managing or suppressing emissions at the source will not be sufficient, politically feasible, nor cost-effective**. Local communities have instead adopted a combined approach of source control, such as paving specific, highly emissive sites, and exposure control, such as home weatherization.

Exposure control refers to actions or efforts to reduce adverse public health impacts where people live, work, and play. Reducing or avoiding exposure to air pollution can include:

- Alerting people to expected dust storms and encouraging them to avoid outdoor exertion on days with poor air quality (UC Dust 2024)
- Installing air filters and weatherizing homes
- Limiting indoor air pollution that may be caused by smoking, gas stoves, or other factors (Laumbach et al. 2015)

Exposure control measures, taken individually or in combination, **can improve indoor air quality and reduce exposure to many pollutants, toxins, and pathogens** (Gaston et al. 2021). Exposure control efforts are a more cost-effective and more feasible means of protecting public health than source control.

Paz (2025) describes the fractured nature of governance in the Salton Sea region and notes opportunities for better coordination. **Communication, coordination, and cooperation between the various agencies with air quality jurisdiction in the region could be improved**, particularly between agencies and programs with different mandates and authorities. Such actions could provide meaningful benefits to communities in the region. Optimizing public investment in efforts to protect public health in the region will require dedicated coordination among agency officials, county governments, community-based organizations, and local residents.

We recommend that the California Environmental Protection Agency convene the following parties in order to revisit the 2017 stipulated order establishing milestones for the state's implementation of Salton Sea projects **and identify potential state investments to optimize public health benefits for local communities:**

- California's State Water Resources Control Board
- California's Air Resources Board
- The two local air districts

- Representatives of the three AB 617 communities in the region
- The parties responsible for the 2017 stipulated order
- Air quality and public health experts
- Community leaders and representatives

These experts could identify new approaches, directing some portion of state investments toward exposure control efforts in communities adjacent to the Salton Sea, or use such funds to match and increase other investments in local communities more broadly. An intentional, coordinated effort would enable these leaders and decision-makers to optimize the allocation of limited state and local funding to protect the health of the people who live, work, and play in the Salton Sea region.

1. Introduction

The Salton Sea, a shrinking terminal lake in southeastern California, depends on Colorado River runoff from irrigated fields in the Imperial and Coachella valleys. Several water conservation and transfer agreements, combined with continuing efforts to protect critical elevations at Lake Mead and Lake Powell, have encouraged the Imperial Irrigation District (IID) to reduce its Colorado River use, reducing the size of the Salton Sea and exposing additional lakebed (known as “playa”), in turn increasing dust emissions affecting the health of the 560,000 people in the region. In the past 30 years, the Salton Sea has shrunk by more than 70 square miles, 19% of its former size. Expected additional water use reductions to protect Colorado River system storage will accelerate this rate of decline and increase the amount of emissive lakebed exposed.

Research on lakebed exposure, air quality, and the public health impacts of additional lakebed exposure has generated a growing body of knowledge[1] on these topics since the publication of the Institute’s *Hazard* in 2006 and *Hazard’s Toll* in 2014. New research suggests that the biological and chemical properties of dust and aerosols emitted from the playa and the lake itself, in addition to the physical characteristics of the dust, may disproportionately affect the health of people living in the area. In this report, we analyze and synthesize this growing knowledge base, making such information readily available to those affected and to decision-makers.

Air quality research in the Salton Sea region often focuses on the deleterious impacts of the lake itself, neglecting the broader context in which people live, work, and play. This broader context is important. The surrounding desert contributes massive amounts of dust to the region, as do unpaved roads and certain farming practices. Particulates from burning fields and fires further degrade local air quality, as do diesel emissions from heavy truck traffic on the two interstate freeways crossing the region and vehicles idling at the international border crossing 35 miles south of the Salton Sea. Confined animal feedlots in the Imperial Valley also contribute to local emissions, while nitrogen and phosphorus fertilizers may contribute precursors to additional contaminants.

The combination of these many factors has adversely affected air quality in the Salton Sea region. The Imperial Valley and parts of the Coachella Valley report some of the worst air quality in the state. Poor air quality, combined with limited access to health care, adversely affects public health in the region. The area suffers from disproportionately high numbers of hospital visits and admissions for respiratory challenges such as asthma. In response, California has designated

1 See the Salton Sea Zotero library at https://www.zotero.org/groups/4998837/salton_sea.

portions of both valleys as parts of the Community Air Protection Program,[2] to improve air quality monitoring and protect public health.

OBJECTIVE

The objective of this report is to inform the planning and implementation of dust-suppression measures and air quality projects intended to protect public health in the Salton Sea region. With this report, we assess and describe the range and sources of contaminants that degrade air quality and public health in the Salton Sea region. We seek to help inform management actions by assessing the relative contributions of Salton Sea playa dust to the overall air quality in the region.

REPORT ORGANIZATION

The next chapter provides background information on the Salton Sea region, including its location and setting, hydrology, and demographics. Chapter 3 describes our methods and data sources. Chapter 4 summarizes recent literature on Salton Sea air quality. Chapter 5 describes pollutant dynamics, including a brief overview of emission mechanics: how pollutants enter the air. Chapter 6 describes what is being emitted in the region: the range, sources, and reported magnitudes of contaminants affecting air quality. Chapter 7 summarizes air quality regulations. Chapter 8 describes some of the local and state dust suppression projects that seek to reduce emissions. Chapter 9 discusses the impacts of the previously described pollutants on public health in the area. Chapter 10 synthesizes these findings and offers recommendations to better allocate limited state and local funding to protect the health of the people in the Salton Sea region.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2 See https://ww2.arb.ca.gov/capp-communities.

2. Study Area

Located in southeastern California, the Salton Sea stretches 35 miles between the lower Coachella Valley in Riverside County and the Imperial Valley in Imperial County (Figure 1) and currently covers about 300 square miles.[3] The Salton Sea is a terminal lake, with a current surface elevation of about 240 feet below sea level (NAVD 1988).[4] The Salton Sea's watershed encompasses 8,360 square miles, extending from San Gorgonio Pass northwest of Palm Springs to a slight rise southeast of Mexicali, Baja California.

The Salton Sea's watershed encompasses 8,360 square miles, extending from San Gorgonio Pass northwest of Palm Springs to a slight rise southeast of Mexicali, Baja California.

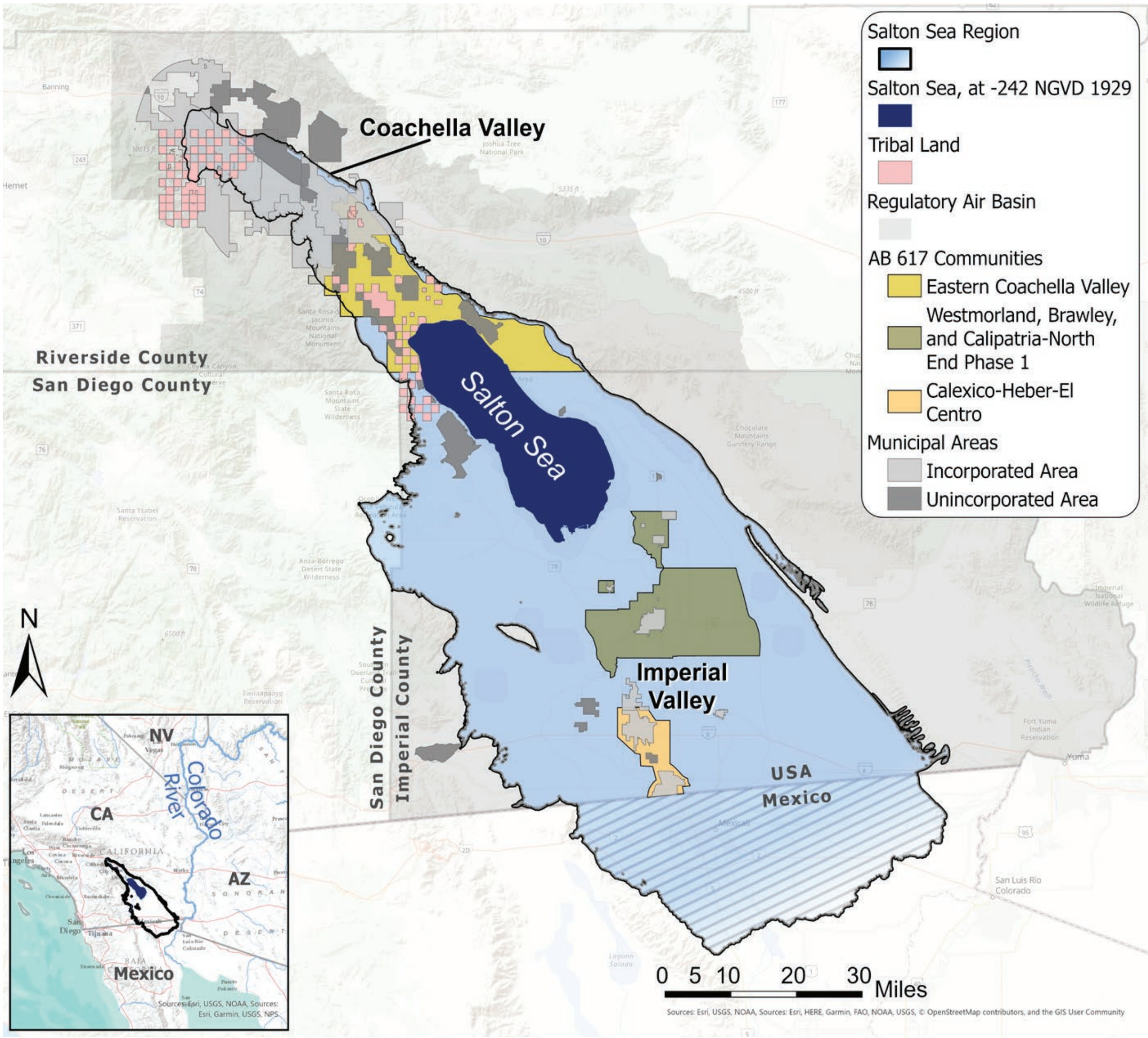
This report focuses on the area immediately surrounding the Salton Sea (the light blue area shown in Figure 1). We use "Salton Sea region" and "study area" interchangeably throughout the report. The study area is distinct from the regulatory "Salton Sea Air Basin," which includes all of Imperial County and the Coachella Valley.[5] The California Air Resources Board (CARB) reports emissions for the full Salton Sea Air Basin, including roughly 1,300 square miles of Imperial County that lie outside of our study area. Due to study limitations, we do not include information about the portion of the air basin that extends into Mexico or impacts of adverse air quality on the more than one million people living in the Mexicali area.

3 See https://pacinst.org/current-information-salton-sea/ for the most recent Salton Sea information. The elevation/area relationship comes from older bathymetry and is approximate.

4 The NGVD 1929 datum is the old standard for Salton Sea elevations, though Salton Sea elevations are also often reported according to the NAVD 1988 datum. The USGS reference gage (10254005 Salton Sea NR Westmorland, CA) did not start reporting Salton Sea elevations in the NAVD 1988 datum until August 29, 2021. At the Salton Sea, the NGVD 1929 datum is about 2.1 feet lower than the NAVD 1988 datum.

5 CARB (pers. comm., 2024) defines an air basin as "a region that has similar meteorological and geographic conditions, and where emissions within the region will stay primarily within that region under low wind conditions. That said, air pollution can be transported between air basins and that transport can be significant at times." We define the Salton Sea study region as the area extending up to 200 feet above the valley floor, from slightly northwest of Palm Springs to the watershed boundary southeast of Mexicali, Mexico, to reflect this "air basin" description.

FIGURE 1. The Salton Sea Region and Air Basin

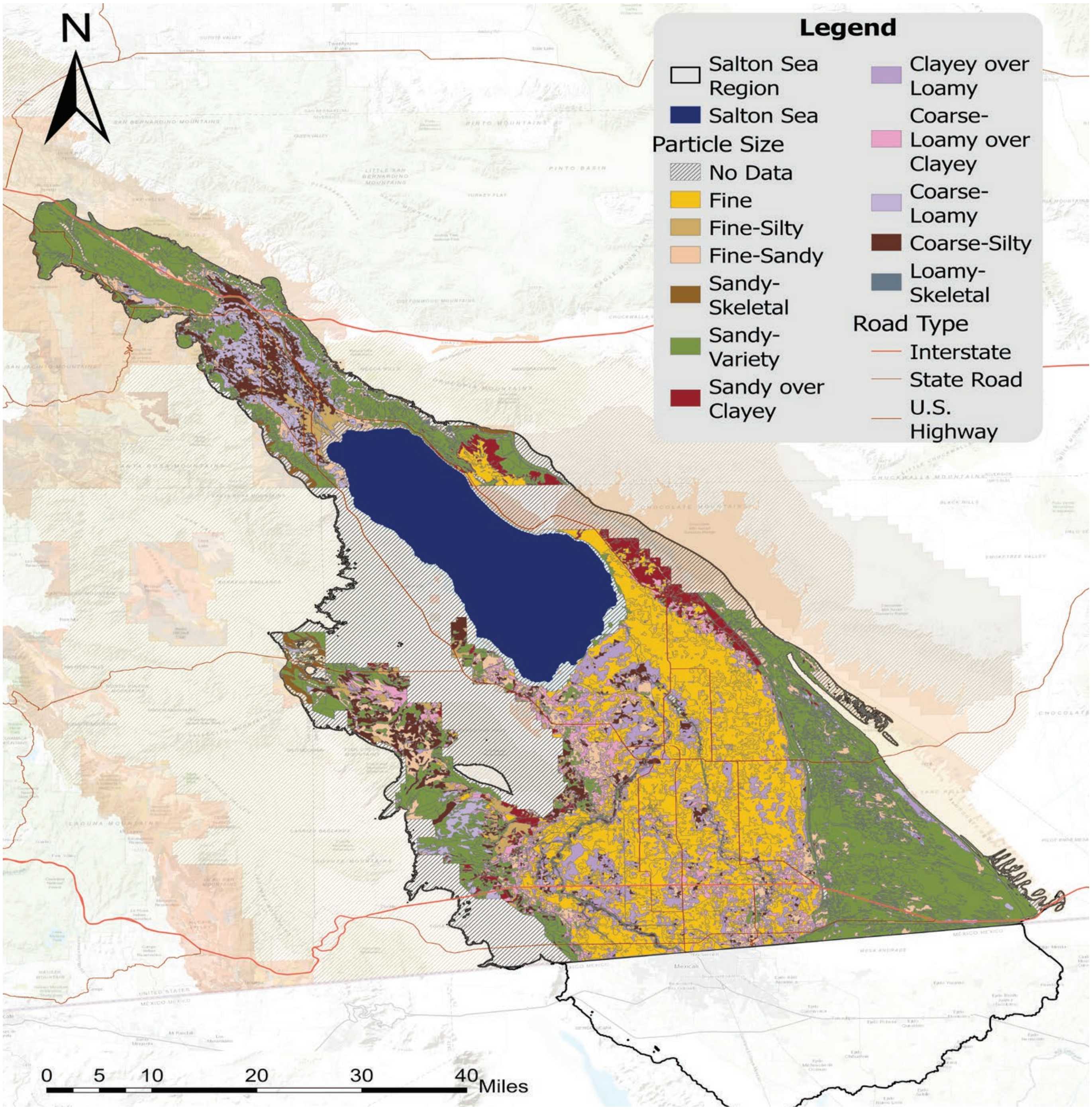


Sources: USGS, ICAPCD, SCAQMD.

The Salton Sea region can be seen as an extension of the Upper Gulf of California (see Figure 1). It is an active rift valley, where the Pacific and North America plates slip past each other at an estimated rate of about 3.5 cm (more than one inch) per year (Han et al. 2016). The Colorado River carved multiple canyons along its course, discharging the resultant sediment into this rift valley and filling it in places to an estimated depth of more than 3.5 miles (Barbour et al. 2016; Ross 2020), as far north as present-day Indio. These extensive Colorado River basin sediments, combined with limited sediments from local streams, created fertile ground for agriculture and the mix of particles that can become emissive throughout the region.

Water and wind shaped and altered the landscape here. Figure 2 shows soil particle sizes in the region, reflecting the dominance of alluvial (water-deposited) and aeolian (wind-blown) soils. While upstream dams now capture most of the Colorado River sediments, storms and local runoff continue to move coarse and fine materials through the region. These materials contribute disproportionately to local particulate emissions when wind events kick up coarse particles (such as sand) that bounce atop bare soils, in turn disturbing and releasing silt (2–50 μ) and finer particles like clay (less than 2 micrometers in diameter; < 2 μ) that the wind can carry along.

FIGURE 2. Major Soil Classes in the Salton Sea Region



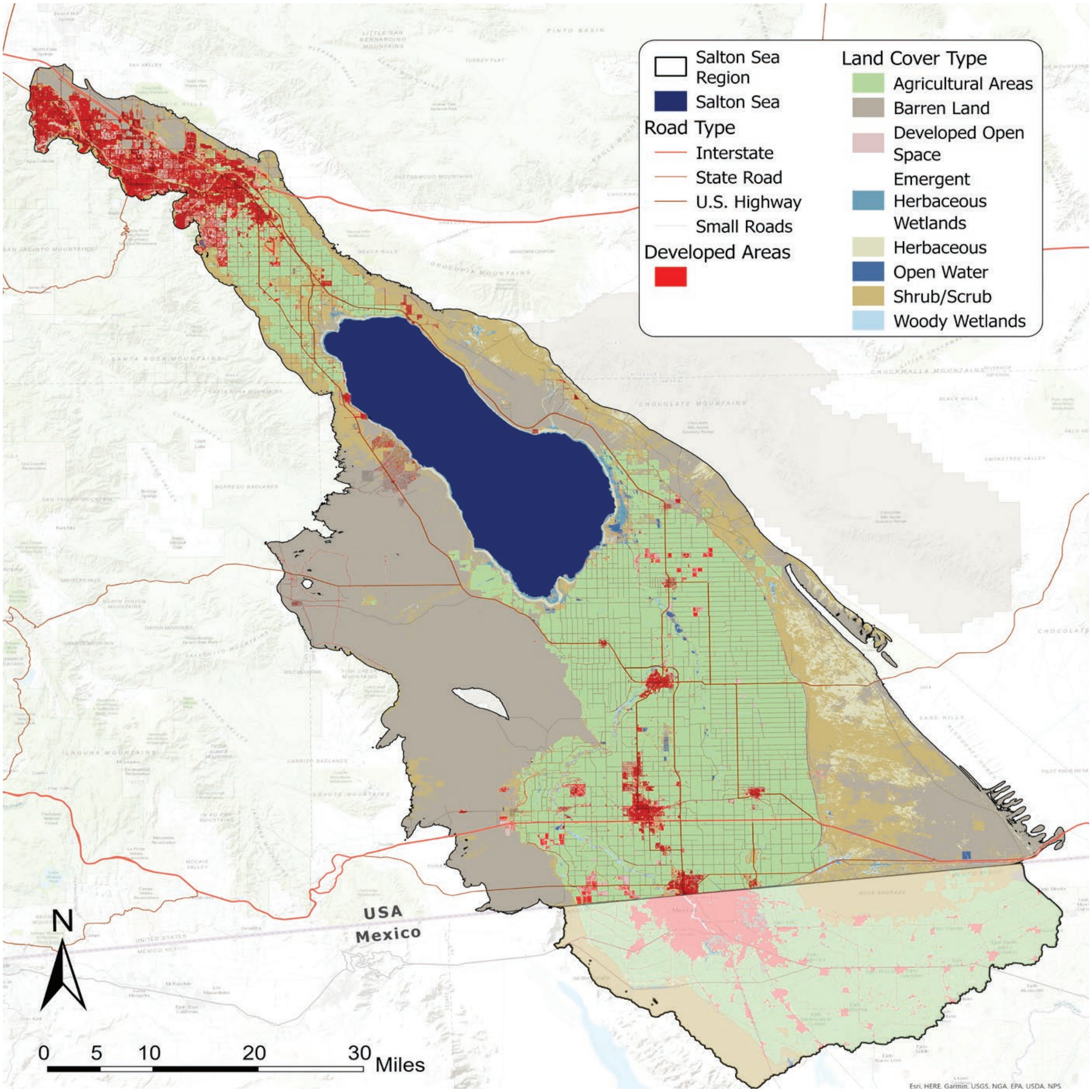
Source: USDA NRCS Web Soil Survey, at https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx.

The Salton Sea region lies within the Colorado Desert (part of the larger Sonoran Desert), bounded by the San Jacinto and Cuyamaca mountains to the west and by the Little San Bernardino, Orocopia, and Chocolate mountains to the east. Local precipitation averages less than three inches per year, while evaporation rates exceed 69 inches per year. Summer temperatures often exceed 110°F. The Anza Borrego Desert (also part of the Colorado Desert) lies immediately to the west, while the Imperial Sand Dunes (also known as the Algodones or Glamis Dunes), a popular off-road vehicle recreation area, lie southeast of the Salton Sea. Figure 2 shows these dunes, formed by eons of wind-driven erosion and deposition.

The mountain ranges bordering the study area affect winds through the region and, in the absence of strong weather fronts, tend to channel winds from the northwest across the Coachella Valley toward the Salton Sea. Prevailing winds also tend to blow from the western desert across the southern portion of the Salton Sea; winds periodically also blow from the southeast across the Imperial Valley toward the Sea. All three tend to converge on the Salton Sea, the lowest elevation in the region. These multiple wind vectors generate complex airflow dynamics and different patterns at the north and south ends of the Salton Sea (CNRA 2006). The duration and intensity of high-speed winds is much lower at the north end of the Salton Sea, in Riverside County, than in Imperial County. Monitoring stations at Bombay Beach, at Salton City, and near the Alamo River regularly report more than 150 hours per year of winds exceeding 21 miles per hour (mph) and more than 50 hours per year of winds exceeding 27 mph, while the Riverside County stations regularly report less than 10 hours per year of winds exceeding 21 mph (IID 2024a). Wind direction and speed varies seasonally as well. At the Mecca wind monitoring station slightly north of the Salton Sea, high winds blow over the Coachella Valley from the northwest in the spring. However, summer storms, known as monsoons, can cause winds that blow from almost any direction, challenging efforts to ascribe a single source — such as exposed playa — to blowing dust. One study reported 179 dust storms over a two-year period at their field site slightly west of the mouth of San Felipe Creek, with a pronounced spring peak and clear seasonal and annual variability (Evan 2024).

> Multiple wind vectors generate complex airflow dynamics and different patterns at the north and south ends of the Salton Sea.

FIGURE 3. **Regional Land Cover in the Salton Sea Region**



Source: USDA.

Figure 3 shows extensive irrigated agriculture northwest and southeast of the Salton Sea, development in the western Coachella Valley, and large areas of land classified "barren" west and south of the lake. At the very bottom of the image, southwest of Mexicali, Mexico, is the Laguna Salada salt flat. Table 1 lists major land cover categories in the 2,867 square-mile study area (excluding portions in Mexico). The Natural Resources Conservation Service (NRCS) regional land cover suggests that areas with less than 5% vegetation cover ("barren land") constitute 31% of the total region.

TABLE 1. U.S. Study Area Land Cover, 2021

CATEGORY	ACRES (1000S)	
Barren Land	576	31%
Farmland	533	29%
Shrub/Scrub	268	15%
Open Water	213	12%
Developed	173	9%
Herbaceous	52	3%
Wetlands	21	1%
Total (rounded)	1,835	

Source: NRCS 2021 Soil Survey geographic database

Table 1 lists farmland as the second-largest landcover in the study region. Farmers in the Imperial and Coachella Valleys irrigate more than 530,000 acres of land, growing alfalfa and other field crops; much of the nation's winter vegetables; fruits such as melons, citrus, grapes, and dates; seed crops; and many others. The Imperial Valley is also home to feedlots that house more than 400,000 animals in some years. The gross value of agricultural production in the study area exceeds $3 billion annually. The total number of agriculture-related jobs in the region likely exceeds 20,000.[6] There are also 124 golf courses in the area, generating roughly three-quarters of a billion dollars in related spending and supporting about 8,000 jobs.[7]

Agricultural runoff, primarily from the Imperial Valley (about 80%), sustains the Salton Sea. Prior to the signing of the Quantification Settlement Agreement (QSA) in 2003, more than 3.4 million acre-feet (MAF) of Colorado River water[8] flowed into the Imperial and Coachella valleys each year. About one-third of this then flowed into the Salton Sea as agricultural runoff (Cohen et al. 1999). Prior to 2003, total annual inflows to the Salton Sea (including local runoff from intermittent streams such as Salt and San Felipe creeks but excluding direct precipitation) averaged more than 1.24 MAF. By 2024, the California Natural Resources Agency (CNRA) reported that total inflow had fallen to 0.909 MAF, a 27% decline (CNRA 2025). Accounting for water used in new habitat projects and captured by emergent wetlands above the current shoreline suggests that inflows to the remnant lake are even lower. Recently signed additional water conservation agreements and other factors could diminish total annual inflows to the Salton Sea below 0.9 MAF through 2026.[9]

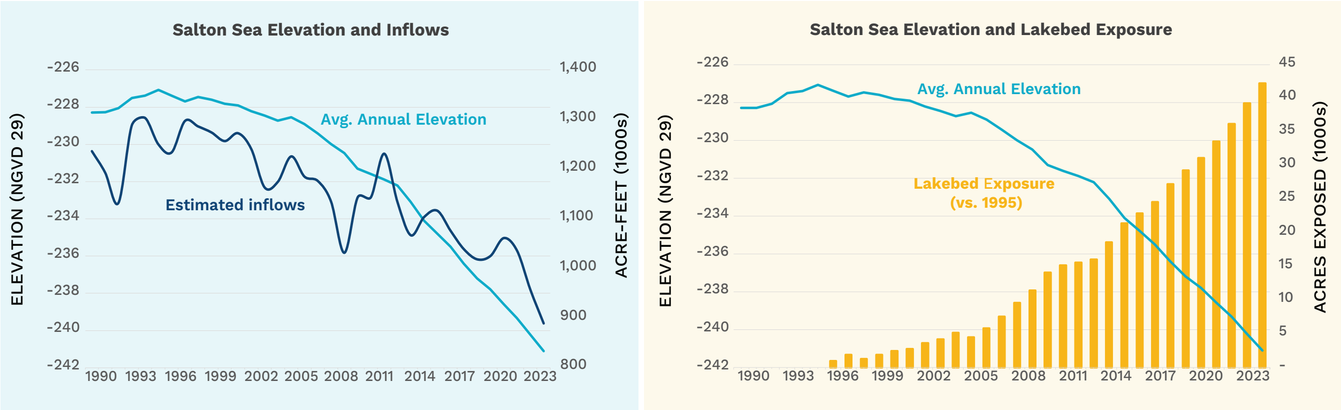
6 See Economic Contributions of Imperial County Agriculture at https://agcom.imperialcounty.org/crop-reports/ and CVWD Crop Reports at https://www.cvwd.org/Archive.aspx?AMID=51.

7 See Economic Impact of the Coachella Valley Golf Industry (2015) at https://www.scga.org/pdfs/CoachellaValley.pdf.

8 More than 23% of the historic average annual flow of the river.

9 See IID 2024-2026 Temporary Colorado River System Water Conservation Project draft Environmental Assessment (2024) at https://www.iid.com/home/showpublisheddocument/22303/638551862512570000.

FIGURE 4. Salton Sea Inflows, Elevation, and Size Reduction, 1990–2024



Sources: USGS, Tetra Tech elevation/area/capacity table.

Figure 4 shows average annual inflows to the Salton Sea, the lake's average annual elevation, and the annual reduction in the size of the lake since its highest recent elevation in 1995. These inflows carry fertilizers, pesticides, and sediment from irrigated lands in the region, as well as salts and selenium from the upper reaches of the Colorado River basin (Glenn et al. 1999). The Salton Sea's water chemistry is complex (Amrhein et al. 2006; Holdren & Montaño 2002; Hung et al. 2024), but essentially, more water evaporates than enters the lake, concentrating the salts, nutrients, and other elements left behind. The lake's salinity is now more than double that of the ocean (CNRA 2025), and high nutrient concentrations fuel extraordinarily high algal production, limiting light penetration and leading to very low concentrations of dissolved oxygen in much of the water column. These anoxic conditions favor bacteria that produce hydrogen sulfide, leading to increasingly frequent releases of the gas and its characteristic rotten egg smell (Hung et al. 2024).

Many factors have driven decisions to reduce water use in the Imperial Valley. As shown in Figure 4, these reductions have led to a decline in the Salton Sea's elevation and extent, increasing the amount of lakebed exposed and the potential for windstorms to increase the amount of dust in the region. Table 2 shows the land cover in 2024 within the Salton Sea's 2003 (pre-QSA) footprint, highlighting both the amount of playa — former lakebed now exposed by the receding shoreline — and the extent of new land covers, both constructed and serendipitous, that reduce emissive surfaces. These land cover changes, including dust suppression projects and the growth of emergent wetlands, have offset almost 40% of the roughly 36,000 acres of lakebed exposed since 2003. See Cheng et al. (2022) for a detailed description and quantification of five classes of "bare playa" and the emissive characteristics of each. Cheng et al. (2022) also note that 63 of 85 playa sites they assessed on April 15, 2020, were "wet" and that, even in the absence of measurable precipitation, at least 35% of the playa was "wet," diminishing the extent of playa that might emit dust.

TABLE 2. Land Cover in 2024 Within the 2003 Salton Sea Footprint[10]

LAND COVER TYPE	ACRES (1,000S)	% OF TOTAL	SOURCE
Salton Sea	196.7	85%	calculated
Bare playa	21.6	9.3%	calculated
Emergent vegetation atop playa	8.1	3.5%	IID, Audubon
Dust suppression projects	5.0	2.2%	IID, SSMP
Open water atop playa	0.8	0.3%	IID
Habitat projects	0.1	0.0%	SSMP

The Salton Sea provides critical habitat for migratory birds and important cultural, economic, and recreational resources (Barnum et al. 2017). More than 400 species of birds, formerly including 80% of the western population of white pelicans and 20 species of concern,[11] reside in or visit the region, making the lake a major stop for migratory birds along the Pacific Flyway (Barnum et al. 2017; Shuford et al. 2002). Rising salinity, habitat loss, and the near-total collapse of the fishery have markedly reduced populations of piscivorous birds such as pelicans and cormorants, while the growing expanse of bare playa and emergent wetlands have contributed to increases in the abundance of some shorebird species.[12]

HUMAN SETTING

The Salton Sea Air Basin includes the Coachella Valley, Imperial Valley, and Mexicali Valley. Table 3 shows recent population estimates for each of these areas but does not include an estimated 100,000 seasonal residents (often known as “snowbirds”) or the hundreds of thousands of people who visit the region periodically for music festivals, tennis and golf tournaments, and other events, and who may also be exposed to adverse air quality.[13] The total year-round population of the U.S. portion of the study area is 561,000 people, as shown in Table 3. A recent study found 4,602 single-family homes within 10 miles of the Salton Sea shoreline (Ayres et al. 2022), while noting that this was likely less than the actual number due to challenges tallying people in Imperial County (Thorman et al. 2019).

A decade ago, we reported that Riverside County and the California Department of Finance projected the total population of Coachella Valley and Imperial County as a whole (the Salton Sea Air Basin) would reach almost 800,000 people by 2020 (Cohen 2014). According to census data, the actual population that year, including people living outside of our study area, was about 612,000. The

10 USGS reports that the surface elevation of the Salton Sea at the end of 2003 was -228.9 feet (NGVD 1929). According to the 2006 CH2M-Hill elevation-area table, the lake’s total extent at that elevation was about 232,300 acres. Based on a December 15, 2024, satellite image, when USGS reported the Salton Sea’s elevation was -241.26 feet, we calculated that the extent of the Salton Sea was within about 0.2% of the table’s reported acreage at that elevation.

11 See https://wildlife.ca.gov/Regions/6/Salton-Sea-Birds/Salton-Sea-Bird-Species.

12 See https://ca.audubon.org/news/intermountain-west-shorebird-survey-preliminary-results-indicate-250000-migratory-shorebirds, visited September 12, 2024.

13 Source: June 3, 2024 Coachella Valley Association of Governments Executive Committee staff report, available at https://cvag.org/downloads/admin/exec/EXEC_06_03_2024_AgendaMerged.pdf.

Coachella Valley population grew by about 7% from 2010 through 2023, well below projections. The population of the Imperial Valley only grew by about 1% over that period. While we include the Mexicali Valley population in Table 3, we do not reference impacts or air pollution sources in Mexico due to study limitations.

TABLE 3. Population of the Salton Sea Region, 2023*

Coachella Valley	385,000
Imperial Valley	176,000
Mexicali Valley	1,032,000
Total	1,596,000

*Mexicali Valley population from 2020

Sources: Coachella Valley: CVAG 2024/25 budget, excluding Blythe and Desert Hot Springs populations (the 2020 Census reported approximately 35,000 fewer people for the region than the 2023 CVAG numbers); Imperial Valley: 2023 Imperial County Census estimate less 2020 Winterhaven–Bard CCD population (approximately 2,700); Mexicali Valley: 2020 INEGI Census, less San Felipe population (approximately 17,000)

The Salton Sea region includes frontline and environmental justice (EJ) communities that are adversely and disproportionately impacted by environmental issues and associated health disparities. Emissions from transportation, industry, agriculture, and the natural environment, including dust from Salton Sea playa and aerosols from the lake itself, take a toll on residents, many of whom suffer from health issues associated with poor air quality. In general, vulnerable communities within the Coachella Valley are exposed to higher levels of contaminants than non-EJ communities, resulting in disproportionate health impacts between EJ communities and wealthier residents (Miao et al. 2022).

Western Coachella Valley communities, such as Rancho Mirage, Indian Wells, and Palm Springs, are some of the wealthiest in the state and show a stark divide with the Eastern Coachella Valley (ECV), which has limited economic resources and populations ranging from 62–99% Hispanic and Latino (Pick 2017). According to the U.S. Census, Spanish is the primary language spoken in 86% of homes in Mecca, located in the ECV. The ECV is also home to the largest Purépecha community[14] in the U.S. (Cheney, pers. comm., 2025), whose primary language is often Purépecha, raising an additional language barrier. As shown in Figure 1, roughly 45,700 acres of tribal lands, including the native lands of Desert Cahuilla Indians, lie within the Salton Sea region. As of 2016, 65% of ECV residents lived below the poverty line (Pick 2017). Singh et al. (2018) report that median household income within 10 miles of the Salton Sea shoreline was less than half the state average. Many ECV residents face challenges related to a shortage of affordable housing, limited public transit, drinking water contamination, and pollution from toxic and hazardous industrial facilities (Huang & London 2016).

ECV communities have higher rates of respiratory illnesses, such as asthma, as high as 17.5% among children (Sinclair et al. 2018). Children with asthma also experience related co-presenting conditions, including other respiratory illnesses, allergies, and nosebleeds (Cheney et al. 2023). Cheney et al.

14 The indigenous ECV Purépecha community originally emigrated from Michoacán, Mexico.

(2018) note that there are only two health care clinics in the ECV, and only one, with limited hours, serves communities west of the Salton Sea, severely limiting health care access and exacerbating health challenges for residents. A 2010 study found there was only one doctor per 8,407 ECV residents,[15] versus one per 1,090 in California as a whole.[16] Language and transportation barriers, concerns about deportation, and a lack of compensated sick time and health insurance further strain life in the ECV, contributing to the overall health care burden (Cheney et al. 2018).

Imperial County as a whole has a population that is 86% Hispanic and 3.2% Black.[17] According to the U.S. Census, Spanish is the primary language spoken in more than 75% of homes, and 17.3% of people in Imperial County live in poverty. Poor air quality in the Salton Sea region, including additional particulate emissions from the accelerated exposure of Salton Sea playa, adversely and disproportionately impacts these communities (Abman et al. 2024; Miao et al. 2022). Gao et al. (2022) report that 17% of students in a local elementary school suffer from asthma, while Farzan et al. (2019) found that parent-reported asthma rates for children in four elementary schools in the northern Imperial Valley exceeded 22%, more than 50% higher than the state average. Imperial County had about 4,890 residents per doctor, one of the worst county-based rates in the state.[18]

WATER TRANSFERS

Water transfers out of the Imperial Valley decrease flows to the Salton Sea, intensifying the growing environmental and public health crisis. The Quantification Settlement Agreement (QSA) authorized 30 million acre-feet of water transfers from agricultural uses in the Imperial Valley to municipal users in coastal southern California over the 75-year term of the agreement.[19] In response to the long-term decline in Colorado River flows and the resultant reduction in Colorado River reservoir storage — which could ultimately fall below the minimum elevation required to release water to Imperial Valley irrigators — IID committed to conserve up to an additional 806,000 acre-feet of water from 2023 to 2026 through a combination of fallowing and efficiency-based practices.[20] Currently, federal funding to implement these conservation practices in 2025 and 2026, or for possible future agreements post-2026, is very uncertain.[21]

A decade ago, we reported estimates that the volume of water flowing into the lake would decrease by 40% by 2029, resulting in a surface level decline of 20 feet and a 60% decrease in volume

15 Reported in https://www.calhealthreport.org/2012/03/25/health care-access-limited-in-east-valley/.

16 Source: Imperial County Public Health Department, 2018-2019 Health Status Report, available at https://www.icphd.org/media/managed/medicalproviderupdates/HEALTH_STATUS_REPORT_2018_2019_final_.pdf.

17 Source: US Census "Quick Facts," July 1, 2024, available at https://www.census.gov/quickfacts/fact/table/imperialcountycalifornia/PST045224.

18 Source: Imperial County Public Health Department, 2018–2019 Health Status Report, above.

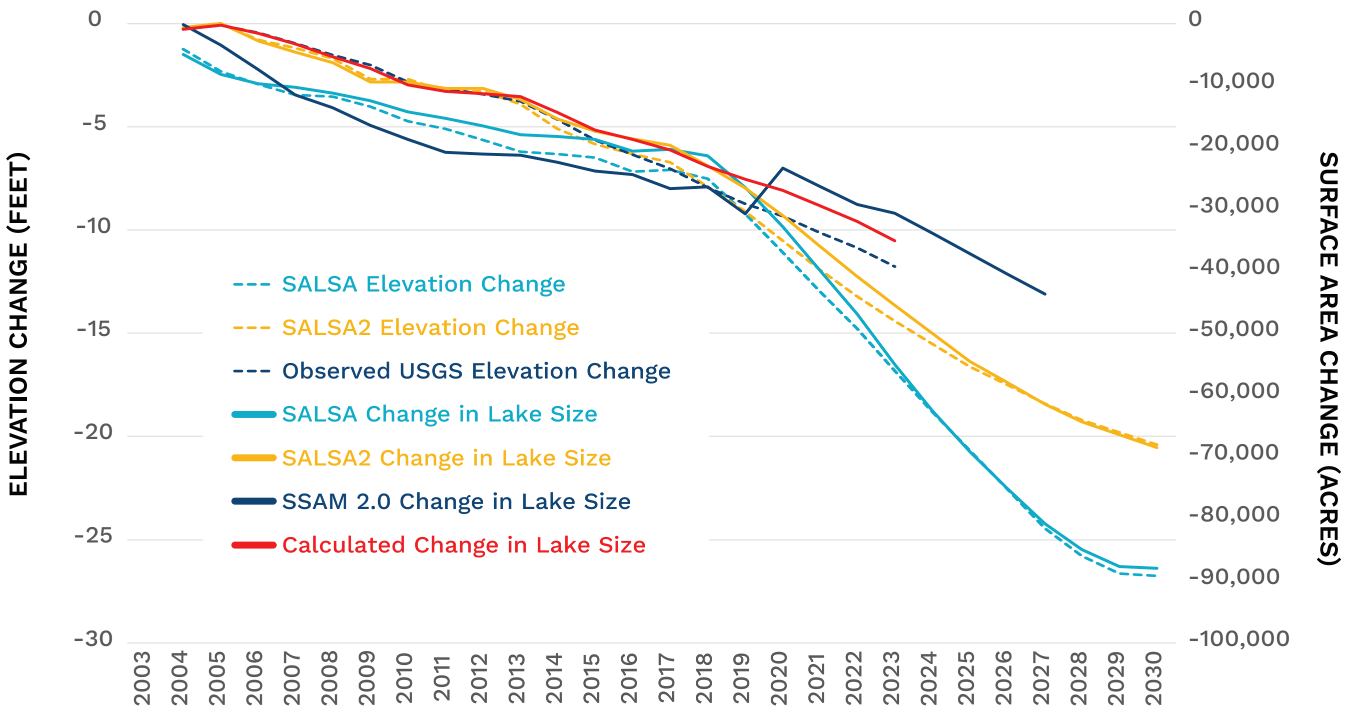
19 QSA documents are posted at https://www.iid.com/water/library/qsa-water-transfer. IID reports annual water conservation volumes at https://www.iid.com/water/water-conservation.

20 See https://www.iid.com/water/water-conservation/deficit-irrigation-program.

21 See https://www.npr.org/2025/02/25/nx-s1-5302718/trump-funding-freeze-includes-payments-to-keep-the-colorado-river-flowing.

(Cohen 2014). After our 2014 report, updates to two Salton Sea models[22] projected a reduced rate of decline, which has been borne out by changes measured by the USGS Westmorland gage.[23] Figure 5 compares projected reductions in lake size over time. Note that, with the exception of the updated SSAM2 projections, each of these earlier models projected that the Salton Sea would shrink more rapidly than has been observed, as documented by the USGS gage and shown by the navy blue dotted line in the figure. The SSAM2 projections underestimate the rate of decline by about 3,500 acres per year. The projected reductions in the size of the Salton Sea — shown as solid lines on the figure and reflected on the right axis — are often labeled "exposed lakebed," but they do not account for playa actively protected by state and local dust suppression or habitat projects, nor do they account for lakebed passively protected by the emergence of wetland vegetation atop the playa (see Chapter 8).[24] Currently, these various protective landcovers reduce the amount of bare, uncontrolled playa by about 14,000 acres (see Table 2). We did not account for these protective landcovers in previous reports.

FIGURE 5. Projected Reductions in the Size of the Salton Sea



22 The U.S. Bureau of Reclamation developed the Salton Sea Accounting Model (SSAM) in the 1990s to aid various Salton Sea assessments (see https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=9376). CH2M-Hill (now Jacobs) developed the original SALSA hydrologic model to aid the State of California's development of alternatives and assessment of impacts for the 2006 programmatic EIR (CNRA, 2006). CH2M-Hill updated the model, as SALSA2, in 2014 (see https://www.iid.com/water/salton-sea/hydrology-modeling). Tetra Tech updated SSAM, as SSAM2, to aid the SSMP's long-range planning process.

23 Data available at https://waterdata.usgs.gov/ca/nwis/uv?site_no=10254005.

24 Many of these models also rely on elevation/area/capacity tables derived from older (and potentially dated) bathymetry; they often do not reflect the lake's current bathymetry, especially changes in the south associated with the construction of the Species Conservation Habitat project (see Chapter 8).

Inflows determine the size and elevation of the Salton Sea. Figure 4 shows the decline in inflows to the Salton Sea, from an annual average of about 1.25 MAF in the 1990s to 1.02 MAF from 2019–2024.[25] This is markedly higher than the 0.91 MAF average annual inflows that the original SALSA model projected for this most recent period, though the recent System Conservation Implementation Agreement (SCIA)[26] could drive inflows closer to the old model projections, at least through 2026. The Bureau of Reclamation is leading a process to develop new Colorado River management guidelines for the post-2026 period;[27] the impact of such new guidelines on the Salton Sea is still very much to be determined. California proposes to conserve as much as 0.44 MAF of water annually as part of the post-2026 Colorado River operations.[28] While intra-state allocation of this reduction has yet to be determined, it is plausible that IID would continue to participate in actions to protect the Colorado River system at some level, and potentially at the 0.20–0.25 MAF per year rate approved as part of the SCIA, especially since it is unlikely that the other California Colorado River contractors could achieve 0.44 MAF of annual reductions without IID contributions at that level.

Hydrological modeling for IID's SCIA projects as much as 7,816 acres of additional lakebed exposure in 2027 relative to the non-SCIA baseline, assuming a combination of fallowing and efficiency-based measures to generate water for the SCIA.[29] During the seven-week period during which IID implemented the SCIA in 2024, the elevation of the Salton Sea dropped by almost 10 inches, exposing an estimated 3,500 acres of playa. This rate of exposure was almost double that of recent years, though CVWD's SCIA and IID's lower-than-expected water use also contributed to this accelerated exposure. IID's and CVWD's combined SCIA reductions likely contributed to the exposure of roughly 800 additional acres of lakebed relative to recent rates of exposure.[30] As irrigators in IID's service area shift from fallowing to efficiency-based measures to generate water for the SCIA, this rate of additional playa exposure will increase.

25 These estimates assume that inflows to the Salton Sea from drains discharging directly into the lake, natural inflow through drainages such as San Felipe Creek, and groundwater contribute an additional approximately 10% of the volume of the USGS-measured flows of the Alamo, New, and Whitewater rivers. We now know that a significant proportion of the water discharged by the direct drains supports emergent wetlands and does not actually reach the Salton Sea. Actual annual Salton Sea inflows are lower than reported, likely by at least 50,000 AF per year.

26 IID's SCIA is posted at www.iid.com/Home/Components/News/News/1207/.

27 See https://www.usbr.gov/ColoradoRiverBasin/post2026/index.html for information on Reclamation's development of post-2026 guidelines.

28 See https://crb.ca.gov/wp-content/uploads/2024/05/April2024-FAQs-LBStates-alt.pdf.

29 See Appendix Hydro-3 in the IID 2024-2026 Temporary Colorado River System Water Conservation Project Environmental Assessment, available at https://ceqanet.opr.ca.gov/2024070036/2.

30 Calculated as additional acreage exposed (approximately 1,800 acres) relative to recent average annual exposure in that period (approximately 1,700 acres) times SCIA conservation (approximately 170 KAF) divided by total reductions (IID & CVWD SCIA) and underruns (approximately 380 KAF).

3. Methods

For this report, we identified and analyzed relevant publications on dust emissions, air quality, and resultant public health outcomes in the Salton Sea region to identify relevant data, key findings, and research gaps. First, we conducted an extensive review of existing literature and research, including public agency reports and peer-reviewed journal articles on dust emissions and public health impacts both in general and within the Salton Sea region specifically. The Pacific Institute maintains a Salton Sea Zotero library with about 1000 entries on a broad range of topics.[31] We categorized the entries, analyzed the sources, and sorted relevant findings by topics, including dust emissions from the exposed Salton Sea playa and surrounding desert areas, unpaved surfaces, diesel emissions, wind events, industrial and agricultural activities, and other episodic and recurrent events. We identified key sources and referenced them in the report.

As we conducted this desktop research, we noted relevant datasets and compiled them into topical spreadsheets. We identified several datasets that were relevant to our research findings from the literature review, such as CARB's California Emissions Projection Analysis Model (CEPAM) Standard Emission Tool and hourly local data from air quality stations maintained by CARB and IID. For each dataset, we first checked the for duplicates, errors, and missing values, and ensured the data were in a consistent format. We found metadata for each dataset, including the dataset's original source and relevant parameters. Lastly, we used Microsoft Excel to visualize the datasets.

DATA SOURCES

We did not perform any new measurements or surveys for this report. Instead, we obtained data from a variety of existing sources, including published reports and information on file with various local, state, and federal agencies. Please see the References section for the complete list of sources and the interactive map at https://pacinst.org/salton-sea/ for locations of the monitoring stations (and other key locations) referenced below. The following describes the major data sources for this report:

- CARB Air Quality and Meteorological Information System (AQMIS): The AQMIS database contains near real-time and historical air quality and meteorological data, including PM_{10} and $PM_{2.5}$ concentrations for the Salton Sea Air Basin and the two counties on specific dates. Data is available in tabular summary reports.

31 Available at www.zotero.org/groups/4998837/salton_sea.

- CARB Air Quality Data Statistics (iADAM System): The iADAM query can be used to retrieve historical data for PM_{10} and $PM_{2.5}$ concentrations in specific air basins or counties on specific dates. Data is provided in tabular summary reports or graphs.
- California Emissions Projection Analysis Model (CEPAM): CEPAM was created to support the development of state implementation plans (SIPs) and air quality modeling. The tool estimates PM_{10} and $PM_{2.5}$ emissions by source category using the 2012 Base Year Emissions inventory.
- California Health and Human Services Agency (CalHHS): CalHHS publishes non-confidential health and human services data online, including asthma emergency department visit rates and asthma hospitalization rates by county.
- California Department of Health Care Access and Information (HCAi): HCAi provides counts of pediatric emergency department visits, admissions, and inpatient stays for California, Imperial, Riverside, and Sacramento counties.
- IID Emissions Estimates and Technical Memoranda: The only published annual (2016/17–2023/24) estimates of playa and western desert emissions available.
- IID Salton Sea Air Quality Monitoring Stations data repositories: IID publishes some of its air quality data from its network of stations on the Salton Sea Air Quality Mitigation Program's website. Additional data are available from IID.
- MesoWest: Part of the University of Utah's Department of Atmospheric Sciences, MesoWest publishes real-time and historical meteorological data, including wind speed.
- Mobile Source Emissions Inventory (MSEI): CARB's central location for information about the population, activity, and emissions from mobile sources operating in California.
- Salton Sea Environmental Timeseries x Alianaza Coachella Valley: Alianza Coachella Valley organizes a community science project that collects limited air quality data, which is published on the Salton Sea Timeseries website.
- U.S. Census Bureau: Provided census data for our study areas in California.

Data from these sources vary in scope and frequency. CARB compiles and projects future PM_{10} and $PM_{2.5}$ emissions based on federal and state reporting requirements (CARB 2023). Both CARB and IID measure hourly local PM_{10} concentrations from monitoring stations in their networks,[32] providing pollutant data for the Salton Sea Basin. Several other organizations also measure air quality parameters, such as the Salton Sea Environmental Timeseries,[33] NASA JPL's Salton Sea Validation website,[34] and IVAN Imperial.[35]

Monitoring Stations

Most of the air quality data in this report comes from the CARB or the IID monitoring stations. The five CARB stations, listed in Table 4, measure PM concentrations and collect hourly local data. We retrieved wind speed data from MesoWest's online database, which lists multiple station networks, including data from CARB's air quality monitoring stations.

32 See the interactive map at https://pacinst.org/salton-sea/ for locations of the monitoring stations.

33 Available at https://saltonseascience.org/.

34 Available at https://saltonsea.jpl.nasa.gov/.

35 Available at https://ivan-imperial.org/.

TABLE 4. Air Quality Monitoring Stations in the Salton Sea Basin

MONITORING NETWORK	STATION NAME	DATA COLLECTION START DATE
CARB	Brawley Main Street #2	August 11, 2009
	Calexico – Ethel Street	January 15, 2016
	El Centro – 9th Street	July 1, 2015
	Niland – English Road	August 10, 2009
	Westmorland	April 1, 1993
IID	Bombay Beach	2010
	Naval Test Base	
	Salton City	
	Sonny Bono	
	Salton Sea Park	
	Torres Martinez	

Sources: Appendices to CARB's Annual Network Plan (CARB 2024a) and IID (2024b)

STUDY LIMITATIONS

Several factors limit the accuracy and precision of the estimates in this report, including:

- Absence of a consensus projection of future emissivity
- Absence of a consensus conversion or relationship between dust loadings (in tons/day or equivalent units) from Salton Sea playa and PM_{10} concentrations (in μg/m^3)
- Errors or gaps in data from station maintenance, equipment calibration, extreme weather, and power outages
- Missing files at public agencies
- The only existing annual estimates of playa emissions assume all playa is "uncontrolled" and potentially emissive, inflating such values
- Reporting areas and periods are not consistent across different data sources
- Air quality monitoring sites often do not reflect community exposure (Dominici et al. 2010)

4. Literature Trends

An extensive literature describes conditions conducive to dust emissions and the public health impacts of dust. The number of peer-reviewed journal articles referencing dust and aerosols, air quality, and public health in the Salton Sea region has increased dramatically since our last report in 2014, when we noted a research gap. Since 2014, researchers have explored these topics at length, as shown in Table 5.

TABLE 5. Journal Articles in the Salton Sea Zotero Library[36]

YEARS PUBLISHED	TOTAL NUMBER OF JOURNAL ARTICLES	NUMBER OF ARTICLES FOCUSED ON **AIR QUALITY AND RELATED TOPICS**	NUMBER OF ARTICLES FOCUSED ON **REGIONAL PUBLIC HEALTH**
Before 2014	239	10	2
2014–2025	287	55	37

The Salton Sea Zotero Library contains 239 journal articles that were published before 2014. Of these, 10 focus on air quality, dust, or emissions in the Salton Sea region or discuss variability in dust emissions and air quality impacts from agricultural burning and energy development. Only two articles in the library that were published before 2014 are related to public health, with one (Ostro et al. 1999) focused on regional public health impacts from air quality and one (Moreau et al. 2007) focused on contaminants in fish species and impacts to human consumers. The library has 287 journal articles published after 2013, with 55 focusing on air quality, dust, and emissions in the Salton Sea region. These articles address approaches to measuring dust emissions, dust and related health impacts, characterizations of emissions and tracking sources, dust storms and transport, the connection between the receding Salton Sea and emissions, and more. An additional 37 articles focus on public health impacts from air quality and dust in the Salton Sea region. Over the past decade, the number of peer-reviewed journal articles on the Salton Sea's environmental crisis and its implications for human health and environmental justice has increased by about a factor of eight relative to the number of such articles published prior to 2014.

36 As of April 24, 2025. The Zotero library is available at https://www.zotero.org/groups/4998837/salton_sea.

We also reviewed more than 160 journal articles that focus more generally on air quality, dust, health impacts, and common emissions sources. One of the most frequently cited articles discusses the challenge of identifying toxic components in particulate matter, presents evidence of varying toxicity in different dust components and sources, and states more research is needed to understand the relative toxicity of particles (Kelly & Fussell 2012). Other critical gaps include air monitoring techniques that lack “real time” speciation, as well as monitoring for volatile compounds, gases (such as methane), and radioactivity.[37] Other frequently cited articles discuss components of PM and potential toxicity, and the spatial and temporal variations of mineral dust and its associated changes in atmospheric impacts (Cassee et al. 2013; Choobari et al. 2014).

37 Lily Wu, personal communication, March 16, 2025.

DRYING LAKES AND AIR QUALITY

Drying terminal lakes and inland seas and the ensuing phenomena of increased lakebed exposure and dust emissions are found in many arid and semi-arid regions. Dust events near terminal lakes are driving adverse human health outcomes among those living nearby, including pulmonary and respiratory diseases, gastrointestinal symptoms, and abnormal renal function (Miao et al. 2022). For example, Mono Lake, Owens Lake, and the Aral Sea experienced dramatic water losses during the 20th century, resulting in degraded air and water quality, habitat loss, and human health impacts (Horowitz 2012). For context, we briefly describe these parallels and the air quality changes of each.

The exposed lakebed of Mono Lake in California is a major source of windblown dust, primarily caused by the diversion of water from Mono Basin to the City of Los Angeles (Ono et al. 2011). This diversion shrunk the lake, exposing playa; dust blown from the dried lakebed frequently exceeds national air quality standards (Herbst & Prather 2014). Los Angeles also diverts water from the Owens Lake watershed, desiccating that lake and creating one of the largest sources of dust in the country (Reheis 1997). Regional downslope winds blow across Owens Lake playa and can generate large dust storms in Owens Valley that exceed air quality standards (Evan 2019). These winds can transport dust emitted from the playa across the Inyo Mountains into Death Valley National Park and are likely responsible for some of the region's worst dust events (Jiang et al. 2011). Nearby residents are frequently impacted by dust and are sensitive to visibility degradation (Cahill et al. 1996).

Since the 1960s, rivers feeding the Aral Sea have been diverted for irrigation, causing an 80% loss in the Aral Sea's volume, shrinking the water body and exposing its bed. This newly exposed seabed and its role as a major dust source are responsible for some of the highest airborne dust emission rates in the world (Bennion et al. 2007). However, the prevalence of asthma is low in the Aral Sea region and studies have shown that dust exposure does not explain variations in lung function between regions surrounding the Aral Sea. Overall, there is no clear evidence of dust from exposed playa in the Aral Sea as the primary cause of health impacts in the region (Anchita et al. 2021).

Exposed playa from the shrinking Great Salt Lake (GSL) in northern Utah, the largest terminal lake in the Western Hemisphere, produces health-harming dust as lake levels drop due to increased use of its tributaries and climate change impacts (Cowley et al. 2025; Grineski et al. 2024). The shrinking lake exposes additional playa, resulting in dust emissions of increasing severity and frequency, creating a major public health concern. With current lake levels, people living in the Salt Lake Valley are exposed to 26 μg/m^3 of $PM_{2.5}$ per 24 hours on average,[38] a rate higher than the World Health Organization's standard of 15 μg/m^3, but lower than the U.S. NAAQS threshold of 35 μg/m^3 per 24 hours (Grineski et al. 2024). Cowley et al. (2025) found that dust from GSL playa produced an inflammatory response in mice and in human epithelial cells in the laboratory. Dust exposure and related health concerns in communities near the GSL reflect social disparities. People of color and those without a high school diploma experience disproportionately higher exposures to GSL dust (Grineski et al. 2024). This is similar to conditions found in the Salton Sea region, where historically marginalized communities also face the greatest impacts from air pollution from dust generated by the shrinking of the Salton Sea and increasing playa exposure (Cheney et al. 2023).

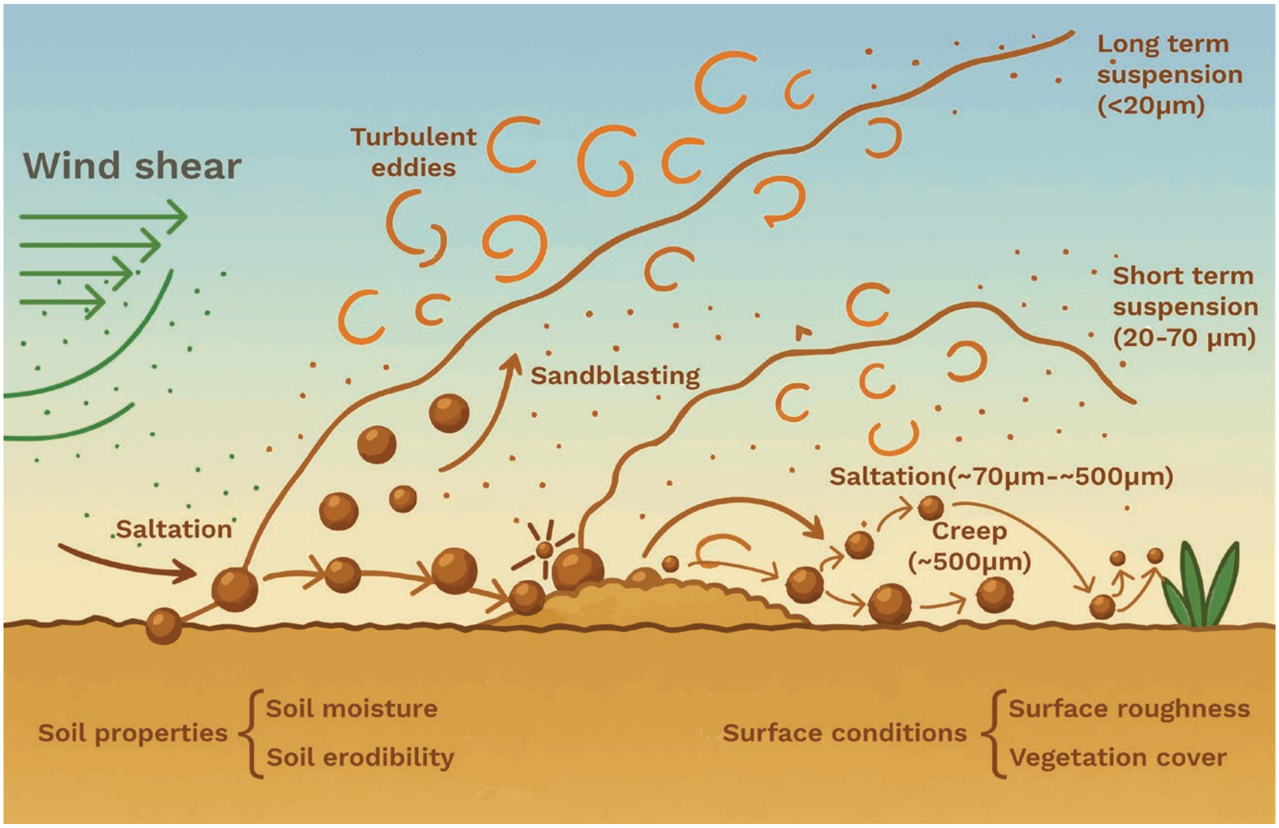
38 According to the study, even at healthy lake levels without exposed lakebed, ambient $PM_{2.5}$ concentrations in the region are 24 μg/m^3, about 10% lower than at current playa exposure (Grineski et al. 2024).

5. Pollutant Dynamics

Solids, liquids, and gases can all impair air quality. The physics (or mechanics) of moving such materials from their place of origin into the air and into contact with people varies by material, as described below. Pollutant dynamics — the physics of emissions — can help explain the prevalence of contaminants in the Salton Sea region and in desert regions more generally. Evan (2023) identifies four factors needed to move solid particulate matter into the air:

- wind (energy) to move particles aloft,
- a source of fine material such as desert washes and playa,
- a dry surface, and
- an open area free from obstacles such as vegetation that interrupt the wind.

FIGURE 6. Dust Mechanics



Adapted from Lancaster, 2009.

As shown in Figure 6, wind can dislodge larger particles, such as sand, which then slide or bounce along the surface, dislodging smaller particles (such as PM_{10}[39] and $PM_{2.5}$) that can be suspended, or entrained, in the air. Management methods to reduce dust emissions include slowing or diverting the wind away from these source materials or trapping the larger particles before they can dislodge smaller particles. Fifteen mile-per-hour (mph) winds are often sufficient to generate emissions from dry, unstable, or disturbed Salton Sea playa (known as the "threshold wind velocity" [40]), while 25 mph winds are typically required to generate emissions from stable, undisturbed playa (CNRA 2006, Appendix E). The magnitude of emissions increases exponentially above the threshold wind velocity (Marsham et al. 2011). For example, a 5-meter-per-second (m/s) (approximately 11 mph) increase in wind speed above the threshold velocity can cause a 125-fold (e.g., x^3) increase in dust emissions (Evan, pers. comm., 2025). Many of the largest dust storms in the Salton Sea region are associated with strong winds out of the west, which accelerate as they travel down the steep eastern slopes of the peninsular mountain range (Evan 2019). Kuwano et al. (2024) found that dust storms at their monitoring site slightly west of the mouth of San Felipe Creek were associated with westerly winds greater than 22 mph.

Researchers have limited confidence in predicting the impacts of climate change on future wind conditions, generally or in the study area (Bedsworth et al., 2018; Seneviratne et al., 2021). Some suggest that wind speeds may increase 5–10% in the region, but there is no consensus on potential changes in extreme wind events (Bedsworth et al. 2018). UC Dust (2024) expects climate change to exacerbate underlying conditions driving California dust emissions, including indirect impacts associated with additional land fallowing. Law et al. (2025) found that wildfire risk increases with climate change; Childs et al. (2022) report that increasing $PM_{2.5}$ concentrations from wildfire smoke have reversed policy- and regulatory-driven decreases and may now account for almost half of national $PM_{2.5}$ air pollution.

Dust particles can linger in the atmosphere for hours, days, or even weeks (Evan, pers. comm., 2025). Particles between 30 and 100 microns in diameter are likely to settle within a few hundred feet of their emission point (US EPA 1995), while wind turbulence can suspend PM_{10} in the air for "tens of kilometers" or more (Lancaster 2009). Abman et al. (2024) note that PM can travel for several miles. Miao et al. (2025) calculate that coarse PM (greater than $PM_{2.5}$ and less than or equal to PM_{10}) drops out of the air at a rate of about 0.08% per minute, with smaller particles remaining suspended longer than larger particles. Lieb et al. (2024) state that aerosols typically persist in the atmosphere for five to ten days. Evan (2024) noted that some monsoon-driven storms are so powerful that they can transport PM_{10} across the length of the Imperial and Coachella valleys and over San Gorgonio Pass (also known as Banning Pass) into the Inland Empire. Graff et al. (2025) report that the frequency and intensity of dust storms have increased, occasionally entraining and transporting dust hundreds of miles across the country.

39 PM_{10} is particulate matter with a diameter of 10 microns or less (approximately 0.0004 inches). The average diameter of a human hair is about 70 microns (or micrometers), equivalent to 0.07 millimeters.

40 Threshold velocities are often calculated on-site using mobile equipment that measures the friction velocity at which dust is first emitted from different soil types. This value may then be converted into a conventional wind speed at 10 meters (approximately 33 feet) above the ground surface. For example, assuming a 1-cm roughness length, the friction velocity threshold for dry soil with loose sand could be 0.3 m/s, equivalent to 15 mph winds at a height of 10 meters (Yimam, pers. comm., February 25, 2025).

Soil type and condition drive emission rates. Wet soils of any type are typically non-emissive, while disturbed dry soils tend to be more emissive than undisturbed dry soils. Dickey et al. (2023) found that emission rates for desert and playa soils in the Salton Sea region can vary from 4 to almost 400 μg/m^2/sec, with disturbed desert washes and lakebeds being the most emissive.[41] Buck et al. (2011) report that wet/dry cycles and capillary action, as may occur on recently exposed playa, can produce weak salt crusts with less cohesive salt crystals that are prone to emissions. However, stable, older salt crusts atop exposed Salton Sea playa decrease emissions (Dickey et al. 2023).

Sculley et al. (2002) report that flash flooding can erode and transport materials that subsequently become a source of wind-driven emissions, as recently documented in the Coachella Valley. As shown in Table 1, the study area contains approximately 576,000 acres of barren land with limited or no vegetation to disrupt the wind and limit particulate emissions. Bare, dry agricultural fields can also be emissive. In addition, an estimated 4,500 miles of unpaved roads[42] in the region contribute to particulate emissions. PM composition can help identify the source of these emissions (Frie et al. 2017; Kuwano et al. 2024), as can wind direction (Sowlat 2024).

The study area receives less than 3 inches of rainfall annually. With the exception of roughly 533,000 acres of irrigated farmland and playa immediately adjacent to the Salton Sea, soils are generally dry. Counterintuitively, large summer storms known as monsoons can generate additional dust emissions, due to both the strong winds that accompany such storms and the cooling effect of precipitation evaporating rapidly in the hot desert. This process causes cold air to “slam” back to the land surface, dislodging particles and generating additional dust (Evan 2024). Strong winds across the Salton Sea can cause storm surges that inundate portions of exposed playa, saturating these soils for as long as several months and eliminating emissions for extended periods (Dickey et al. 2023).

Wind speeds greater than 5 m/s (greater than 11 mph) can cause whitecaps and sea spray, a fine mist that can contain and concentrate chemicals and biological material from the water, entraining these particles in the air and transporting them across the land (Leibensperger 2024). While the process of sea spray production has been documented in other areas (Callaghan et al. 2008; Leeuw et al. 2011; Harb & Foroutan 2022), it is not well understood at the Salton Sea, though it likely shares similar properties (Miao et al. 2025). Some suggest that particles in Salton Sea spray can travel up to 30 miles (Gewin 2024).

PREVAILING WIND DIRECTION

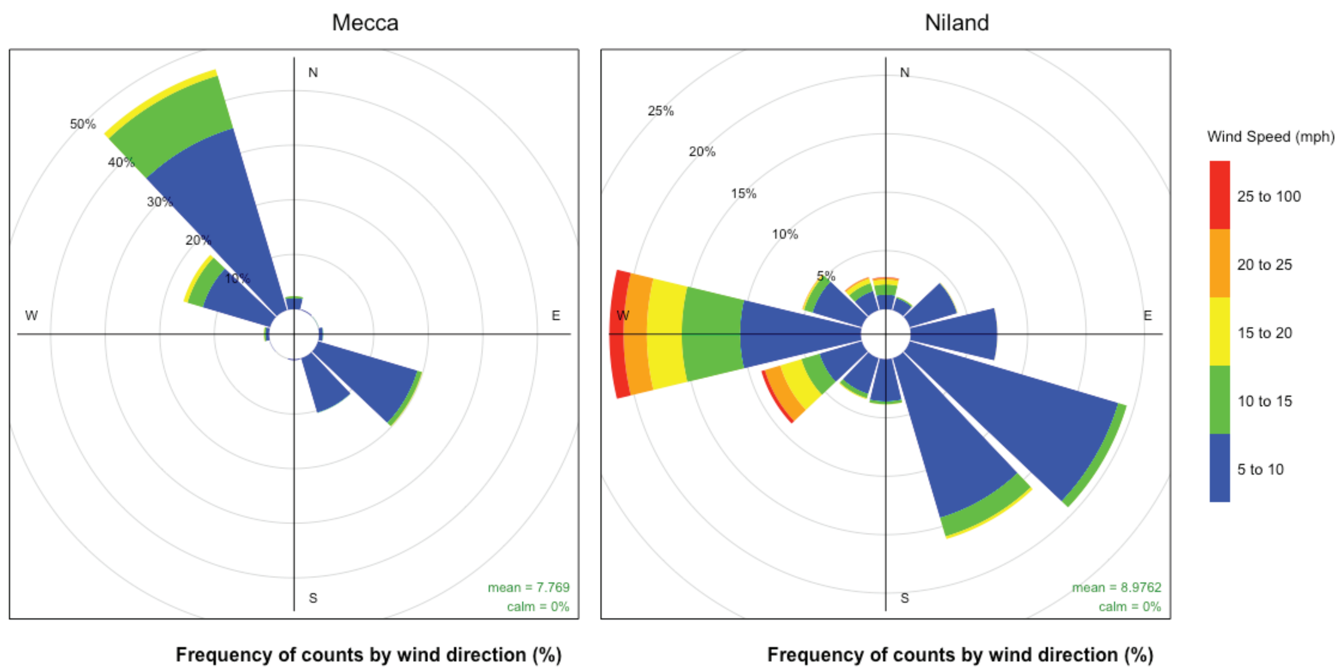
Wind direction can be used to predict which communities may be affected and the types of contaminants to which they are exposed. The wind direction — conventionally depicted in a graphic known as a wind rose — varies across the study area and seasonally. The wind roses in Figure 7 show the differences in reported hourly wind speeds at Mecca and Niland in 2024. At Mecca, four miles north of the Salton Sea, winds tend to blow from the northwest, carrying materials from

41 See Dickey et al. (2023) for a detailed description of regional soil types and emission rates.

42 We were unable to find any published or posted estimates of the total amount of unpaved roads in the region. We estimated this value as the sum of Imperial County’s reported 1,200 miles of unpaved county roads plus an estimated 4 miles of unpaved road per section of irrigated farmland, assuming 1 mile per side of each section (irrigation canals and ditches separate many but not all sections, with a road on either side), but did not include an estimate of unpaved roads within communities.

Coachella Valley agricultural fields and communities and, infrequently, from California's Inland Empire, west of San Gorgonio pass. Niland, about five miles east of the current Salton Sea shoreline and about four miles from the former shoreline, lies directly downwind of about one mile of partially vegetated playa. Niland's wind rose shows the prevalence of stronger westerly winds, potentially carrying materials from exposed Salton Sea playa and particulate matter from the western desert, as well as spray from the lake itself. Both wind roses also show the frequency of weaker winds from the southeast. In 2024, Mecca experienced about 60 total hours of winds greater than or equal to 15 mph (0.91% of hours with reported values[43]), and Niland experienced about 545 total hours of winds greater than or equal to 15 mph (6.3% of hours with reported values); Niland also experienced about 75 total hours of winds greater than or equal to 25 mph. In 2025, wind speeds were less than 5 mph about 61% of the time in Mecca and about 47% of the time in Niland. Figure 8 depicts these prevailing winds by location, showing that winds from the west are stronger and more frequent.

FIGURE 7. Mecca and Niland Wind Roses

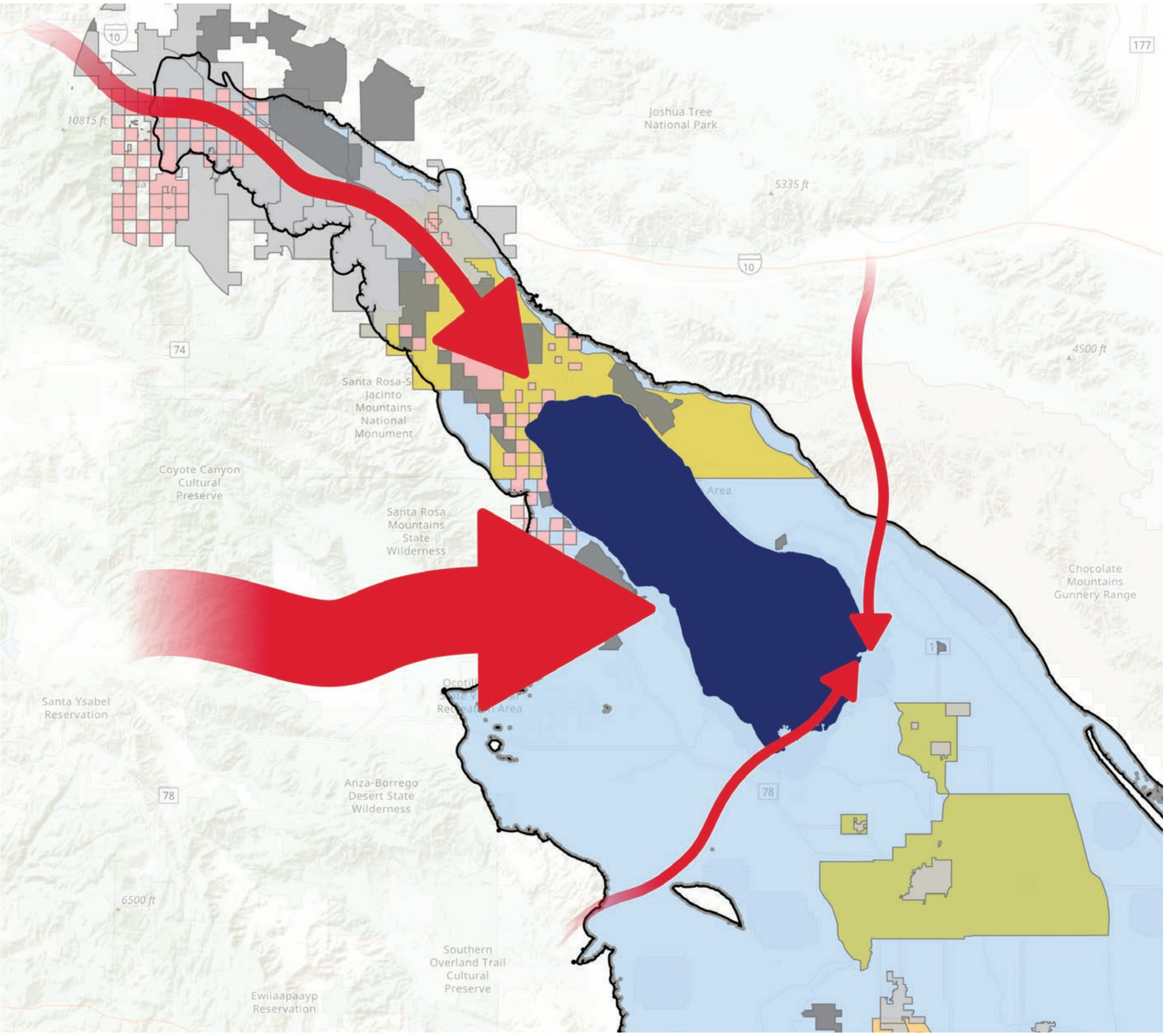


Source: AQMIS hourly 2024 data, plotted in R

Sowlat (2024) reported a distinct seasonal wind pattern at the Mecca monitoring station, 4 miles north of the Salton Sea, with a clear difference between May and August dust storms. Winds during the May event consistently came from the northwest, while the August winds were more variable, blowing from the east and the southeast and carrying less dust and anthropogenic material, indicating that they blew over the Salton Sea.

43 The Mecca air quality monitoring station had 8,766 hours with reported values and the Niland monitoring station had 8,648 hours with reported values in 2024.

FIGURE 8. Prevailing Winds Through the Region



The California Salton Sea Management Program's Dust Suppression Action Plan notes:

> The prevailing high winds in the Salton Sea region are from the northwest through the southwest. High wind speeds vary by region around the Sea and are important for this work because of the potential for suspending dust from exposed areas. Winds greater than 25 mph are recorded on the central and southern shores of the Sea on [*sic*] about 1.4% of annual hours, and about 0.01% of annual hours on the northern shore. Peak hourly wind speeds reach 47 mph on the central and southern shores, and 28 mph on the northern shore. Periods of high winds occur most frequently during April and May (CNRA 2020).

Evan (2023) identifies four factors affecting particulate emissions, each strongly linked to the land surface and spatial variability. The next chapter describes different sources of particulate matter and other materials that impair air quality, as well as how these vary across the study area.

6. Pollutants and Emissions

Almost 20 years ago, the Salton Sea Ecosystem Restoration Program Draft PEIR noted:

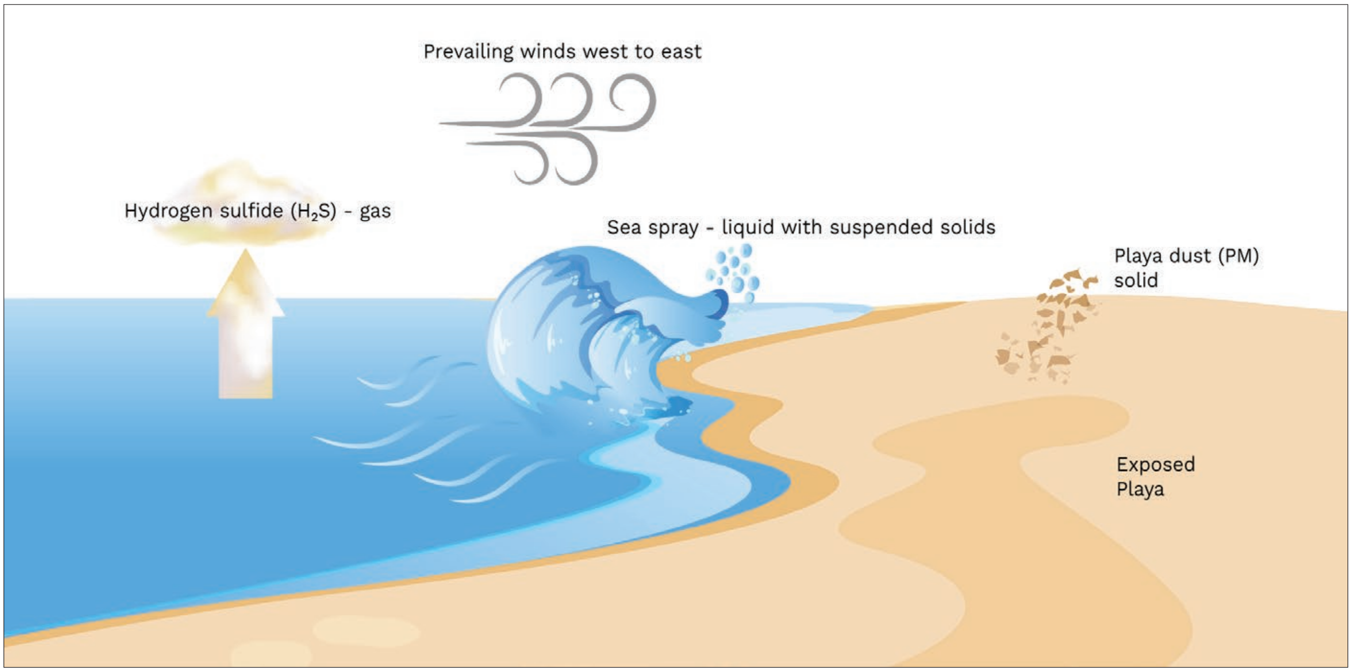
> The pollutants of greatest concern in the Salton Sea Air Basin are ozone and the ozone precursors, nitrogen oxides (NOx) and volatile organic compounds (VOCs), primarily from vehicle and equipment exhaust, and particulate matter (PM_{10} and $PM_{2.5}$) from soil disturbance and wind erosion (fugitive dust). Agricultural operations and transport of pollutants from Mexico also contribute to air quality issues in the area (CNRA 2006, p. 10-7).

More recently, communities in the region identified the following as their top air quality priorities:

- Salton Sea
- Pesticides
- Open burning and illegal dumping
- Fugitive road dust and off-roading
- Diesel mobile sources
- Farming operations
- Fuel combustion
- Greenleaf Desert View Power Plant (ICAPCD 2024; SCAQMD 2021a).

Recent research suggests that biological contaminants (Biddle et al. 2021, 2023; Freund et al. 2022) and hydrogen sulfide (Centeno et al. 2025) are also pollutants of concern. Pursuant to California Fish & Game Code section 2930, et seq., and State Water Resources Control Board Order WR 2017-0134, California's Salton Sea Management Program *Dust Suppression Action Plan* (CNRA 2020) focuses more narrowly on reducing the amount of fugitive dust — predominantly PM_{10} — emitted from exposed Salton Sea lakebed (see Chapter 8 for a description of these projects).

FIGURE 9. Salton Sea Contaminants — Gases, Liquids, and Solids



There are many ways to categorize air pollutants. Figure 9 shows that, even within the Salton Sea's 2003 shoreline, air pollutants can be solids, liquids, or gases. Particulate matter (PM) may itself consist of a combination of solids and liquids, including materials such as dust, fly ash, soot, smoke, aerosols, fumes, mists, and condensing vapors. In addition to the size of the PM, the chemical and biological characteristics of the material may pose additional risks. To protect public health, the U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS) for six contaminants, known as criteria pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, PM, and sulfur dioxide.[44] Regulators such as CARB distinguish between mobile sources (both on-road and off-road), stationary sources (point sources such as power plants), areawide sources (such as farming operations), and natural sources (such as wildfires).[45] Primary sources of PM include both human activities (such as agricultural operations, industrial processes, combustion of wood and fossil fuels, construction, and road dust), and natural activities (including windblown dust and wildfires). PM, especially $PM_{2.5}$, can also form in the atmosphere from other contaminants such as sulfur oxides, nitrogen oxides, volatile organic compounds, and ammonia (Hodan & Barnard 2004). This complicated set of air pollutant categories defies quick characterization or efforts to attribute adverse public health outcomes to a single source or manage emissions based on a single characteristic or source. Air pollution is regulated at the local, state, and federal levels — with local air districts overseeing stationary sources, the state air board overseeing mobile sources, and the EPA overseeing criteria air pollutants and other hazardous air pollutants used in various sectors, such as military sites.

44 See https://www.epa.gov/criteria-air-pollutants/naaqs-table.

45 See https://ww2.arb.ca.gov/emission-inventory-documentation.

Emissions from the Salton Sea region have distinct physical, chemical, and biological characteristics, all of which may impact local communities. While the *quantity* of particulate matter emitted from western deserts may be up to 100 times greater than that emitted from exposed Salton Sea playa (and from the lake surface itself), the *quality* of the Salton Sea material, in terms of its chemical and biological properties, may have disproportionately adverse effects (cf. Biddle et al. 2021; Centeno et al. 2025; Freund et al. 2022; Miao et al. 2025). The chemical and biological properties of pollutants emitted from other anthropogenic sources, including vehicle emissions, fires, and feedlots, are also likely to create a disproportionate impact on nearby communities.

PHYSICAL

Local, state, and federal agencies have set regulatory thresholds based on the size of the particulate matter. As described later in this chapter, key air pollution metrics in the Salton Sea region reflect the physical size of pollutants and do not account for their chemistry or potential toxicity. In light of these regulatory thresholds, we start our discussion with a focus on two classes of particulate matter: PM_{10} — particulate matter less than 10 microns in diameter — and finer particles known as $PM_{2.5}$ (see Figure 10). $PM_{2.5}$ comprise roughly 13% of the total PM_{10} burden[46] in the larger Salton Sea Air Basin (including Coachella Valley and all of Imperial County). While $PM_{2.5}$ are a subset of PM_{10}, they often differ in origin, not just in size. A key difference between PM_{10} and $PM_{2.5}$ is that the former can be emitted directly from soil disturbance (from wind or vehicles, for example), while $PM_{2.5}$ often forms from precursors and gaseous pollutants such as SO_2 and NO_x (CNRA 2013). Fossil fuel combustion is a major contributor of $PM_{2.5}$ (Dockery et al. 1993). ICAPCD found that:

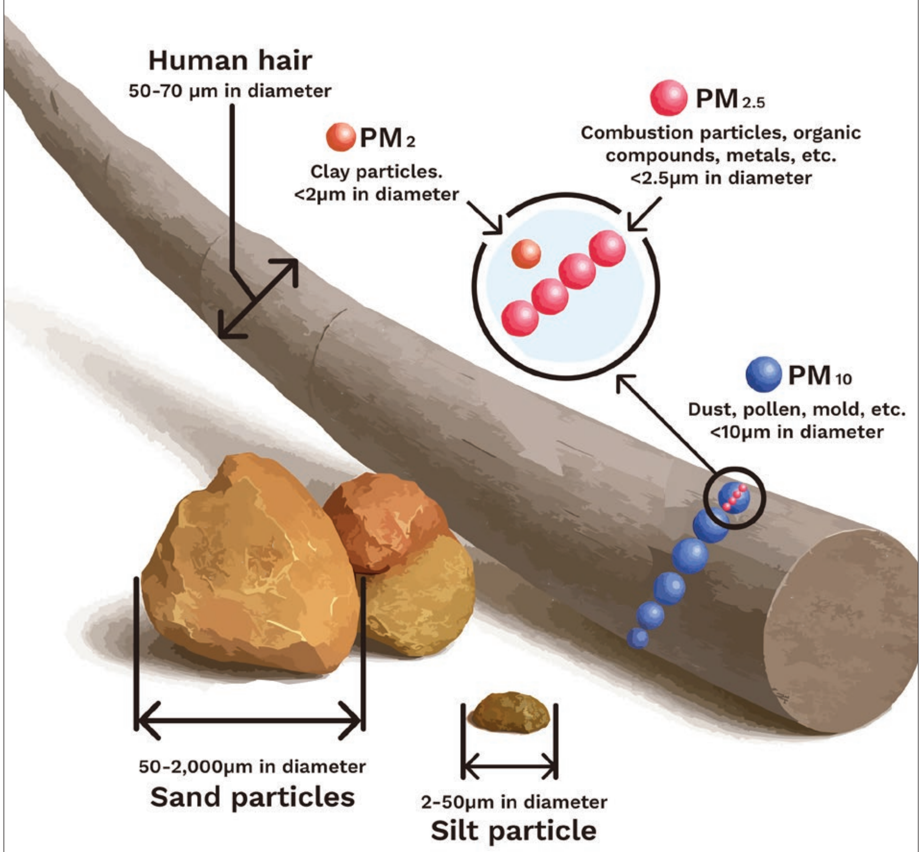
> the top five contributors to the [El Centro–Heber–Calexico AB 617] Community's $PM_{2.5}$ emissions are: fugitive windblown dust (50.2%),[47] fuel combustion from stationary and area-wide sources (8.8%), unpaved road dust (8.3%), on-road and off-road mobile sources (7.9%), and cooking (6.3%) (ICAPCD 2024, 3).

Particles larger than PM_{10} also contribute to dust storms and are often responsible for impaired visibility.

46 Per Table 6, annual $PM_{2.5}$ emissions in the SSAB are approximately 15,000 tons annually, out of about 112,000 tons of annual PM_{10} emissions.

47 Per Table 7, fugitive windblown dust constituted approximately 66% of total $PM_{2.5}$ emissions in Imperial County as a whole. CARB's Rule 402 (amended January 13, 2022) defines wind-generated fugitive dust as "visible emissions from any disturbed surface area that is generated by wind action alone." Available at https://ww2.arb.ca.gov/sites/default/files/classic/technology-clearinghouse/rules/RuleID4881ulso.pdf.

FIGURE 10. Particle Sizes



Categories include clay (<2 microns (µm) in diameter), silt (2–50 µm), and sand (50–2,000 µm) (Sculley et al. 2002).

Adapted from US EPA, at https://www.epa.gov/sites/default/files/2016-09/pm2.5_scale_graphic-color_2.jpg, visited 12/12/2024.

Regional air pollution control districts provide the most comprehensive estimates of PM emissions. The Imperial County Air Pollution Control District (ICAPCD), South Coast Air Quality Management District (SCAQMD), and other air districts within the state send updated emissions estimates to CARB annually, which posts selected emissions data on its website (Soucier, pers. comm., 2024). CARB's California Emissions Projection Analysis Model (CEPAM) Standard Emission Tool projects emissions from various pollutants and sources for the years 2000–2050.[48] Emissions estimates are based on a methodology approved by CARB and the EPA through a State Implementation Plan (SIP) (Soucier, pers. comm., 2024).

CEPAM estimates emissions based on growth factors directly related to social and economic activities such as population and housing, since these indicators are associated with increased

48 The CEPAM emissions estimates are based on the original 2012 Base Year Inventory, which was selected to maintain consistency across the state's multiple air pollution control planning efforts (Dessert et al. 2018a).

emissions. CEPAM also includes control factors, such as existing rules and regulations, compliance rates, and public awareness, to project future emissions reductions (CARB 2023). Air districts are required to develop and report control factors for each adopted rule to CARB but may develop their own growth factors for source categories (CARB 2023). For example, SCAQMD's 2016 Air Quality Management Plan listed Rule 444 for Open Burning as a control factor for $PM_{2.5}$, estimating an annual average emission reduction of 0.25 tons per day of $PM_{2.5}$ by 2031 (Lee et al. 2017).

Tables 6 and 7 show the relative contributions of major particulate emissions sources for selected years for the full Salton Sea Air Basin. For comparison, we also include CARB's estimated emissions for the year 2000, prior to the QSA, and contributions from Imperial County in 2012 (the base-year inventory), expressed as percentages of total emissions in the full Air Basin for those years. Note that the relative contributions of Imperial County and the full Air Basin are similar across most categories, with the exceptions of construction and demolition, paved road dust, and mineral industrial processes, all of which are higher in the Coachella Valley than in Imperial County. Although Imperial County comprises 63% of the area of the Salton Sea Air Basin, it contributes 95% of the total PM_{10} emissions and more than 99% of the fugitive windblown dust, according to CARB. The Imperial County (ICAPCD) numbers shown in the tables reflect values for the entire county, about 44% of which lies outside the Imperial Valley (as defined in our study area and shown in Figure 1). The data in tables 6 and 7 are projections from earlier estimates and, apart from the 2012 base-year inventory, are not actual measured emissions.[49]

49 Base-year inventories are costly and require significant resources, analyses, and modeling. Costs for actual inventories can be difficult to estimate and vary widely depending on the complexity of the inventory and whether it is conducted in-house or by an outside organization (Kiddoo, pers. comm., 2024).

TABLE 6. Annual Average PM_{10} Emissions in the Salton Sea Air Basin (SSAB)

	SSAB	SSAB	ICAPCD*	SSAB	SSAB	SSAB	SSAB	SSAB
Category	2000	2012	2012	2017	2020	2025	2030	2040
Fugitive windblown dust	62.45%	69.22%	68.92%	69.82%	69.39%	69.19%	68.82%	68.13%
Unpaved road dust	17.8%	20.04%	19.13%	17.88%	17.77%	17.21%	17.12%	16.96%
Farming operations	10.0%	2.91%	2.77%	2.88%	2.85%	2.82%	2.78%	2.72%
Construction and demolition		2.82%	0.97%	4.33%	4.61%	5.08%	5.30%	5.73%
Paved road dust	3.38%	2.03%	0.68%	2.35%	2.42%	2.59%	2.82%	3.13%
Mineral industrial processes		1.11%	0.00%	1.26%	1.17%	1.22%	1.22%	1.33%
On-road motor vehicles		0.60%	0.22%	0.47%	0.45%	0.45%	0.48%	0.53%
Managed burning and disposal		0.47%	0.47%	0.15%	0.15%	0.14%	0.14%	0.13%
Other**	6.37%	0.80%	1.52%	0.86%	1.21%	1.30%	1.31%	1.34%
Total	**100%**	**100%**	**95%**	**100%**	**100%**	**100%**	**100%**	**100%**
Total PM_{10} Emissions (tons)	**102,693**	**112,708**	**106,719**	**111,587**	**112,236**	**112,480**	**113,022**	**114,058**

*ICAPCD values shown are percentages of the Salton Sea Air Basin Total.
**"Other" includes on-road motor vehicles, aircraft, food and agricultural industrial processes, fuel combustion, mineral industrial processes, and off-road recreational vehicles.

Source: Values for the year 2000 from IID, 2002; other values from CARB's California Emissions Projection Analysis Model (CEPAM)

TABLE 7. Annual Average $PM_{2.5}$ Emissions in the Salton Sea Air Basin (SSAB)

	SSAB	ICAPCD*	SSAB	SSAB	SSAB	SSAB	SSAB
Category	2012	2012	2017	2020	2025	2030	2040
Fugitive windblown dust	66.62%	66.32%	68.66%	67.24%	66.81%	66.42%	65.70%
Unpaved road dust	14.30%	13.66%	13.05%	12.78%	12.33%	12.27%	12.14%
Managed burning and disposal	3.20%	3.18%	1.04%	0.99%	0.96%	0.94%	0.91%
Farming operations	2.98%	2.83%	3.01%	2.93%	2.89%	2.85%	2.78%
On-road motor vehicles	2.87%	1.07%	1.80%	1.55%	1.40%	1.50%	1.62%
Paved road dust	2.17%	0.73%	2.58%	2.61%	2.79%	3.03%	3.36%
Construction and demolition	2.02%	0.69%	3.16%	3.32%	3.64%	3.80%	4.10%
Other**	5.84%	4.13%	6.70%	8.57%	9.17%	9.20%	9.38%
Total	**100%**	**92%**	**100%**	**100%**	**100%**	**100%**	**100%**
Total $PM_{2.5}$ Emissions (tons)	**15,781**	**14,504**	**15,282**	**15,596**	**15,686**	**15,767**	**15,920**

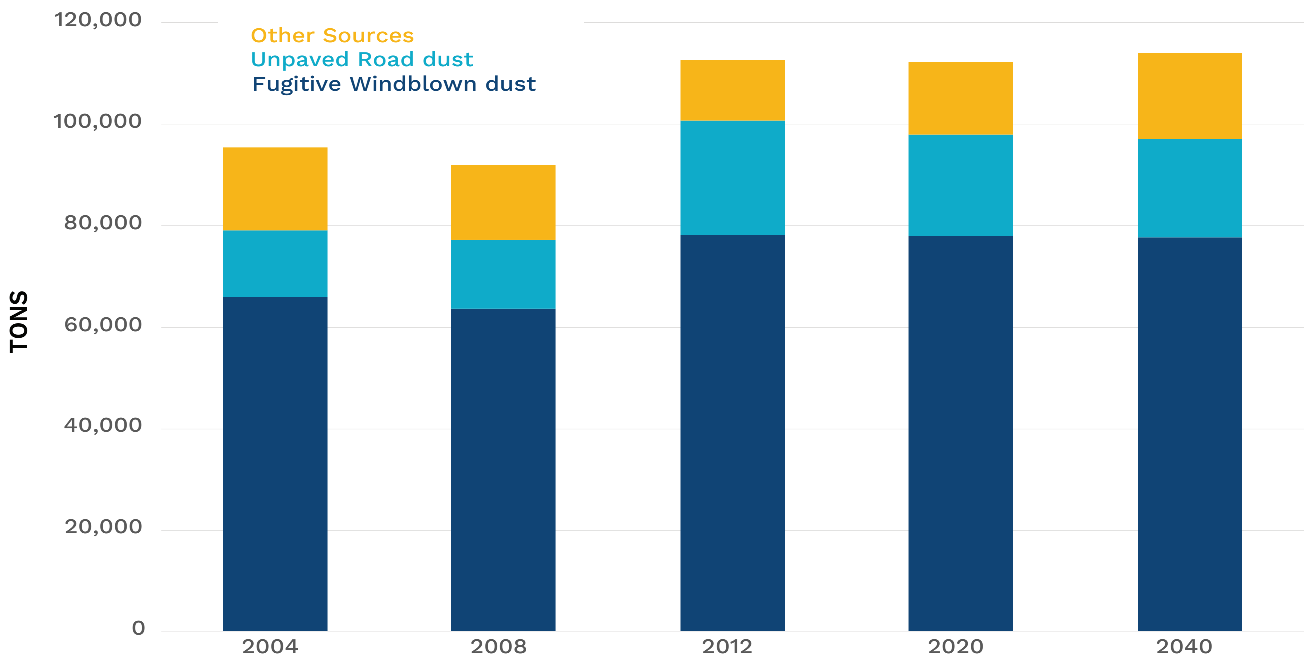
*ICAPCD values shown are percentages of the Salton Sea Air Basin Total.
**"Other" includes various industrial processes, aircraft, cooking, fuel combustion, trains, farm equipment, and off-road recreational vehicles.

Source: CARB's California Emissions Projection Analysis Model

The two tables above show fugitive dust to be the largest source of PM_{10} emissions in the Salton Sea Air Basin. Fires, including agricultural burning and structural and automobile fires, accounted for a significant portion of projected $PM_{2.5}$ emissions in 2012 and 2020. Imperial County's 2018 SIP for $PM_{2.5}$ notes that no growth is assumed for fires in projected emissions and is shown as a significantly lower percentage of projected annual emissions for future years. Similar to PM_{10}, fugitive windblown dust accounts for more than 65% of projected $PM_{2.5}$ emissions. Unpaved road dust is the second major projected contributor, accounting for over 13% of $PM_{2.5}$ emissions (Dessert et al. 2018b).

As shown in Tables 6 and 7, CARB projects that the amount of fugitive windblown dust will remain relatively stable in coming years, while the amount of dust from unpaved roads will decline slightly. However, CARB projects that the amount and percentage of dust from construction and demolition activities will more than double from 2012 to 2040, despite control factors, contributing thousands of additional tons of dust to the air basin each year.[50] Figure 11 compares CARB-reported annual PM_{10} estimates for several years, showing a distinct increase from the 2008 estimate to the 2012 base-year inventory, and relatively stable amounts of emissions from that 2012 inventory forward.

FIGURE 11. Salton Sea Air Basin PM_{10} Emissions, 2004–2040



Source: CARB (2004 CARB data from (California Natural Resources Agency 2006), 2008 CARB data from 2010 SCH DEIR).

IID prepares annual reports on its Salton Sea Air Quality Mitigation Program (AQMP), including annual PM_{10} emissions estimates for exposed Salton Sea playa and fugitive dust emissions from the much larger Western Desert.[51] The methods and data for these annual reports underwent independent

50 Dust composition is also expected to shift, potentially including more composite building materials that could contribute to more toxicity. For example, the demolition of old structures that contain asbestos could contribute to toxic emissions (Wu, pers. comm., 2025).

51 These and other reports are available at https://saltonseaprogram.com/documents/. See Dickey et al. (2023) for a detailed description of the methods and review process used in these annual reports.

peer review and provide the only available longitudinal series for such emissions. These estimates assume that all playa acreage is "uncontrolled;" they do not account for emissions reductions in the roughly 40% of playa that includes emergent wetlands, dust suppression projects, or other features that can reduce emissions (see Table 2).[52] To better reflect winter emissions as a whole, the reports provide data for a July 1–June 30 monitoring year. IID's annual reports focus on playa and western desert fugitive emissions, both of which affect the study area. About 15% of the western desert emissions occur in San Diego County, outside the Salton Sea Air Basin (Yimam, pers. comm., Feb. 18, 2025).

Table 8 shows the increasing amount of playa exposed from 2016–2022, the much larger amount of western desert, and the median estimated emissions for both, based on each of the IID annual reports to date. IID estimates a range of total playa emissions for each reporting period. For example, from 60–1,253 tons per year in the 2021/22 reporting period, which is at the 25th and 75th percentiles. The values shown in Table 8 are the medians reported for each period. In the 2021/22 reporting period, results indicate that total playa PM_{10} emissions decreased by about 21% compared with previous monitoring periods, despite increasing playa exposure (IID 2023). IID reported that playa exposure increased from 16,447 acres at the end of 2016 to 29,907 acres at the end of 2022, while total annual PM_{10} emissions increased from about 295 tons to about 320 tons over that period. In most years shown, roughly 10% of the total annual playa emissions occurred in one day. Note also the significant interannual variability, driven by weather conditions, with wet years dramatically reducing total emissions, especially 2019–2020. As discussed at the end of this chapter, emissions occur disproportionately across both time and place in the region.

TABLE 8. Estimated Salton Sea Playa and Desert PM_{10} Emissions

ANNUAL	2016/17	17/18	18/19	19/20	20/21	21/22	22/23	23/24
Playa Exposure (acres, 1000s)*	16.4	17.6	20.3	23.0	25.6	27.7	29.9	32.5
Estimated PM_{10} emissions (tons)	294.8	354.4	291.4**	34.4***	428.7	336.1	319.6	141.7
Maximum daily tons	31.8	26.3	23.0	2.66	42.9	45.5	55	18
Western desert (acres, 1000s)	1,026	1,026	1,026	1,026	1,027	1,027	1,027	1,027
Estimated PM_{10} emissions (tons)	29,680	27,752	24,858	15,218	30,348	38,429	30,267	25,334
Maximum daily tons	3,560	1,681	1,843	1,572	1,610	4,181	2,996	2,900

*Exposed playa for each period is defined as the total area of exposed land between the former Salton Sea shoreline at the end of 2002 and the shoreline at the end of the first year shown (e.g., in 2016 for 2016/17).
**2018/19 was estimated to be less emissive than 2017/18 as a result of relatively higher precipitation and fewer high wind events in 2018/19 compared to 2017/18.
*** 2019/20 was estimated to be much less emissive than previous reporting periods as a result of wetter surfaces and lower winds.

Source: IID (annual), Salton Sea Emissions Monitoring Program, Annual Report and PM_{10} Emissions Estimates. Table 1. Monthly and Annual PM_{10} Emissions for the Playa. Available at https://saltonseaprogram.com/documents/.

52 IID's annual reports note that existing and planned dust suppression projects (through the SSMP and AQMP) are located in areas that contribute over 70% of the five-year average annual emissions estimate.

Many other sources contribute PM to the region, including unpaved surfaces, diesel emissions and traffic, landfill fires, dust from industrial sources, and agricultural activities. The following section describes these sources and their implications for regional emissions.

Natural Sources

The Salton Sea region has multiple natural sources of particulate emissions. Frie et al. (2019) distinguish between "Colorado alluvium" and "local alluvium" as dust sources. Prior to the construction of dams, the Colorado River periodically carried tremendous quantities of sediment — Colorado alluvium — into the study area. This material contains aluminum, iron, titanium, and high concentrations of calcium. Colorado alluvium accounts for 8–28% of the total sampled mass of PM in their study (Frie et al. 2019). Several alluvial fans at the far north end of the Coachella Valley are well-known dust sources, which Frie et al. (2019) believe to be the source of local alluvium, based on soil composition. Local alluvium accounted for 20–44% of the total sampled mass of PM and contains aluminum, iron, and titanium, but lacks the calcium found in Colorado alluvium.

On August 20, 2023, Tropical Storm Hilary dropped more than 3 inches of rain on the Coachella Valley and more than 13 inches in Upper Mission Creek, in the mountains north of the valley, leading to flooding and transporting millions of cubic feet of fine sediment into the valley. One local source estimated that 6,500 acres of sediments were deposited in the valley.[53] This storm-generated fine sediment has since become a source of particulate emissions, including PM_{10} and coarser materials that can impair visibility and cause fatal traffic accidents (Damien & Rode 2023; Ludwig 2024).

Unpaved Surfaces

Many vehicles travel on unpaved roads in the Salton Sea region for agricultural and industrial activities. Studies in other areas suggest that such emissions could be significant (Aleadelat & Ksaibati 2018; Gillies et al. 2022). CARB's 2017 estimated emissions from unpaved roads in Imperial County were 51.86 tons of PM_{10} per day, or a total of almost 19,000 tons per year. This 2017 estimate is more than 50 times greater than the estimated 336 tons per year emitted from Salton Sea playa.

Off-Highway Vehicle Recreation

Off-highway vehicles (OHVs), also known as off-road vehicles, can generate dust directly, creating emissions as they travel, and indirectly, by disturbing the land surface (see Figure 12). In Utah, the increasing use of OHVs and the creation of new OHV trails increases dust emissions by reducing vegetation cover and breaking the soil crust, causing the soil to become more emissive. One unpublished study found that OHV trails in Utah produce at least 10 times more dust emissions per unit area than undisturbed surfaces (Wiebelhaus & Sweeney 2024). In California, Gillies et al. (2022) found that the mean windblown dust emissivity of areas open to OHVs at the Oceano Dunes State Vehicular Recreation Area was 1.9 to 3.6 times higher than closed areas. They also found that the cessation of OHV activity at the site in 2020, due to the global COVID-19 pandemic, led to a 46.5% decrease in PM_{10} emissions in four months. Research on the Colorado Plateau found dust emission

53 Source: June 3, 2024 Coachella Valley Association of Governments Executive Committee staff report, available at https://cvag.org/downloads/admin/exec/EXEC_06_03_2024_AgendaMerged.pdf.

rates as high as 7,460 g/m^2 per day in an OHV area, though rates generally ranged from 50–2,000 g/m^2/day, with an average of 414 g/m^2/day, or about 670 tons/acre/year (Nauman et al. 2018).

FIGURE 12. ATVs in the Ocotillo Wells State Vehicular Recreation Area

Source: The Courts, https://www.thecourts.net/

The federal Bureau of Land Management (BLM) operates several OHV recreation areas in the Salton Sea region. The Imperial Sand Dunes is the largest mass of sand dunes in California and receives around one million visitors per year. BLM's Plaster City OHV Open Area and Superstition Mountain OHV Open Area are both south of the Salton Sea and west (and generally upwind) of El Centro and Brawley, respectively. Plaster City sees an average of 8,300 visitors per year, and Superstition Mountain sees an average of 112,700 visitors per year. Several State Vehicular Recreation Areas (SVRA) or parks are open for OHV recreation in the Salton Sea region. The Ocotillo Wells SVRA, west of the Salton Sea, receives more than 1 million visitors per year. Nearly 250,000 people visited the area in November 2023 alone. The California Department of Parks and Recreation counted 105,800 vehicles at Ocotillo Wells in a visitor study period from 2012–2013, the most recent study available. Most visitors came specifically for OHV recreation (Erickson et al. 2014).

There is limited research on dust emissions from OHV recreation in the Salton Sea region. Cheung et al. (2021) compared OHV activity and environmental impacts in the Imperial Valley Sand Dunes Recreation Area and the Algodones Dunes Wilderness Area, both southeast of the Salton Sea and managed by the BLM (see Figure 1). They found a positive correlation between OHV activity and vegetation loss, along with subsequent increased temperatures, which are precursors to increased dust emissions and poor air quality (Cheung et al. 2021).

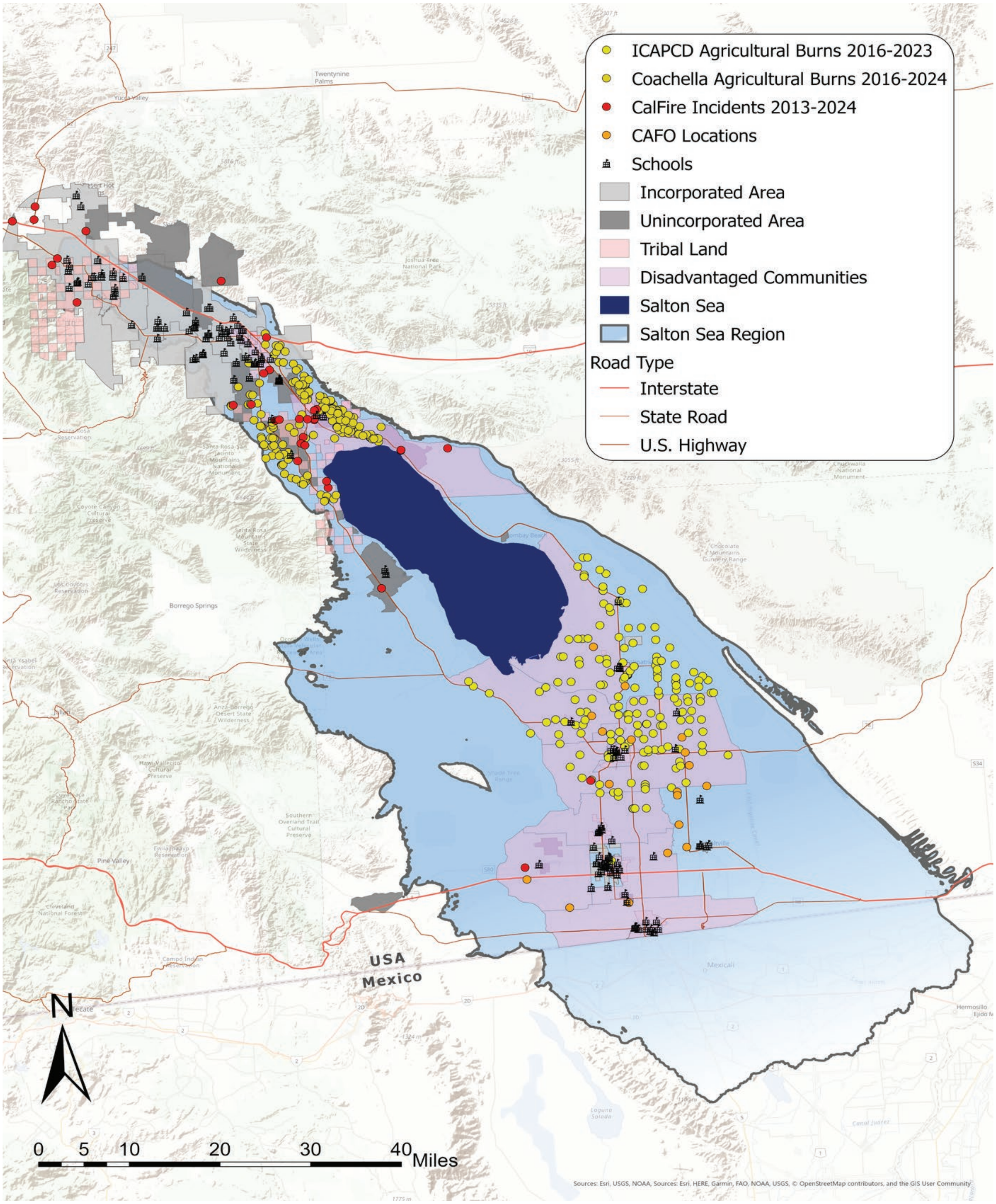
Fire and Smoke

Fires emit gases and solids, degrading air quality (Law et al. 2025). In the Salton Sea region, significant fire sources include agricultural burning, wildfires, incinerators, and landfill fires. Kamai et al. (2023) found that burning post-harvest crop remnants can adversely affect air quality and public health in the region. Lieb & Faloona (2025) found that biomass burning was the major contributor to $PM_{2.5}$ exceedances in Calexico, at the U.S.–Mexico border.

Table 9 shows recent average acreage burned and the average number of fires per year in the Salton Sea Air Basin. Figure 13 shows locations of permitted agricultural fires from 2020–2023, along with locations of nearby schools for context. Crop remnants burned in Imperial County were predominantly Bermuda grass and wheat, and grapevines in the Coachella Valley. Harnly et al. (2012) observed agricultural burning at the Sonny Bono and Wister sites in the study and reported that hourly PM_{10} concentrations increased by a factor of 1,000 — to 6,500 μg/m^3, downwind of an agricultural burn in the Imperial Valley, but returned to pre-burn levels within a few hours. They found that both PM_{10} and $PM_{2.5}$ concentrations were highly elevated during five specific agricultural burns in the Imperial Valley (Harnly et al. 2012). Figure 14 shows a small agricultural burn near Oasis, in the Coachella Valley. Crop burning emits a mix of particulates, including organic carbon (Watson & Chow 2001), potassium, and phosphate (Frie et al. 2019). Frie et al. (2019) also observed agricultural burning at the Sonny Bono and Wister sites and noted that dust from agricultural burning contributed the most to total dust collected during the May, June, and July sampling periods.

Fires emit gases and solids, degrading air quality. In the Salton Sea region, significant fire sources include agricultural burning, wildfires, incinerators, and landfill fires.

FIGURE 13. Locations of Agricultural Burns and Other Fires in the Salton Sea Region



Sources: CalFire, ICAPCD, SCAQMD.

FIGURE 14. Fire Near Oasis, October 16, 2024

Photo by M. Cohen.

Table 9. Permitted Agricultural Fires, 2016–2023.

	IMPERIAL COUNTY	COACHELLA VALLEY	SALTON SEA AIR BASIN
Average acres/year	6,557	738	7,295
Number of fires/year	87	132	218

Values may not total due to rounding.
Sources: ICAPCD, SCAQMD

Periodic brushfires and landfill fires also contribute to the air pollution burden in the study area. For example, roughly 400 acres of brush and wetlands burned near the Alamo River delta on November 23–24, 2024 (Brown 2024), as shown in Figure 15, and a brushfire destroyed 37 homes in Niland on June 28, 2020 (Atagi & Damien 2020). Air quality monitoring stations near these fires showed slightly elevated PM concentrations on these dates relative to more distant monitoring stations.[54] Fires from various sources, including illegal dumping, disproportionately affect marginalized, under-resourced communities in the Eastern Coachella Valley (Hopfer et al. 2024). Casey et al. (2024) note that such communities consistently experience disproportionate exposure to wildfire $PM_{2.5}$.

54 The Brawley station reported a maximum hourly $PM_{2.5}$ concentration of 67.2 μg/m^3 on November 23, 2024, versus a maximum of 39 μg/m^3 at the Calexico and El Centro monitoring stations.

FIGURE 15. Brushfire Southeast of the Salton Sea

Photo courtesy of County of Imperial

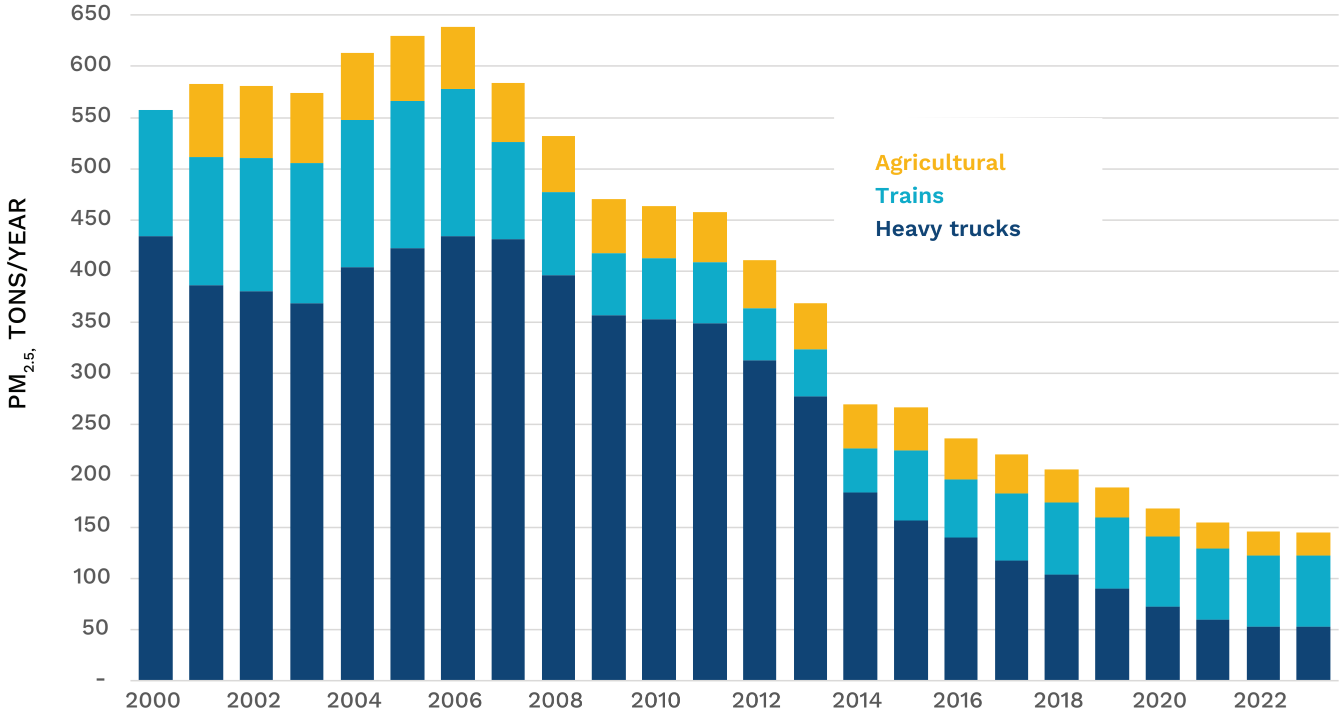
Geothermal Energy and Lithium Extraction

Lithium is a critical component of rechargeable batteries. New technological advances have made it possible to extract lithium from geothermal brine. This shift to co-locating geothermal energy and lithium production in the same facilities is becoming more economically viable (Toba et al. 2021). The southeast portion of the Salton Sea is a Known Geothermal Resource Area (Paz et al. 2022). Interest in lithium extraction in the Salton Sea region is growing, but there are potential public health risks associated with air pollution. There are currently 11 operating geothermal power plants in the Salton Sea region, with an installed capacity of 414 megawatts (MW) and an estimated 2 million metric tons of lithium thousands of feet below the southeastern corner of the Salton Sea. According to a draft Environmental Impact Report, the construction phase of a new lithium plant adjacent to the Salton Sea could generate a total of as much as nine tons of PM_{10} annually, while cooling tower emissions could emit about half as much, each year (Chambers Group, Inc. 2023).

Other Sources

Other sources also contribute to the regional air quality burden. There are 31 feedlots (known as confined animal feeding operations, or CAFOs, shown in Figure 13) in the Imperial Valley, feeding about 400,000 animals annually. In a study of commercial feedlots in the Texas Panhandle, Wilson et al. (2002) found that $PM_{2.5}$ concentrations increased from about 39 μg/m^3 upwind to 177 μg/m^3 downwind of a feedlot. Figure 16 shows annual diesel emissions from various sources, as reported by CARB. Estimated recent emissions from these sources average about 150 tons per year of $PM_{2.5}$; total PM_{10} emissions (not shown) from these sources are slightly higher. We did not determine the factors contributing to the decline in these emissions over the past 20 years.

FIGURE 16. Estimated Annual $PM_{2.5}$ Emissions from Diesel Vehicles in the Salton Sea Air Basin, 2000–2023



Source: CARB Mobile Source Emissions Inventory.

CHEMICAL

The chemical elements present in emissions can pose additional risks above and beyond those caused by the physical size of the material. State and federal standards limit emissions of several specific "criteria pollutants," such as nitrogen and sulfur oxides (NOx and SOx), as well as ozone. As described in Chapter 7, long-term exposure to hydrogen sulfide may also be associated with impaired health. Exposure to heavy metals and pesticides in the air may also be dangerous. SCAQMD's *Multiple Air Toxics Exposure Study* reports provide detailed information on emissions and related risks of contaminants such as acetone, benzene, toluene, and acetaldehyde in the Coachella Valley.[55]

State and federal standards list nitrogen dioxide as a criteria pollutant, though exceedances of these standards occur less than once per year in the study area.[56] Almaraz et al. (2018) found that fertilized agricultural fields can increase NOx emissions by as much as 51%. Lieb et al. (2024) estimate that agricultural fields in the study area emit 11 (±4) tons/day of NOx, or about 4,000 tons annually. Baum et al. (2008) estimated that as much as half of the nitrogen consumed by feedlot animals is subsequently released as ammonia (NH_3), which works out to as much as 3,000 metric tons of nitrogen released from feedlots per year in the Imperial Valley.[57] However, SCAQMD (2021) reports that mobile sources generate more than 80% of the total NOx emissions in the northern portion of the study area.

Frie et al. (2019) found trace metals and anthropogenic copper in dust from the Salton Sea region. Palm Desert, the most urban of the sites sampled, had the highest levels of anthropogenic trace metals from November to February, reflecting seasonal prevailing winds and emissions from the Inland Empire and the L.A. Basin. They report that anthropogenic copper accounted for as much as 10% of the total mass sampled and is associated predominantly with motor vehicle use (especially brake dust) and industrial production.

Magnesium, calcium, and sulfate minerals may be important components of emissive playas in the Salton Sea, given their high concentrations in the playa (Frie et al. 2017). The Salton Sea is also highly saline; playas have higher concentrations of sodium than local desert soil, and therefore emissions from the playa, including PM_{10}, are expected to reflect these concentrations (Frie et al. 2017). Alonso et al. (2005) found that deposition of chlorine, sulfate, and sodium in the terrestrial ecosystem beyond the Salton Sea shoreline to be related to sea spray.

Ozone

Ozone contributes to poor air quality in the Salton Sea region. Both the Coachella Valley and Imperial Valley are in nonattainment of federal ozone standards. The Salton Sea Air Basin, the state-level designation, is in nonattainment of state ozone standards (CARB, n.d.-b). Ozone is not directly emitted into the atmosphere but is formed through a photochemical reaction between volatile organic compounds (VOCs) and nitrogen oxides (NOx), which are primarily emitted from industrial sources such as factories and mobile sources such as passenger vehicles (US EPA 2024). Lieb et al. (2024) found that heavily fertilized agricultural land in the Imperial Valley disproportionately contributes to NOx emissions in the region.

55 For detailed estimates, see SCAQMD's MATES V Appendix VIII —- 2018 Emissions by Major Source Category, at http://www.aqmd.gov/home/air-quality/air-quality-studies/health-studies/mates-v.

56 See https://www.arb.ca.gov/adam/.

57 Assuming each of the roughly 400,000 feedlot animals in the Imperial Valley consumes 400 g of nitrogen (N) per day. According to https://insideclimatenews.org/news/18082023/californias-top-methane-emitter-is-cattle-feedlot/, one Imperial Valley feedlot is the single largest methane emitter in California.

Miao et al. (2022) found that the most vulnerable communities in the Coachella Valley are more likely to be exposed to higher levels of $PM_{2.5}$ but lower levels of ozone than wealthier communities in the northwestern portion of the valley. The higher ozone concentrations are partly attributable to prevailing winds blowing ozone into the valley from the Los Angeles/South Coast region. Table 10 shows the highest daily maximum 8-hour ozone levels in Palm Springs and Indio, which exceed the 2015 national standard of 0.070 ppm. The highest level, 0.093 ppm in Palm Springs, would rate the area as "Unhealthy for Sensitive Groups," as described in Chapter 5.

Imperial Valley also has high ozone levels, which may be a byproduct of heavy truck traffic near the U.S.–Mexico border (Bojórquez 2023). ICAPCD's 2017 implementation plan notes that children are particularly at risk for ozone exposure in Imperial Valley, but little research explores the relationship between local health impacts and ozone pollution in Imperial County (Dessert & Romero 2017). Table 10 shows that the highest maximum 8-hour ozone average at El Centro was 0.091 ppm in 2023, similar to the 2021 and 2023 averages shown for Palm Springs.

TABLE 10: Highest Daily Maximum 8-Hour Ozone Averages in the Salton Sea Basin

STATION	YEAR	DATE	8-HOUR AVERAGE (PPM)
Palm Springs – Fire Station	2021	18-Jun	0.092
	2022	22-Jul	0.089
	2023	14-Jul	0.093
Indio - 29 Palms Reservation	2021	18-Jun	0.094
	2022	22-Jul	0.076
	2023	6-Jul	0.072
El Centro - 9th St	2021	12-Jun	0.083
	2022	26-Aug	0.078
	2023	8-Jul	0.091

The 2015 national 8-Hour ozone standard is 0.070 ppm.

Source: CARB's iADAM tool

Pesticides

USGS collected data on pesticide concentrations in water and sediment samples from the Alamo and New Rivers in the early 2000s and detected 12 pesticides, with the highest concentrations detected at the mouths of both rivers (LeBlanc et al. 2004). A 2007 study found 42 organic pesticides and 48 polychlorinated biphenyls (PCBs) in whole-body and fillet samples of fish from the Salton Sea. Arsenic, selenium, total dichlorodiphenyltrichloroethane (DDT), and PCBs may have bioaccumulated in fish and been harmful to people (Moreau et al. 2007).[58] Xu et al. (2016) found that

58 PCBs are man-made organic chemicals that were used in a variety of industrial and commercial applications, including heat transfer and hydraulic equipment, paints, and dyes. They were banned in 1979. For more information, see https://wwwn.cdc.gov/tsp/substances/ToxSubstance.aspx?toxid=26.

DDT, polycyclic aromatic hydrocarbons (PAHs),[59] PCBs, chlorpyrifos, and some current-use pesticides exceeded risk thresholds in the Sea. Pesticides and heavy metals sequestered in Salton Sea sediments could be emitted with dust from the playa as the lake continues to recede.

During the spray application of pesticides, some may drift, potentially affecting rural communities and agricultural workers. The amounts of pesticides left in the air depend on application techniques, wind speed and direction, other weather conditions, and the pesticide itself (Coscollà & Yusà 2016). Pesticides can attach to aerosol particles; their half-life in the atmosphere ranges from days to months, implying that they can be transported over long distances (Socorro et al. 2016). Most of the adverse health impacts associated with pesticide exposure are related to $PM_{2.5}$, but they can also be present in PM_{10} (Yusà et al. 2014).

In the ECV's Community Emissions Reduction Plan (CERP), members of the Community Steering Committee (CSC) cited concerns about the use and application of pesticides on the community's agricultural lands. Members reported that pesticides are being used during restricted hours, despite current regulations, and that they drift into homes and schools near the application sites (SCAQMD 2021a). There is no mention of pesticides in Imperial County's CERPs, but the county's agricultural commissioner's office does require permits for pesticide use and tracks pesticide purchases for agricultural commodities.[60]

Hydrogen Sulfide

Hydrogen sulfide (H_2S), a gas people can detect in concentrations as low as 1 part per billion, has a characteristic rotten egg smell (Batterman et al. 2023). Bacterial decomposition in the absence of oxygen, in landfills and in the Salton Sea (Amrhein n.d.; Watts et al. 2001), generates H_2S, as does geothermal production. Twenty years ago, Amrhein et al. (2005) estimated that sulfate-reducing bacteria may have been generating some 78,000 metric tons of H_2S annually at the Sea; we were unable to find more recent estimates. In September 2012, people in the San Fernando Valley complained about the smell after a storm blew H_2S 150 miles from the Salton Sea (James 2016). Communities in the ECV have expressed concern about chronic H_2S exposure (Centeno et al. 2023).

Several factors will affect hydrogen sulfide production in the future: dissolved oxygen levels in and above the Sea's sediments; the persistence of stratified conditions; the availability of detrital organic material; sulfate (SO_4^{2-}) concentrations; and the salinity tolerance and persistence of the sulfate-reducing bacteria. Although primary productivity in the Sea will decrease markedly as salinity rises, sediments will continue to offer large volumes of accumulated organic material to sulfate-reducing bacteria. Reclamation[61] reported that sulfate concentrations rose from about 10.5 grams per liter (g/L) in 1999 to about 16.4 g/L in 2020, a 55% increase, while the water volume of the lake decreased by 30%.

59 PAHs are produced by the incomplete combustion of organic matter, such as in engines or from burning biomass. See https://www.epa.gov/sites/default/files/2014-03/documents/pahs_factsheet_cdc_2013.pdf.

60 See Imperial County's CERPs at https://www.icab617community.org/south-end-committee-documents. For more information about pesticide permits, see https://agcom.imperialcounty.org/pesticide-use-enforcement/.

61 Reclamation reported water quality parameters at https://www.usbr.gov/lc/region/programs/SaltonSea_data_2004-2020.xlsx, available via https://www.usbr.gov/lc/region/programs/saltonsea.html (accessed October 22, 2024).

In a recent study, Centeno et al. (2025) found that hydrogen sulfide (H_2S) concentrations at the north end of the Salton Sea frequently exceed California's 30 parts per billion (ppb) hourly exposure standard, particularly in the summer, with peak concentrations exceeding 100 ppb in most years at the monitoring site closest to the Sea and exceeding 200 ppb in several years. They also found a dramatic decrease in the number of hours of exceedances at monitoring stations farther from the Sea, potentially reflecting the difference between the emissions source and the location of monitoring stations. While they correlated winds blowing over the Salton Sea with the highest reported H_2S concentrations and the greatest number of hours exceeding the hourly exposure standard, Centeno et al. (2025) also show, for the monitoring station closest to the Sea, multiple hours of exceedances and concentrations greater than 60 ppb when winds blew from the northwest, over the Coachella Valley. They note that H_2S is often detected at lower wind speeds. SCAQMD has noted that higher wind speeds can reduce H_2S concentrations while increasing PM_{10} concentrations.[62]

Vehicle Emissions

Vehicle emissions contain trace metals (Schroeder et al. 1987). Manalis et al. (2005) found a strong correlation between nitrous oxides and copper concentrations and heavily impacted traffic areas in Athens, Greece. Watson & Chow (2001), in their study characterizing major emission sources in the Imperial and Mexicali Valleys along the U.S.–Mexico border, found that high abundances of lead in motor vehicle exhaust could indicate different vehicle fleets between the border cities. Emissions from diesel trucks and vehicles contain black carbon and heavy metals, which are both harmful to human health. Black carbon, the sooty black material emitted from burning fossil fuels, can carry a host of toxic chemicals (Cassee et al. 2013; Costa 2011). We did not find any specific studies on black carbon emissions in the Salton Sea region. SCAQMD (2021a) reports that diesel PM, primarily from on- and off-road mobile sources, is the major toxic air pollutant in the ECV.

Other Chemical Sources

The Greenleaf Desert View Powerplant, located about 1 mile northwest of Mecca, was a 45-megawatt biomass-fueled generation plant that closed in May 2024 following a June 2022 notice of violation for exceeding threshold levels of mercury, nitrogen oxide, and other contaminants (Coulter & Wilson 2024). Major air pollutants released by incinerators generally include $PM_{2.5}$, toxic metals, and other potentially hazardous elements. The exact composition of the contaminants varies depending on the material incinerated and may include carcinogens and hormone disrupters (Thompson & Anthony 2005). Fly ash, another byproduct of incineration, is highly toxic and poses significant long-term health risks.

Geothermal energy production can emit hydrogen sulfide (H_2S), mercury, and radon. Communities near the Geysers Power Plant in Northern California have complained about H_2S odor and health impairment (Anspaugh & Hahn 1979). Communities near the Salton Sea have expressed concern about potential adverse environmental impacts from these plants.[63]

62 See https://patch.com/california/palmdesert/odor-advisory-issued-part-riverside-county.

63 See https://www.courthousenews.com/judge-dismisses-environmental-justice-groups-suit-challenging-lithium-extraction-in-imperial-valley/.

BIOLOGICAL

Ongoing research at several labs at UC Riverside has identified the additional threats posed by biological elements found in aerosols from the lake and some dust. Biddle et al. (2021, 2023) report that dust collected near the Salton Sea triggered acute pulmonary responses in mice, suggesting that microbial components may be responsible. Freund et al. (2022) note that microorganisms travel along with contaminants and minerals in local dust emissions. Airborne pathogenic microorganisms, and portions of such organisms originating in the Salton Sea and associated playa, may be associated with impaired human health (Aronson 2024). Miao et al. (2025) report a strong correlation between Salton Sea algal blooms and increased hospitalization rates in downwind communities, though they note the need for further research to identify the chemical and/or microbial constituents in Salton Sea aerosols that may be causing these impacts.

Nutrient loadings have been an issue for more than 25 years (Cohen et al. 1999). Hung et al. (2024) state that the very high quantities of nutrients entering the Salton Sea have generated harmful algal blooms (HABs) and resultant toxins, adversely affecting fish and wildlife. On April 23, 2021, the Regional Water Quality Control Board (RWQCB) issued a news advisory warning people to avoid contact with the Salton Sea due to a HAB with toxic cyanobacteria.[64] Geraci (2023), of the RWQCB, noted the presence of multiple species of cyanobacteria in the Salton Sea, many in algal mats along much of the shoreline. He reports detection of four distinct cyanotoxins in an algal mat while at times finding none in the nearby water column. Gewin (2024) noted ongoing research that has documented the presence of such toxins in aerosols above lakes in other areas, indicating that direct water contact is not the only exposure pathway. Abbas et al. (2024) suggest that climate change will increase the frequency and magnitude of biogenic compound emissions from salt lakes.

Concentrated animal feeding operations, or feedlots (including dairy operations), in the Imperial Valley can degrade air quality, emitting PM, including bioaerosols that carry endotoxins capable of producing an inflammatory response when inhaled (D'Evelyn et al. 2021). The average population of feedlot cattle in the Imperial Valley is 400,000 animals, across 31 feedlot operations (Figueroa-Acevedo, pers. comm., 2024). Wei et al. (2023) reported *E. coli* in 50 of 300 samples collected near Imperial Valley feedlots, with detection decreasing linearly with distance from the feedlot but increasing by a factor of 2.57 when a nearby disturbance — such as plowing or truck traffic — occurred. They also found that lower relative humidity increased the likelihood of detecting *E. coli*, but found an inverse correlation with *E. coli* concentrations and wind speed, suggesting atmospheric dilution (Wei et al. 2023). Wilson et al. (2002) reported that, in a study in the Texas Panhandle, sites downwind of feedlot pens had higher numbers of bacteria and fungi than sites upwind.

VARIABILITY IN TIME AND SPACE

In this chapter, we described the many forms, phases, and sources of emissions impairing air quality in the region. Adding to the complexity is the fact that each of these factors, as well as the frequency and magnitude of emissions, also varies across both time and place in the region. As noted in Chapter 3, emissions can increase exponentially once threshold wind speeds are exceeded: infrequent or rare high-wind events generate much higher emissions than average winds. Similarly, a

64 See https://www.waterboards.ca.gov/press_room/press_releases/2021/FINAL%20Salton%20Sea%20HABs%20advisory%20pdf.pdf.

small fraction of the landscape, particularly disturbed areas, emits a disproportionately high amount of total fugitive dust emissions. Total emissions vary both intra- and interannually, while emissive locations can also vary in response to changing wind speeds, precipitation, localized flooding, disturbance, management efforts, and emergent vegetation. Rather than reviewing average emission rates, highlighting peak emission times and sources can provide a better understanding of the risks various air pollutants pose to local communities. We describe this variability to highlight the importance of broadening management actions beyond a specific pollutant or location.

For example, the only existing multi-year estimates of Salton Sea playa emissions suggest that they account for less than 1% of total PM_{10} emissions in the region (IID, annual). Emissions from the playa itself also vary across space and time. IID's most recent report states:

> a relatively small percentage of the playa is responsible for the majority of playa emissions. Specifically, approximately 10% of the playa is responsible for over 49% of playa emissions, and approximately 20% of the playa is responsible for nearly 73% of playa emissions. The majority of these areas already have existing or planned [dust control measures], which in actuality will mitigate the majority of these emissions. (IID 2024b)

As shown in Figure 17, IID reports that almost 90% of playa emissions come from the western and southern portions of the Salton Sea, due to less stable soil crusts, stronger prevailing winds, and greater playa exposure in these areas.

FIGURE 17. Playa Exposure and 8-Year Average Annual Emissions by Location (2016–2024)

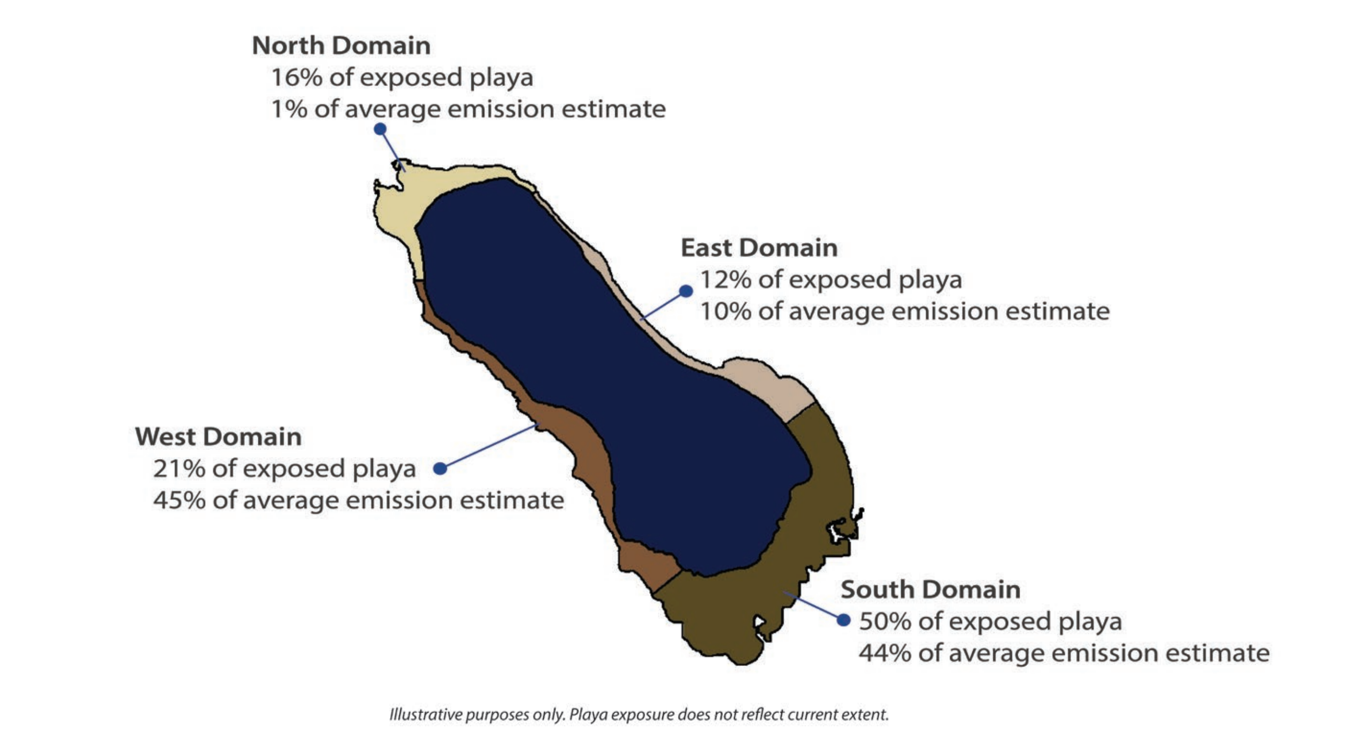


Figure courtesy of IID.

IID's annual emissions reports show high variability in emissions both year to year and within each year. The highest recorded dust emissions typically occur in March, April, and May, accounting for about 60% of total annual playa emissions. Just three dust events in the July 2021 through June 2022 reporting period contributed more than one-third of total playa emissions during that time (IID 2023). On many days, there are no dust emissions from exposed playa at all. As described further in the **Appendix**, there is also significant variability in total emissions from year to year.

While IID focuses on direct playa and western desert emissions, other studies have found a notable difference in dust sources in communities north of the Salton Sea versus those to the south. Miao et al. (2025) estimated the paths of the non-$PM_{2.5}$ fraction of PM_{10} based on 12 years of hourly data from six monitoring stations in the region. They found that dust in the Coachella Valley came predominantly from sparsely vegetated and urban areas, while dust in the Imperial Valley included a greater fraction of PM_{10} from agriculture and from Mexico.[65] They calculated that dust that had blown over the Salton Sea accounted for only 0.5% of the total at the Indio monitoring station (north of the lake), but 2.3% at the Brawley station (south of the lake).

Pollutant sources also vary over time, based in part on the seasonal variability of prevailing winds. SCAQMD is currently analyzing the physical and chemical composition of dust in the Eastern Coachella Valley, highlighting links between the timing of emissions and their sources. Initial findings indicate higher concentrations of lead and titanium during a May dust storm, correlated with winds blowing from the northwest over anthropogenic sources in the valley, while an August dust storm produced higher concentrations of selenium, correlated with Salton Sea spray (Sowlat 2024).

PROJECTED EMISSIONS

Projections of future emissions vary markedly depending on assumptions about the rate of playa exposure, local regulations, project implementation, and other factors. IID's model predicts that the Salton Sea's elevation will stabilize around 2047, with an estimated maximum reduction in the size of the Salton Sea of more than 84,000 acres. Parajuli & Zender (2018) projected a 38% decrease in the size of the Salton Sea by 2030, with PM_{10} emissions in the region increasing by 11%. They also projected that newly exposed playa would concentrate at the center of the southwest side of the lake, and that dust mobilized from the exposed playa would generally move southward. With these increased emissions, the Salton Sea region would exceed California's PM_{10} standard for an additional 22 days per year (Parajuli & Zender 2018).

The SSMP used the CALPUFF dispersion model to predict and analyze future PM_{10} concentrations at and around the Salton Sea for the air quality evaluation in its 2024 Long Range Plan.[66] The model assumes that the SSMP will have constructed 29,800 acres of habitat and dust suppression projects on Salton Sea playa by the end of 2028. CALPUFF predicts that, based on prevailing winds, future Salton Sea playa PM_{10} emissions[67] generally will not affect communities north of the lake and that

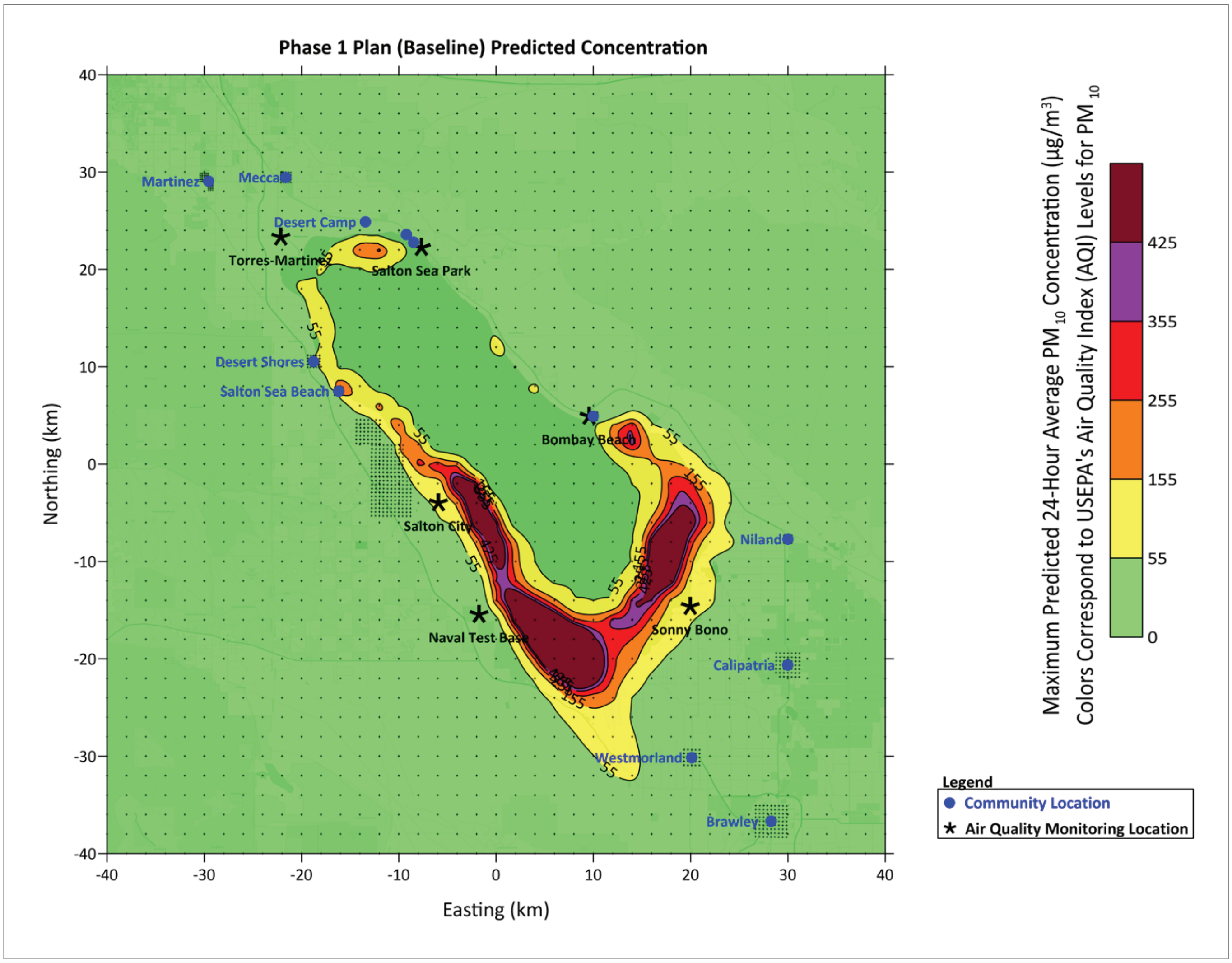
65 Miao et al. (2025) define the non $PM_{2.5}$ fraction of PM_{10} (or particles with an aerodynamic diameter between 2.5 and 10 micrometers) as coarse PM (PMc).

66 See LRP Appendix E Air Quality Evaluation for a description of the CALPUFF model and a detailed discussion of projected playa PM_{10} emissions and air quality impacts.

67 The CALPUFF model does not account for non-playa PM_{10} sources or project regional changes to ambient PM_{10} concentrations.

playa emissions affecting communities to the south will not exceed ambient air quality standards[68] (CNRA 2024b). Figure 18, from the Long Range Plan, shows CALPUFF-projected maximum 24-hour average PM_{10} concentrations, projecting hazardous conditions along many areas of the shoreline (see Table 11 for AQI categories). Based on King et al. (2011), CNRA increased its estimated exposed playa emissions rate by a factor of six in 2014 compared to its 2006 estimate (CNRA 2014).

Figure 18. Modeled Maximum Predicted 24-Hour Average PM_{10} Concentrations



Source: CNRA 2024b, App E (p. 32).

68 EPA standards were not set with region-specific contaminants in mind. All dust can impair public health, but, as discussed in Chapter 9, the specific chemical and biological characteristics of the pollutant can increase its toxicity. Chapter 7 describes regulated "criteria pollutants," which were not assessed by the CALPUFF model and not analyzed as part of the SSMP's Long Range Plan air quality evaluation.

7. Air Quality

Several factors, including wind speed, availability of source materials, and diffusion rates, affect the conversion from emissions (often reported as mass per unit area per unit of time, such as g/m^2/sec or tons/acre/year) to concentrations in the air (often reported as μg/m^3 or ppm), especially since pollutant concentrations may diminish over time and distance from the source. Additionally, the concentration at which a specific contaminant poses a health risk can vary by orders of magnitude. For example, under its Air Quality Index (AQI), the U.S. Environmental Protection Agency (EPA) considers up to 53 parts per billion (ppb) of NO_2 to be "good" air quality, while concentrations of up to 4,400 ppb CO are also considered "good."[69] Table 11 shows the color-coded EPA AQI and the criteria pollutant concentration "breakpoints" for each category. The highest value among the six criteria pollutants[70] determines the reported AQI (e.g., the concentration of ozone at a given time might be "moderate" while PM_{10} is "unhealthy," so the AQI overall would be "unhealthy"). These index values are not additive: "moderate" scores for several pollutants still yield an AQI of "moderate," not the sum of their AQI scores. While a person may be sensitive to more than one pollutant, the reported AQI does not reflect cumulative exposures. The AQI also does not reflect concentrations of other pollutants such as hydrogen sulfide, though regional air boards often issue warnings if concentrations of such pollutants exceed thresholds, such as 30 ppb for hydrogen sulfide.

While a person may be sensitive to more than one pollutant, the reported AQI does not reflect cumulative exposures.

69 See https://aqs.epa.gov/aqsweb/documents/codetables/aqi_breakpoints.html and https://www.airnow.gov/aqi/aqi-basics/.

70 The six criteria pollutants are ground-level ozone (O_3), $PM_{2.5}$, PM_{10}, CO, SO_2, and NO_2.

TABLE 11. Color-Coded Air Quality Index and Criteria Pollutant Breakpoints

THESE BREAKPOINTS...							...EQUAL THIS AQI	...AND THIS CATEGORY	
O_3 (ppm) 8–hour	O_3 (ppm) 1–hour	$PM_{2.5}$ (µg/m³) 24–hour	PM_{10} (µg/m³)	CO (ppm) 8–hour	SO_2 (ppb) 1–hour	NO_2 (ppb) 1–hour			AQI Description
0–0.054		0–9.0	0–54	0–4.4	0–35	0–53	0–50	Good	Satisfactory, air pollution poses little or no risk
0.055–.07		9.1–35.4	55–154	4.5–9.4	36–75	54–100	51–100	Moderate	Acceptable, though there may be a risk to people who are unusually sensitive to air pollution
0.071–0.085	0.125–0.164	35.5–55.4	155–254	9.5–12.4	76–185	101–360	101–150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
0.086–0.105	0.165–0.204	55.5–125.4	255–354	12.5–15.4	186–304	361–649	151–200	Unhealthy	Some members of the general public may experience health effects. Members of sensitive groups may experience more serious health effects.
0.106–0.2	0.205–0.404	125.5–225.4	355–424	15.5–30.4	305–604	650–1249	201–300	Very unhealthy	Health alert: The risk of health effects is increased for everyone.
0.201–	0.405+	225.5+	425+	30.5+	605+	1250+	301+	Hazardous	Health warning of emergency conditions: everyone is more likely to be affected.

O3 – ozone; CO – carbon monoxide; S02 – sulfur dioxide; NO2 – nitrogen dioxide

Source: U.S. EPA

REGULATORY SETTING

State and federal air quality regulations establish standards for emissions in the Salton Sea region and govern many activities. These are codified by local rules and regulations established and enforced by the Imperial County Air Pollution Control District (ICAPCD) and the South Coast Air Quality Management District (SCAQMD)[71] Additional laws, regulations, and State Water Board orders regarding the QSA and the Salton Sea specifically address exposed lakebed and emissions. We briefly discuss these below.

State/Federal Air Quality Status

Sections 108 and 109 of the Clean Air Act guide the establishment, review, and revision of the National Ambient Air Quality Standards (NAAQS), which set the standards for six criteria air pollutants: ozone, $PM_{2.5}$, PM_{10}, carbon monoxide, nitrogen dioxide, sulfur dioxide, and lead.[72] The EPA designates a geographic area as being in “attainment” if it meets the national standard, “non-attainment” if it exceeds the standards for a pollutant, or “unclassified” if there is insufficient information to determine its status (US EPA 2014). The California Ambient Air Quality Standards (CAAQS) follow a process similar to that of the federal process, but state standards are often more stringent and include additional pollutants, such as sulfates, hydrogen sulfide, and visibility-reducing particles (CARB n.d.-a). The tables below show state designations for the Salton Sea Air Basin and federal designations for the Coachella Valley and Imperial County.

The EPA designated the Imperial Valley and the Coachella Valley as serious nonattainment areas for PM_{10} in 1987 (US EPA n.d.). In 1993, the EPA reclassified Coachella Valley from a moderate to a serious nonattainment area. The Coachella Valley’s 1991 implementation plan indicated that 97% of the area’s PM_{10} emissions were due to fugitive dust emitted from construction activities, re-entrained dust from paved roads, and windblown dust from agricultural and disturbed lands (EPA 1993). In 2020, the EPA reclassified the Imperial Valley from nonattainment to attainment for PM_{10}. The Coachella Valley remains a federal nonattainment area for PM_{10}, where hourly concentrations exceed the 50 $\mu g/m^3$ standard roughly one-third of the time (Espinoza 2023). The Imperial Valley is a federal nonattainment area for $PM_{2.5}$. The Salton Sea Air Basin is a state nonattainment area for PM_{10} and ozone, one of 12 state air basins[73] in nonattainment for PM_{10} and one of 10 in nonattainment for ozone as of 2023. Four of the state’s air basins, not including the Salton Sea Air Basin, are in nonattainment for $PM_{2.5}$, though the EPA recently lowered the annual mean standard for $PM_{2.5}$ from 12 $\mu g/m^3$ to 9 $\mu g/m^3$, which may lead to the basin being redesignated as nonattainment (Lieb & Faloona 2025).

71 See https://apcd.imperialcounty.org/rules-and-regulations/ for ICAPCD’s rules and regulations and http://www.aqmd.gov/home/rules-compliance/rules/scaqmd-rule-book for SCAQMD’s rules and regulations.

72 Hydrogen sulfide was also originally included in the proposed criteria pollutant list (Batterman et al. 2023).

73 California has 15 air basins (see https://ww2.arb.ca.gov/sites/default/files/classic/isd/fuels/gasoline/rvp/airbasinbw.pdf) and 35 local Air Districts (see https://ww2.arb.ca.gov/california-air-districts).

TABLE 12. State Area Designations — Salton Sea Air Basin

POLLUTANT	STANDARD (CONCENTRATION / AVERAGING TIME)	DESIGNATION (2022)
Ozone	0.09 ppm / one hour OR 0.070 ppm / 8 hours	Nonattainment
$PM_{2.5}$	12 µg/m³ / 24-hour samples (annual arithmetic mean)*	Attainment*
PM_{10}	50 µg/m³ / 24 hours (10am-6pm PST)	Nonattainment
Carbon monoxide	20 ppm/hour OR 9.0 ppm / 8 hours	Attainment
Nitrogen dioxide	0.18ppm / 1 hour	Attainment
Sulfur dioxide	0.25 ppm / 1 hour	Attainment
Sulfates	25 µg/m³ / 24 hours	Attainment
Lead	1.5 µg/m³ / 30-day average	Attainment
Hydrogen sulfide	0.03 ppm / 1 hour	Unclassified
Visibility reducing particles (e.g.: dust)	In sufficient amount to produce extinction coefficient of 0.23 per kilometer due to particles when relative humidity is less than 70%	Unclassified

*As noted in Table 13, the EPA lowered the annual mean standard from 12 µg/m³ to 9 µg/m³.[74] Lieb & Faloona (2025) state that the new, lower standard means the Salton Sea Air Basin will be redesignated as being in nonattainment.

Sources: CARB (2024b, n.d.-b)

TABLE 13. Federal Area Designations — Coachella Valley and Imperial Valley

POLLUTANT	STANDARD (CONCENTRATION / AVERAGING TIME)	COACHELLA VALLEY DESIGNATION (2022)	IMPERIAL VALLEY DESIGNATION (2022)
Ozone	0.070 ppm / 8 hours	Nonattainment	Nonattainment
$PM_{2.5}$	35 µg/m³ / 24 hours*	Unclassified/attainment	Nonattainment
PM_{10}	150 µg/m³ / 24 hours	Nonattainment	Attainment
Carbon monoxide	35 ppm / 1 hour OR 9 ppm / 8 hours	Attainment	Attainment
Nitrogen dioxide	100 ppb / 1 hour	Attainment	Attainment
Sulfur dioxide	75 ppb / 1 hour	Attainment	Attainment
Lead	1.5 µg/m³ / calendar quarter	Attainment	Attainment

*Effective May 6, 2024 (with technical revisions December 19, 2024), the EPA revised the primary annual $PM_{2.5}$ standard but retained the primary 24-hour standard referenced here.[75]

Source: CARB (n.d.-b)

74 See CalEPA discussion of the new rule and subsequent redesignations at https://ww2.arb.ca.gov/our-work/programs/state-and-federal-area-designations/federal-area-designations/pm2-5.

75 Per 40 CFR Parts 50 and 58 (12/19/2024), the EPA "revised the primary annual $PM_{2.5}$ standard by lowering the level from 12.0 µg/m³ to 9.0 µg/m³, retained the current primary 24-hour $PM_{2.5}$ standard and the primary 24-hour PM_{10} standard, retained the secondary 24-hour $PM_{2.5}$ standard, secondary annual $PM_{2.5}$ standard, and secondary 24-hour PM_{10} standard," available at (89 FR 16202) and (89 FR 103652).

Table 14 shows that multiple days exceeded federal and state PM_{10} and $PM_{2.5}$ standards in the Salton Sea Air Basin each year from 2016–2023. The Imperial County 2018 PM_{10} Plan accounts for these exceedance days as "exceptional events," where PM_{10} emissions occurred as a result of uncontrollable natural events such as wildland fires or high-wind episodes (Dessert et al. 2018a).

TABLE 14. Days in Exceedance for Nonattainment Pollutants in the Salton Sea Basin

SALTON SEA AIR BASIN DAYS IN EXCEEDANCE FOR NONATTAINMENT POLLUTANTS (STATE AND FEDERAL)									
Pollutant	**Standard**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
PM_{10}	National - 150 μg/m³ in 24 hours	18	No data	No data	2.1	10	3	19.4	14.4
PM_{10}	State - 50 μg/m³ in 24 hours	135.7	81.5	113	112	166.3	150.7	163.9	134.1
$PM_{2.5}$	35 μg/m³ in 24 hours	5.9	5.5	6.1	1.1	5.4	2.1	5.1	3.1
Ozone	National - 0.070 ppm 8-Hour Standard	46	57	56	43	49	35	39	38
Ozone	State - 0.09 ppm 1-Hour Standard	6	18	11	5	9	10	7	8

Source: CARB's iADAM and AQMIS databases

CARB established the Community Air Protection Program to implement AB 617,[76] aiming to reduce exposure to harmful air pollutants in high-priority areas or designated "disadvantaged communities." Disadvantaged communities are defined as areas that are either "disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects, exposure of environmental degradation," or as areas with "concentrations of people that are of low income, high unemployment, low levels of homeownership, high rent burden, sensitive populations, or low levels of educational attainment," or both.[77] Figure 1 shows the boundaries of the three designated AB 617 communities in the region.

As directed by SB 535, the California Environmental Protection Agency identified the Eastern Coachella valley (ECV) and the Imperial Valley as disadvantaged communities in 2017. In 2019, CARB selected the ECV and the Calexico–Heber–El Centro corridor in the Imperial Valley for Community Air Monitoring Plans and Community Emissions Reduction Programs due to concerns over the impacts of fugitive dust from various sources (CARB n.d.-b). The North Imperial Phase I area, encompassing Westmorland, Brawley, and Calipatria, was selected in 2022 for a Community Air Monitoring Plan and Community Emissions Reduction Program (ICAPCD n.d.).

76 AB 617 Nonvehicular Air Pollution: Criteria Air Pollutants and Toxic Air Contaminants, 2017.

77 California Health and Safety Code Chapter 4.1. Greenhouse Gas Reduction Fund Investment Plan and Communities Revitalization Act [39710-39723].

State Water Board Orders

In addition to state and federal air quality rules and regulations, California's State Water Resources Control Board sanctioned an air quality monitoring and mitigation plan through its continuing jurisdiction over the IID-SDCWA water transfer agreement. State Water Board Order WRO 2002-0013[78] directed IID to implement the four-step air quality monitoring and mitigation plan described in the water transfer final EIR[79] for "as long as project-related air quality impacts occur." These four steps are:

- Restrict public access, especially OHVs, to minimize soil disturbance.
- Research and monitor.
- Create or purchase offsetting emission reduction credits.
- Direct emission reductions at the Salton Sea.

California State Water Board Order WR 2017-0134,[80] adopted in November 2017, set annual habitat and dust suppression project acreage milestones "to address public health and environmental concerns during Phase 1 of the SSMP." The order directs the SSMP to complete a total of 29,800 acres of projects by the end of 2028, at least half of which "shall provide habitat benefits for fish and wildlife that depend on the Salton Sea ecosystem," with the remainder providing dust suppression. The order also directs the SSMP to submit an annual report to the State Water Board describing annual project implementation and related information.[81]

Water Quality

As described in Chapter 4, the Salton Sea's impaired water quality contributes to chemical and biological contaminants, including hydrogen sulfide and harmful algal blooms, that can enter the atmosphere and impair air quality. The California Regional Water Quality Control Board, Colorado River Basin Region, has jurisdiction over the study area. The Regional Board has several efforts underway to improve water quality in the Salton Sea and its tributaries, including multiple total maximum daily load (TMDL) control plans. The Regional Board is currently developing a Salton Sea Dissolved Oxygen and Nutrients TMDL.[82]

78 Available at www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/orders/2002/wro2002-13.pdf.

79 IID Water Conservation and Transfer Project, Final Environmental Impact Report/Environmental Impact Statement, dated June 2002 (incorporates Draft EIR/EIS), issued by IID, available at https://www.iid.com/water/library/qsa-water-transfer/environmental-assessments-permits.

80 Available at www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/orders/2017/wro2017_0134_with_exhibit_a.pdf.

81 See https://www.waterboards.ca.gov/waterrights/water_issues/programs/salton_sea/ for additional information about the annual Salton Sea workshops and the State Water Board's role.

82 See https://www.waterboards.ca.gov/coloradoriver/water_issues/programs/salton_sea/ for more information on Regional Board activities and links to relevant TMDLs.

8. Remediation

Local and state agencies have implemented projects and control measures in the study region, reducing emissions and improving air quality. For example, more than 5,000 acres of dust suppression projects have been constructed on exposed Salton Sea playa to date, primarily on the most emissive portions of the playa, and emergent vegetation has grown to cover thousands more acres (see Table 2). Rules and regulations (see Chapter 5) have also improved air quality. SCAQMD estimates that, in the absence of various regulatory measures, total diesel emissions in the South Coast Air Basin (excluding the Coachella Valley)[83] would be 86% higher than current rates (SCAQMD 2021b). The following section briefly describes some of the emissions remediation measures in the region, including state and local efforts focused on Salton Sea playa and other emissions sources, as well as representative efforts to reduce exposure to such emissions. Where available, we include information on costs and estimated efficacy.

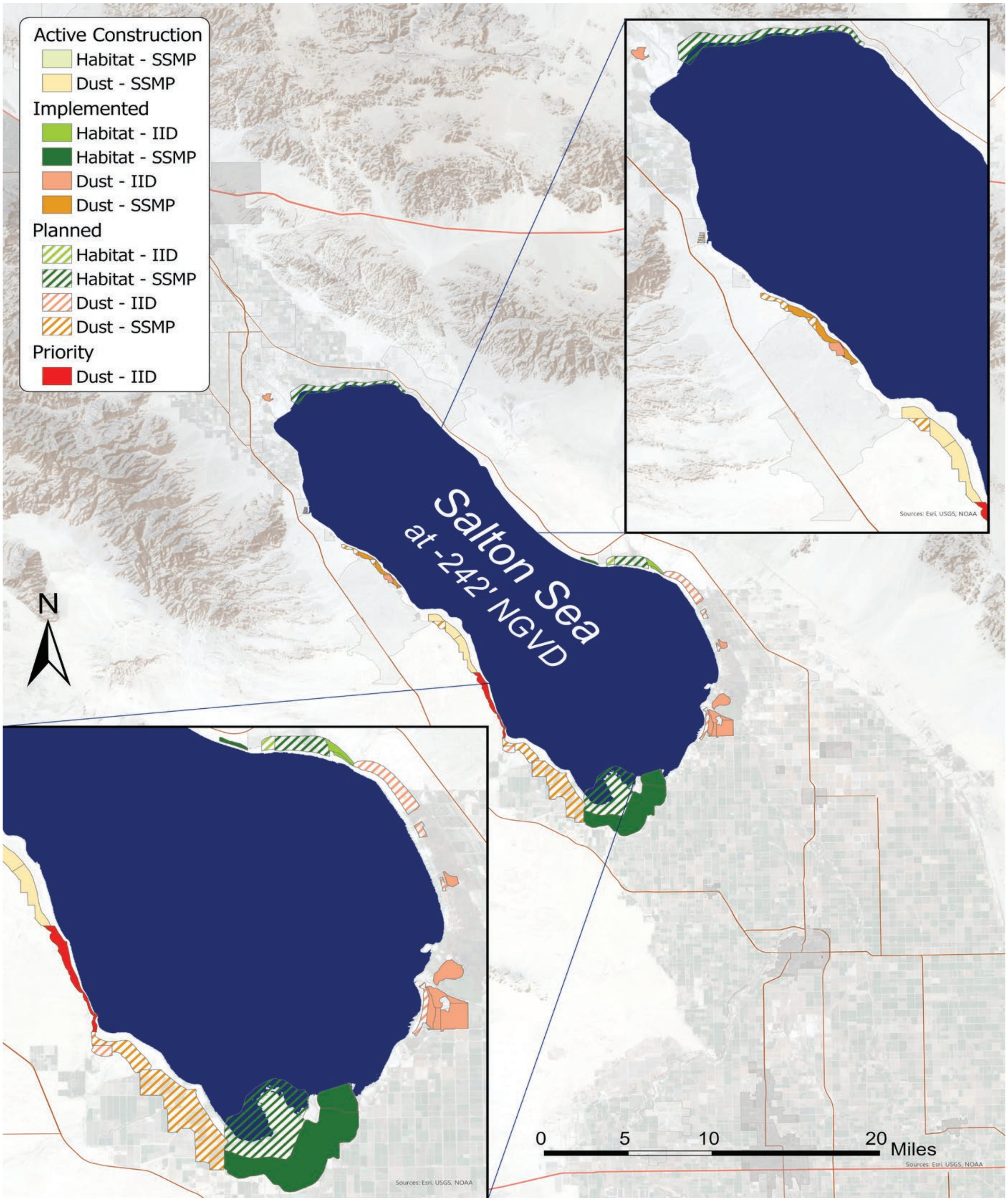
STATE PROJECTS

To date, the SSMP has constructed 2,878 acres of temporary and permanent dust suppression projects around the Salton Sea. Future habitat projects will replace some of the temporary project acreage, especially around the New River delta.[84] Figure 19 shows the extent and location of the SSMP's roughly 1,400 acres of permanent dust suppression projects. These projects include rows of straw bales and, on the west side of the lake, drip irrigation to help establish local plants, measures intended to interrupt blowing winds and stabilize the playa. The total cost of these projects to date is about $49 million, primarily for wells, irrigation, plants, bales, staff time, and access road construction. The SSMP reports that, over a 3-year monitoring period, these methods have reduced dust-emitting processes by more than 95% at the Clubhouse C vegetation enhancement project, near Salton City (CNRA 2025).

83 The MATES V report relies on empirical data from a network of 10 monitoring stations in the South Coast Air Basin but models emissions and risk in the Coachella Valley (SCAQMD 2021b).

84 See SSMP Project Tracker at https://projects.saltonsea.ca.gov/Results/ProgressDashboard.

FIGURE 19. State and Local Remediation Projects



Sources: IID, SSMP

Habitat projects also suppress dust. The SSMP has constructed 347 acres of open-water habitat projects at and around the New River delta, as shown in Figure 19, and commissioned and began operating nearly 2,000 additional acres of habitat projects in May 2025. The SSMP has completed construction of the roughly 2,800-acre central and west ponds of the Species Conservation Habitat (SCH) project and could fill and operate them in 2026; most of this area is currently managed with temporary dust suppression measures. Another 4,400 acres of SCH habitat expansion are being designed and may be constructed, contingent on future funding (CNRA 2024a).

LOCAL PROJECTS

California statute and State Water Resources Control Board (SWRCB) Order WRO 2002-0013 directed IID to implement a four-step plan for PM_{10} dust emission mitigation as a condition of the QSA water transfers. Through June 2024, IID had constructed 2,880 acres of dust control measures, identified 660 acres of priority playa, and planned construction of an additional 1,570 acres (IID 2024a). IID expects to have spent about $55 million on its Salton Sea Air Quality Mitigation Program by June 2025, including emissions inventories, planning, air quality monitoring, and project implementation and maintenance (QSA JPA 2024).

The Imperial County Air Pollution Control District (ICAPCD) and the South Coast Air Quality Management District (SCAQMD) are regulatory agencies that work to clean the air and protect the health of the people in their respective jurisdictions. ICAPCD is part of the county administration, serving roughly 180,000 residents, with an annual budget of about $20 million and 29 full-time employees. SCAQMD is an independent agency covering much of Los Angeles, Orange, and Riverside counties, serving about 16.6 million people, with an annual budget of about $196 million and 913 full-time employees. Both agencies regulate numerous air pollutants and both manage AB 617 communities[85] within their jurisdictions, responding to community concerns and implementing projects to reduce emissions, improve monitoring, and reduce exposure to air pollution.

Figure 1 shows the locations of the two AB 617 communities in Imperial County. The *2024 El Centro–Heber–Calexico Community Annual Report*[86] notes two main objectives (reducing exposure to toxic air contaminants and $PM_{2.5}$) and 28 strategies to meet these objectives, including “regulatory, air quality permitting, enforcement, incentives-based, land use, transportation, and mitigation strategies” (ICAPCD 2024). The report describes actions taken to date, including reductions in the maximum allowable agricultural acres burned per day and prioritization of smaller burns, resulting

85 AB 617 (C. Garcia, Chapter 136, Statutes 2017) directs CARB and local air districts to enact measures that promote public health and welfare by reducing air pollution on a local scale, particularly in communities disproportionately burdened by air pollution.

86 Available at https://www.icab617community.org/_files/ugd/40c59d_6f7f96735303449c90aaaf77e9fd720a.pdf.

in an estimated reduction of up to 6.6 tons per day of $PM_{2.5}$. ICAPCD also completed a paving project in Heber to reduce the extent of unpaved roads and parking lots, thereby decreasing annual PM_{10} emissions. In addition, ICAPCD funded the installation of 30 air quality filtration systems at schools in Calexico, El Centro, and Heber.[87]

Figure 1 also shows the location of the Eastern Coachella Valley (ECV) AB 617 community. The main objectives of their Community Emission Reduction Plan (CERP) are to reduce air pollution emissions and exposure and to address the community's air quality priorities. The ECV CERP identifies seven priorities: land use, the Salton Sea, pesticides, road dust, open burning, diesel emissions, and the Greenleaf power plant.[88] Strategies to achieve these objectives include installing air filters at homes and schools near the Salton Sea, home weatherization projects, paving roads, and planting trees (SCAQMD 2021a). As of August 8, 2024, the program had provided 378 air filters to 294 households.[89] ECV projects that it will achieve its 5-year emissions reduction targets for nitrogen oxide (NOx) and diesel particulate matter (SCAQMD 2021a).[90]

87 However, some have expressed concerns about the efficacy of these systems and the limited post-installation monitoring and testing (Porter, pers. comm., August 8, 2024).

88 SCAQMD AB 617 2024 Annual Progress Report, available at 2024 Final Annual Progress Report.

89 Ibid.

90 See https://www.aqmd.gov/docs/default-source/ab-617-ab-134/steering-committees/2024-final-annual-progress-report-apr-november-board-package.pdf?sfvrsn=8.

9. Public Health

More than 30 years ago, Dockery et al. (1993) reported that "exposure to air pollution contributes to excess mortality." There are clear, well-established links between air pollution and higher rates of disease and death, even at low levels of pollution (Pozzer et al. 2023). However, factors such as distance to pollution sources, duration of exposure, and exposure to complex pollutant mixtures complicate efforts to attribute effects on public health to ambient air pollution exposures (Wu, pers. comm., 2025). Multiple studies have found that short-term, and especially long-term (or "chronic"), exposure to air pollution can reduce life expectancy and increase the risk of heart disease, asthma and other respiratory conditions, diabetes, and cancer (Pozzer et al. 2023). Research on the public health impacts of air pollution in the Salton Sea region has grown tremendously since the release of our 2014 report, as shown in Table 5. This section briefly summarizes general research on the health effects of air pollution, as well as recent findings on the particular impacts of Salton Sea contaminants.

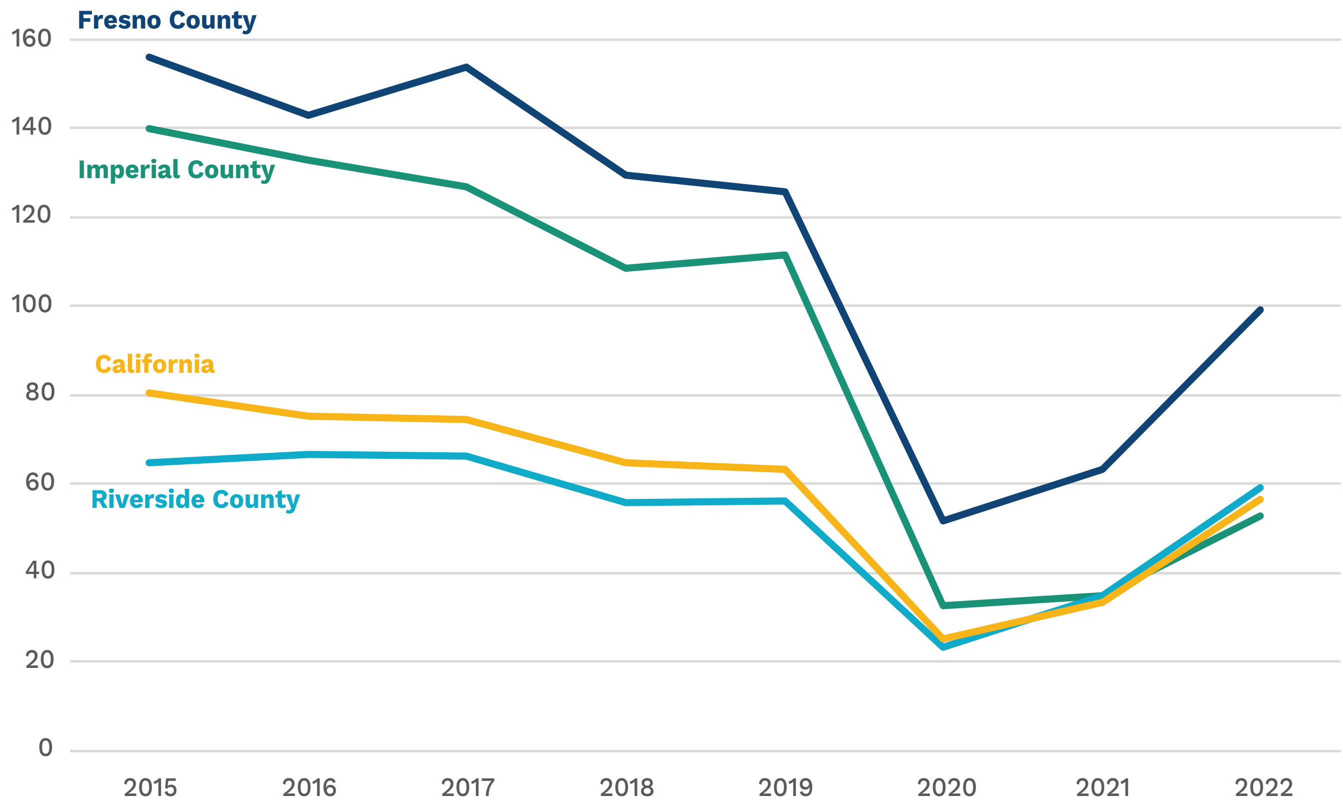
In our 2014 report, we noted the many studies outside of the Salton Sea region documenting links between PM_{10} exposure and a range of adverse health outcomes (Cohen 2014). For example, Norris et al. (1999) found that elevated PM_{10} concentrations were associated with increased asthma-related emergency room visits among children. Anderson et al. (2005) reviewed 95 studies and found a strong positive association between PM_{10} and asthma-related hospital admissions. Zanobetti and Schwartz (2005) found that a 10 μg/m^3 increase in PM_{10} concentrations was associated with a 0.65% increase in the risk of hospitalization for heart attacks among elderly populations.

Figure 20 shows relative rates of emergency department visits for asthma among children (under 18 years of age) in Imperial and Riverside counties, including rates for Fresno County and California as a whole for comparison (Fresno County typically experiences the highest such rates in the state).[91] Although these county rates include children outside the study area, they suggest that rates for children within the study area (using Imperial County as a proxy) were about 75% higher than the state average prior to the pandemic (pre-2020). Asthma hospitalization rates were also about 75% higher than the state average for the same period (see Figure 21). The roughly 27% increase in hospitalization rates between 2018 and 2019 in Imperial County shows a strong disconnect from the dramatic decline in PM_{10} emissions that year, as shown in Table 8, though this may reflect

91 The American Lung Association (2025) reports that Fresno County experienced the third-highest average annual $PM_{2.5}$ concentrations in the state for the years 2021 to 2023, after Kern and Tulare counties. Riverside County ranked 11th, while Imperial County did not make the list of the 25 most polluted counties. See https://www.lung.org/research/sota/city-rankings/states/california for county-level rankings for ozone and $PM_{2.5}$ pollution in California.

differences between the calendar year reported in Figure 21 and the reporting period shown in Table 8. It may also suggest that factors beyond PM_{10} emissions, such as ozone or $PM_{2.5}$ concentrations, or the biological or chemical characteristics of PM_{10} itself, are more closely associated with hospitalization rates.

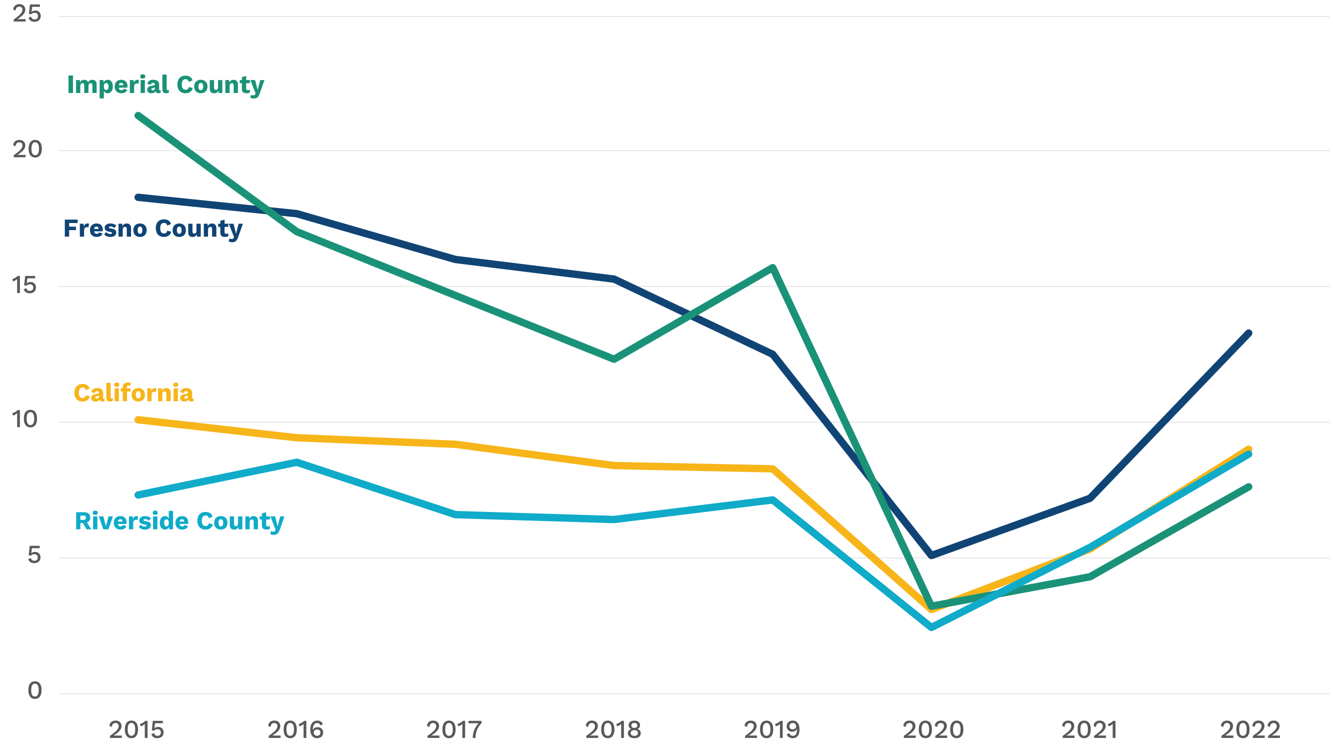
FIGURE 20. Age-Adjusted Pediatric Asthma Emergency Department Visit Rates, 2015–2022



Source: California Department of Public Health[92]

92 The age-adjusted rate is calculated by dividing the number of emergency department visits for asthma by the estimated population in that county and age group, age-adjusting to the 2000 U.S. Census and multiplying by 10,000. See https://data.chhs.ca.gov/dataset/asthma-emergency-department-visit-rates.

FIGURE 21. Age-Adjusted Pediatric Asthma Hospitalization Rates, 2015–2022



Source: California Department of Public Health[93]

Sculley et al. (2002) note that the variable composition of particulate matter — including physical characteristics such as size, shape, density, and whether it is liquid or solid — as well as its specific chemical composition, can affect its public health impacts. Some particles may act as physical irritants, particularly to the respiratory tract, while others, such as heavy metals, may be systemic toxins. Some airborne particles can also be carcinogenic (Sculley et al. 2002; Turner et al. 2020). The following section describes some public health impacts associated with specific physical, chemical, and biological attributes of air pollution.

PHYSICAL IMPACTS

Size matters. While the respiratory tract typically can block or remove particles larger than 10 microns in diameter (greater than PM_{10}), PM_{10} can lodge in the lungs and $PM_{2.5}$ can lodge in the alveoli, where the lungs exchange oxygen and carbon dioxide with the bloodstream. Water-soluble $PM_{2.5}$ can pass quickly into the bloodstream itself. Short-term exposure to $PM_{2.5}$ and PM_{10} can cause asthma symptoms in asthmatic children and adults, while long-term exposure can compromise lung function (Guarnieri & Balmes 2014). $PM_{2.5}$ is associated with 220,000 lung cancer mortalities and 3.5 million cardiopulmonary mortalities worldwide each year (Anenberg et al. 2010). Short-term exposure to $PM_{2.5}$ or smaller particles can trigger cardiovascular disease-related mortality and other non-fatal

93 See above description of age-adjusted rates. Data available at https://data.chhs.ca.gov/dataset/asthma-hospitalization-rates-by-county.

health events (Bennion et al. 2007). Long-term exposure to $PM_{2.5}$ increases the risk of cardiovascular mortality and reduces life expectancy (Brook et al. 2010). Du et al. (2016) summarize multiple studies linking PM to cardiovascular disease.[94]

A community-based participatory research project on the north end of the Salton Sea found a high incidence of nosebleeds, allergies, and asthma among children, which caregivers ascribed to the Salton Sea, pesticides, and burning trash (Cheney et al. 2023). Johnston et al. (2024) assessed guardian-reported respiratory symptoms among schoolchildren near the south end of the Salton Sea and found that exposure to 100 hours of dust storms — defined as hourly PM_{10} concentrations greater than 150 μg/m^3 — in the preceding year was associated with a slight increase in symptoms among children living within six miles of the Salton Sea shoreline. Each additional 100-hour increment of dust storm exposure increased some respiratory symptoms by almost 10% among children living near the Sea. Johnston et al. (2024) also found no correlation between average annual PM_{10} concentrations and respiratory symptoms, though the study did not account for wind direction.

Nationally, Law et al. (2025) estimate that climate change has exacerbated wildfire-generated emissions, leading to an additional 1,000 $PM_{2.5}$ -related deaths per year, on average. A study of 13 cities in southern Europe found that a short-term 10 μg/m^3 increase in PM_{10} from deserts was associated with a 0.65% increase in hospital admissions and mortality rates (Stafoggia et al. 2016). Miao et al. (2025) correlated a 10 μg/m^3 increase in PM_{10} (excluding $PM_{2.5}$) that they identified as coming from the Salton Sea with an 8.6% rise in hospital admissions for respiratory factors, a risk that increased to nearly 25% when associated with Salton Sea algal and gypsum bloom events.[95] The authors note the need for further research to identify the specific contaminant(s) and mechanisms that may be causing these adverse health impacts (see *Biological Impacts* for further discussion of potential mechanisms and impacts). Jones & Fleck (2020) report that, based on calculations made from satellite data calibrated with ground-based monitoring data, average annual $PM_{2.5}$ concentrations increased by 1.55 μg/m^3 from 1998 to 2014 in Imperial and Riverside counties, which they associate with a cumulative increase of about 4.2 instances per 100,000 of lower respiratory mortality.

Dust storms can impair visibility, increasing the risk of traffic accidents, injuries, and fatalities. Although Ashley et al. (2015) ascribe the majority of visibility-impaired vehicular accidents to fog, Van Pelt et al. (2020) report multiple fatal vehicle accidents caused by dust clouds along one stretch of Interstate 10 in New Mexico near a dry lakebed. Large dust storms, known as "haboobs,"[96] periodically impair visibility in the Salton Sea region. For example, on October 6, 2022, SCAQMD issued and then extended a windblown dust advisory for a storm (Graff 2022):

> The geographical area of this advisory has also been expanded to cover the Coachella Valley, Eastern Riverside County and much of the Inland Empire. Elevated PM_{10} levels have become more widespread

94 In 2024, the EPA stated: "the health effects evidence for $PM_{10\text{-}2.5}$ exposures is somewhat strengthened since past reviews, although the strongest evidence still only provides support for a suggestive of, but not sufficient to infer, causal relationship with long- and short-term exposures and mortality and cardiovascular effects, short-term exposures and respiratory effects, and long-term exposures and cancer, nervous system effects, and metabolic effects" (89 FR 16202).

95 See Tiffany et al. (2007) for a discussion of Salton Sea gypsum blooms.

96 The image on the cover of this report is a haboob.

> throughout the day on Friday as winds transported dust far from the regions initially affected by the haboob, or wall of dust, yesterday evening. Since vast amounts of dust are still airborne, PM_{10} concentrations are expected to decline slowly from southeast to northwest.[97]

On September 3, 2023, another dust storm impaired visibility and led to a multi-vehicle collision that killed three people in Palm Springs (Damien & Rode 2023). Figure 22 shows dust impairing visibility along North Gene Autry Road in the Coachella Valley, leading to a road closure (Ludwig 2024).

FIGURE 22. Dust Impairing Visibility in the Coachella Valley

Source: (Shutterstock) (Ludwig 2024) https://patch.com/california/palmdesert/santa-ana-winds-palm-desert-higher-temps-return

97 SCAQMD windblown dust advisory available at http://www.aqmd.gov/docs/default-source/news-archive/2022/wbd-extened-oct7-2022.pdf?sfvrsn=8.

Parajuli et al. (2024) recently found that evaporation from the intensely irrigated fields in the Imperial Valley can increase nighttime heat stress in downwind areas. Imperial County has the highest number of heat-related illness cases per worker in the state. This humidity-related increase in wet bulb globe temperature, in a region where the average low temperature in the summer is about 82°F, can exacerbate other health challenges, especially for vulnerable populations (Parajuli et al. 2024).

CHEMICAL IMPACTS

While the size of particulate matter (PM) is associated with asthma and other respiratory ailments, fine and ultrafine PM can also carry chemical and biological components that exacerbate these impacts. Power plants, smelters, incinerators, furnaces, and vehicles can emit trace metals that adhere to dust particles. These metals can cause oxidative stress and contribute to symptoms commonly associated with asthma (Schroeder et al. 1987). Manalis et al. (2005) observed a strong correlation between heavily traffic-impacted sites in their study in Greece with nitrous oxides and copper concentrations, supporting other research associating copper with vehicle traffic. The presence of copper in dust can increase its toxicity, leading to potential human health effects (Frie et al. 2019).

Our 2014 report noted that toxic constituents in dust emitted from Salton Sea playa could pose additional public health impacts, but that insufficient information existed at the time to assess such impacts. Since then, several studies have documented the composition of playa dust and the additional health impacts of other airborne toxics in the region. For example, Frie et al. (2019) found anthropogenic trace metals (including antimony, arsenic, zinc, cadmium, lead, and sodium), as well as anthropogenic copper, in dust from the Salton Sea region. SCAQMD (2021) measured concentrations of 32 different metals, various forms of carbon, and indicators of burned biomass. Miao et al. (2025) note that these metals can cause respiratory illnesses. Hung et al. (2024) note that, as the Salton Sea continues to shrink, toxic heavy metals sequestered in the lakebed may be exposed and emitted with playa dust. However, Frie et al. (2017) found that neither playa emissions nor regional PM had high toxic metal concentrations, suggesting that they were not "exceptionally toxic."

Black carbon, generated by fossil fuel combustion, is associated with mortality and adverse respiratory impacts in children (Kelly & Fussell 2012). Janssen et al. (2011) found that increases in black carbon particle concentrations (in $\mu g/m^3$) led to 10 times the increase in mortality and hospital admissions compared to similar increases in PM_{10} and $PM_{2.5}$ concentrations. Miao et al. (2025) also note the higher toxicity of traffic-related emissions relative to other sources. SCAQMD (2021) reports that diesel emissions[98] account for half of the air toxics cancer risk in its region, a total of 255 per million for the Coachella Valley, a rate much lower than that of the broader South Coast region. This diesel emissions cancer risk for the full South Coast region declined by 84% in 20 years, largely due to stricter emissions rules. While air toxics cancer risks in environmental justice (EJ) communities decreased at a slightly higher rate than in non-EJ communities, EJ communities continue to experience higher risks overall (SCAQMD 2021a).

98 For additional information on the health impacts of diesel PM, see https://ww2.arb.ca.gov/resources/summary-diesel-particulate-matter-health-impacts.

Aguilera et al. (2021) report that a 10 μg/m^3 increase in $PM_{2.5}$ from wildfires was associated with a 1.3%–10% increase in respiratory hospitalizations, greater than the increase associated with other sources of $PM_{2.5}$. Kamai et al. (2023) found that children exposed to four or more days of agricultural burning in the Salton Sea region experienced greater rates of wheezing (5.9%) and bronchitic symptoms (5.6%), with higher increases among children with asthma.

In our 2014 report, we noted the absence of research on the magnitude or impacts of airborne salts on agricultural production in the Salton Sea region. There still do not appear to be any studies on or measurements of the impacts of airborne salts, also known as "salt-dust scatter," on public health in the study region. Lake Urmia, in northwest Iran, is roughly three times saltier than the Salton Sea (Safaie & Jamaat 2024) and is shrinking rapidly due to decreased inflows. Feizizadeh et al. (2023) found a roughly eightfold increase in the incidence of hypertension in communities downwind of Lake Urmia, which they associated with salt-dust scatter and the shrinking lake.

Gases such as ozone, nitrous oxides (NO_x), and hydrogen sulfide (H_2S) can also adversely affect public health in the Salton Sea region. Exposure to ozone has many negative human health implications and can cause respiratory inflammation and precursors to asthma (Guarnieri & Balmes 2014). Even at low exposure, ozone can cause chest pain, coughing, throat irritation, and congestion (Dessert & Romero 2017). A recent long-term study found that increased exposure to $PM_{2.5}$ generally increased the risk of harmful blood clots by 39%, while exposure to elevated NO_x in particular increased the risk by as much as 174%. However, the study did not find an association with ozone concentrations (Lutsey et al. 2024).

Gases such as ozone, nitrous oxides (NOx), and hydrogen sulfide (H2S) can also adversely affect public health in the Salton Sea region.

As noted previously, sulfate-reducing bacteria reportedly generated some 78,000 metric tons of hydrogen sulfide (H_2S) annually at the Salton Sea 20 years ago (Amrhein et al. 2005), though studies to date have not calculated the amount of H_2S that escapes the Sea (Centeno et al. 2025); presumably, most returns to the lakebed as gypsum (Tiffany et al. 2007). The health effects from exposure to high concentrations of H_2S are well understood and include death, loss of consciousness, and pulmonary edema (Bustaffa et al. 2020). Batterman et al. (2023) note that chronic exposure to H_2S concentrations of less than 30 ppb (California's standard) is associated with increased risks of neurological effects, and even concentrations below 1 ppb have been associated with adverse impacts to the eyes, nose, and lungs. Centeno et al. (2025) note that other studies have associated chronic exposure to low concentrations of H_2S with a host of adverse public health impacts in environmental justice communities, including headaches, nausea, and sleeplessness, in addition to the impacts noted above.

Pesticides can cause a variety of health impacts. They can affect the nervous system, irritate the eyes or skin, disrupt the hormone or endocrine system, and can be carcinogenic (US EPA 2015). Inhaling particles containing pesticides can adversely affect farmworkers and residents in the Salton Sea region. A 2024 study found associations between pesticide applications near Imperial Valley residents and wheeze symptoms among children; 75% of children in the study group lived within

400 meters of at least one possible pesticide application in the year prior to the study (Ornelas Van Horne et al. 2024). Farmworkers in the study area reported health risks associated with pesticide exposure, especially for pregnant women, and limited ability to reduce their exposure (Cheney et al. 2022). Larsen et al. (2017) found that high levels of pesticide application in the San Joaquin Valley adversely affected pregnancies and the health of newborns in nearby homes.

Alvarez et al. (2024) found an increased risk of cancer associated with air pollution in people living near U.S. military facilities, especially among disadvantaged communities. The Naval Air Facility El Centro is less than 6 miles west of El Centro and Imperial, but we were unable to find any information on emissions from this facility.

BIOLOGICAL IMPACTS

A new book describes aerobiology, the airborne transmission of bacteria, viruses, and fungi, and how this transmission can impair public health (Zimmer 2025). Many published studies note that biological constituents can exacerbate the adverse effects of PM. For example, an algal species associated with red tides produces a toxin that can become aerosolized and affect communities downwind, causing acute and chronic respiratory symptoms (Zaias et al. 2011), especially in people with asthma (Fleming et al. 2007). Monitoring in Florida suggests that these aerosolized toxins can remain airborne for up to four days (Zaias et al. 2011). Farmworkers' exposure to dust, especially in large animal operations, can lead to the development of chronic respiratory disease, potentially due to microbes that activate an inflammatory response (Poole & Romberger 2012). Sinclair et al. (2018) note that residential mold contamination rates and self-reported asthma rates in Mecca and the City of Coachella are both higher than the national average. Construction and farm workers may be particularly vulnerable to increased inhalation risk and dust-associated microorganisms (Freund et al. 2022). While the specific microorganisms and risks differ, Polymenakou et al. (2008) report that a dust event in Africa contained airborne microorganisms and pathogens in the PM associated with adverse impacts on human health.

Several new studies from the Salton Sea Task Force[99] at UC Riverside suggest that biological elements in Salton Sea sediments and/or spray may be associated with additional adverse public health impacts. Hung et al. (2024) calculated that the Alamo and New rivers contribute about 6,300 metric tons of nitrate-nitrite and 1,152 metric tons of total phosphate to the Salton Sea each year; they noted that direct drains and the Whitewater River contribute additional nutrient loadings but did not estimate them. Strong winds can mix the water column and disturb sediments (Lee & Stenstrom 2023), feeding algal blooms that release cyanotoxins and may threaten public health (Geraci 2023). For example, on April 23, 2021, the Regional Water Quality Control Board issued a news advisory warning people to avoid contact with Salton Sea water due to the presence of cyanotoxins, in response to a report of a dog dying shortly after swimming in the lake.[100] Miao et al. (2025) note that while adverse health impacts associated with direct water contact with harmful algal blooms or through consumption have been well documented, the impacts of exposure to aerosols containing such toxins have not.

99 See https://www.saltonseataskforce.ucr.edu/.

100 RWQCB news advisory posted at https://www.waterboards.ca.gov/press_room/press_releases/2021/FINAL%20Salton%20Sea%20HABs%20advisory%20pdf.pdf.

Freund et al. (2022) describe the microbial organisms found in the Salton Sea, on the playa, and in wind blowing over these areas, and note the need for a better understanding of these organisms to assess their potential impacts on public health. They noted that some microbes, including bacteria, fungi, and viruses, can tolerate harsh conditions, move from water into the air, and attach to particles, though the specific emission mechanisms and types of particles such microbes may inhabit remain unclear.

Biddle et al. (2021) found an unusual, non-allergic inflammatory response in the lungs of mice exposed to Salton Sea spray. In a subsequent study, Biddle et al. (2023) found that aerosolized dust, particularly that collected from a site within the Wister Unit, slightly east of the Salton Sea, triggered an immune response resembling that caused by exposure to lipopolysaccharides (LPS), components of gram-negative bacterial cell membranes. Dust collected from recently exposed Salton Sea playa generated a smaller response. Yisrael-Gayle (2024) suggested that the high salinity, low dissolved oxygen concentrations at the Salton Sea may promote the generation of additional LPS in bacteria as a resilience mechanism. This could then lead to the higher concentrations of LPS found in dust at two sites south of the Salton Sea, potentially linked to higher nutrient inputs from southern Salton Sea tributaries and to the greater prevalence of asthma diagnoses in families living south of the Sea (29%) compared to those living north (12%) (Yisrael-Gayle 2024).

CUMULATIVE IMPACTS

As described above and shown in Table 11, short-term ("acute") exposure to high concentrations of air pollution can impair public health. Long-term ("chronic") exposure to low concentrations of a pollutant, even at levels not typically considered harmful, can also result in cumulative impacts that impair public health (Xia & Tong 2006). For example, Toczylowski et al. (2021) found a strong relationship between long-term, cumulative exposure to $PM_{2.5}$ and flu-like illness. Local communities have recognized the threat of cumulative impacts and are taking steps to reduce it. One of the two main health objectives of the southern Imperial County AB 617 Community Emissions Reduction Plan is "Maximizing progress on reducing exposure to toxic air contaminants (TACs) that contribute to cumulative exposure burdens within selected communities" (ICAPCD 2024).

MULTI-POLLUTANT IMPACTS

The various physical, chemical, and biological components of air pollution combine to create a multi-pollutant air quality burden on communities in the study region. While assessing the impacts of individual components can be informative, the combined impacts may be much greater than the sum of the individual contributors. Dominici et al. (2010) discuss the impacts of exposure to multiple air pollutants, the synergistic effects of exposure to different classes of pollutants (such as ozone and PM), and challenges associated with attempting to model or quantify such impacts. Reported PM concentrations can mask the fact that PM itself is often a multi-pollutant, consisting of multiple particulate sizes (e.g., PM_{10} includes $PM_{2.5}$ and ultrafine particles) and often containing various chemical components, each of which may present its own set of health impacts (Dominici et al. 2010).

In a study investigating the impacts of multiple pollutants on a large population in the Netherlands, Traini et al. (2022) found a strong association between $PM_{2.5}$ and overall mortality and a moderate association between PM_{10} and mortality. They also noted multiple exposure pathways beyond respiration, including ingestion and skin exposure, contributing to systemic inflammation, higher blood pressure, and diminished lung function.

Miao et al. (2025) caution that the association they identify between increased Salton Sea emissions and respiratory hospitalizations could arise from many different factors, including biological or chemical compounds or the shape of the particles themselves. London et al. (2013) note that, in addition to multiple air pollutants, impaired water quality and other factors can also adversely affect human health in the region.

The impacts of occupational exposure, combined with limited medical services and high health care costs, create additional burdens for low-income communities. Community members north of the Salton Sea identified multiple pollutants, including hydrogen sulfide, dust, chemicals, and smoke, as responsible for impairing children's health (Cheney et al. 2023). In another study, ECV farmworkers reported that a host of factors, including extreme heat, long hours of intense physical labor, pesticide exposure, air pollution, mosquitos, and dehydration, led to headaches, physical injuries, skin conditions, and respiratory and vision problems, among others (Cheney et al. 2022).

10. Discussion and Recommendations

Our understanding of the many physical, chemical, and biological factors contributing to air pollution in the Salton Sea region has increased dramatically in the past decade (see Chapters 2 and 6). State and local government efforts to prevent and remediate threats to public health have increased, including new rules and regulations (see Chapter 7), dust suppression projects, air filter installations, and home weatherization (see Chapter 8). Childhood asthma hospitalization rates for those in the Salton Sea region have declined dramatically in the past decade and recently appeared to approach the state average (see Chapter 9), though the reasons for this decline are not clear. Nevertheless, air quality in the region continues to regularly exceed state and federal standards for ozone, PM_{10}, $PM_{2.5}$, and hydrogen sulfide (see Chapter 7). The Salton Sea will continue to shrink, exposing more emissive playa (see Chapter 1) and exacerbating existing conditions.

Recent research findings highlight the potential risk associated with the chemical and biological components of Salton Sea particulate matter (PM), including both dust from exposed playa and spray from the lake itself, as well as the harmful effects of frequent, low-level emissions of hydrogen sulfide from the lake. Many researchers have noted that high nutrient loadings into the Salton Sea drive the chemical and biological processes generating these emissions (Centeno et al. 2023, 2025; Hung et al. 2024). Although the Regional Water Quality Control Board (RWQCB) is developing new rules to limit nutrient loadings,[101] Hung et al. (2024) note that, given the massive amounts of nutrients already in the Salton Sea and its sediments, meaningfully reducing the lake's overly productive biological processes would require a 70–90% reduction in external nutrient loadings. The pace of regulatory change to date and the political and economic challenges associated with reducing nutrient loadings by more than 70% at the scale of the Salton Sea region suggest that **biological and chemical emissions are likely to persist for the foreseeable future**.

The combined and cumulative impacts of exposure to multiple pollutants, especially over long periods, can exceed or exacerbate the impacts of short-term exposure to high concentrations of a single pollutant (see Chapter 7). Assessing individual pollutants in isolation can improve our understanding of specific threats but may mask the broader regional context in which impacts occur. Dominici et al. (2010) suggest a multi-pollutant approach for estimating and managing complex interactions. Chapter 4 describes the many pollutants degrading regional air quality,

101 See https://www.waterboards.ca.gov/coloradoriver/water_issues/programs/tmdl/.

including more than 70,000 tons of dust per year from barren land and more than 20,000 tons per year from unpaved roads (see Table 6). These fugitive and dispersed emissions challenge efforts to control them at the source. Mobile sources generate thousands of additional tons of harmful diesel particulate matter; federal, state, and local rules have decreased these emissions, though they still pose a measurable threat to those living in the region.

A recent report by experts at seven University of California campuses found that:

> Dust source mitigation is an expensive technique that requires continued investment in application and monitoring that is limited to discrete anthropogenic sources of dust. While minimizing any wind-blown erosion should improve air quality, the exact benefits to human health are difficult to quantify (UC Dust 2024).

The broad range of pollutants in the region, the expected persistence of factors driving emissions, climate exacerbations (e.g., drought, extreme heat, and more intense storms), powerful local stakeholders, and the diffuse and dynamic range of the sources of these pollutants (Lieb & Faloona 2025) suggest that the business-as-usual approach of managing or suppressing emissions at the source will not be sufficient and is unlikely to be politically feasible or cost-effective. The three designated AB 617 communities in the region have instead adopted a combined approach of source control (such as paving specific, highly emissive sites) and exposure control (such as home weatherization). The broad range of emissive areas and sources suggests that this combined approach is likely to be more effective, from both a cost and a public health perspective.

Exposure control refers to actions or efforts that reduce adverse public health impacts where people live, work, and play, as opposed to source control efforts, such as paving roads or restricting vehicle access to emissive areas. Reducing or avoiding exposure to air pollution can include installing air filters in homes,[102] schools, and workplaces; notifying people to avoid outdoor exertion on days with poor air quality;[103] and limiting indoor air pollution that may be caused by smoking, gas stoves, or other factors (Laumbach et al. 2015). Porter (2024) found that an inexpensive indoor air filter known as a Corsi-Rosenthal Box (see Figure 23) can reduce indoor $PM_{2.5}$ concentrations by 36%. These measures, taken individually or in combination, can effectively improve indoor air quality and reduce exposure to many pollutants, toxins, and pathogens (Gaston et al. 2021).

102 See SCAQMD's Residential Air Filtration Program at https://www.aqmd.gov/nav/about/initiatives/environmental-justice/ab617-134/community-air-protection-incentives/residential-air-filtration-incentives.

103 For example, https://ivan-imperial.org/air.

FIGURE 23. Corsi-Rosenthal Box

Source: Festucarubra, licensed under the Creative Commons Attribution-Share Alike 4.0 International license

Currie et al. (2014) note the high return on investments in protecting public health, especially for vulnerable and disadvantaged communities. Ayres et al. (2022) estimated that per-acre public health damages from playa emissions generally fall range from $500–$5,000 per acre. State and local dust suppression project costs typically exceed this range (Chapter 6), suggesting that it may be more cost-effective to invest such funds in exposure control efforts in the future. Assuming an inflation-adjusted cost of $4,000 to weatherize a home[104] and two $100 air filters per home (Porter 2024), the total cost to remediate indoor air quality for the approximately 4,000 homes within six miles of the Salton Sea (Ayres et al. 2022) would be less than $20 million. The cost of expanding such exposure control efforts to homes, businesses, and schools within the three AB 617 communities would be significantly greater but would likely still be less than the SSMP will invest (at current rates) in dust suppression projects at the Salton Sea.[105] Community residents have also requested additional

104 Rough estimate from https://www.yardibreeze.com/blog/2022/11/fast-ways-winterize-manufactured-homes/.

105 We recognize that these measures are not widely available and that implementing such a program would require significant effort and oversight and coordination. We also note that many people in affected communities face challenges with the size of the air filters in very small living spaces and with the ongoing costs of changing filters.

health care centers and clinics, clean drinking water, cooling centers, and shade structures (Better World Group 2024).

Miao et al. (2025) note the complex interactions between agricultural practices in the watershed, biogeochemical processes within the lake, various emission pathways, and implications for human health and the challenges these pose for identifying and implementing effective management plans. The many agencies with jurisdiction and planning efforts in the study area reflect these complex physical interactions (see Chapter 5). Paz (2025) described the fractured nature of governance in the Salton Sea region and opportunities for better coordination. Communication, coordination, and cooperation between the various agencies with jurisdiction in the region could be improved, particularly between agencies and programs with different mandates and authorities, such as the SSMP and AB 617 communities, though even ICAPCD and SCAQMD could formalize their communication and coordination.[106] Optimizing public investment in efforts to protect public health in the region will require a dedicated effort to coordinate among senior officials at CARB, the SSMP, county governments, community-based organizations, and local residents themselves. Communities and community-based organizations have the “institutional memory” and persistence to help coordinate and advocate through the political ebbs and flows of changing government administrations (Wu, pers. comm., 2025).

A recent community needs report commissioned by CNRA recommends:

> a working group between SSMP, CNRA, California Environmental Protection Agency and California Air Resources Board on public health, air quality and environmental justice in Salton Sea shoreline communities to share data and develop a path to implement public health interventions that are identified by Salton Sea shoreline communities, but which may be outside the funding and regulatory limitations of SSMP (Better World Group 2024).

The California Environmental Protection Agency (CalEPA) is best positioned to coordinate these activities. CalEPA houses CARB and the State Water Resources Control Board, which maintains continuing jurisdiction over the QSA water transfers and the SSMP’s compliance with WR 2017-0134. This order established annual milestones for the completion of habitat and dust suppression project acreage (see Chapter 5). We recommend that CalEPA convene the State Water Board, CARB, ICAPCD, SCAQMD, representatives of the three AB 617 communities in the region, the parties that developed WR 2017-0134, air quality and public health experts, and other community leaders and representatives to revisit WR 2017-0134 and identify potential state investments to optimize public health benefits for local communities.[107] These experts could determine that the existing approach does not need to be changed, or they could identify a new approach, directing some portion of state investments toward exposure control efforts in communities adjacent to the Salton Sea, or using those funds to match and expand other investments in the three AB 617 communities.

106 Scott Epstein (SCAQMD), October 19, 2024, Salton Sea Summit.

107 As a separate matter, the State Water Board should also revise WR 2017-0134 in light of the expansion and habitat value of emergent wetlands atop exposed Salton Sea playa.

Chapter 4 notes that, relative to total fugitive windblown emissions in the Salton Sea Air Basin (about 78,000 tons of PM_{10} per year) and even relative to unpaved road emissions (about 23,000 tons of PM_{10} per year), estimated daily and annual PM_{10} emissions from the Salton Sea playa are very low (about 300 tons of PM_{10} per year, or less than 0.4% of total fugitive windblown emissions and less than 0.3% of total estimated annual PM_{10} emissions in the basin).[108] Existing state and local dust suppression projects, sited on some of the most emissive portions of the playa, have reduced the magnitude of these emissions. However, new research suggests that the chemical and biological components of dust emissions from exposed playa, and potentially from sea spray and hydrogen sulfide emitted from the lake itself, pose additional threats to the health of downwind communities. Controlling these multiple, diffuse sources of pollution will require multi-agency coordination and investment in nontraditional air quality improvement methods and may not be politically or economically feasible, especially in the near term. A multi-pollutant approach that invests in limiting exposure to these many pollutants is likely to be the more effective and beneficial path forward. We recommend that CalEPA convene relevant agencies, community members, and other stakeholders to assess the costs and benefits of shifting from source control to exposure control, to better allocate limited state and local funding to protect the health of the people who live, work, and play in the Salton Sea region.

108 Actual playa emissions are likely even lower, as IID's projections do not account for emergent wetlands or existing dust suppression projects.

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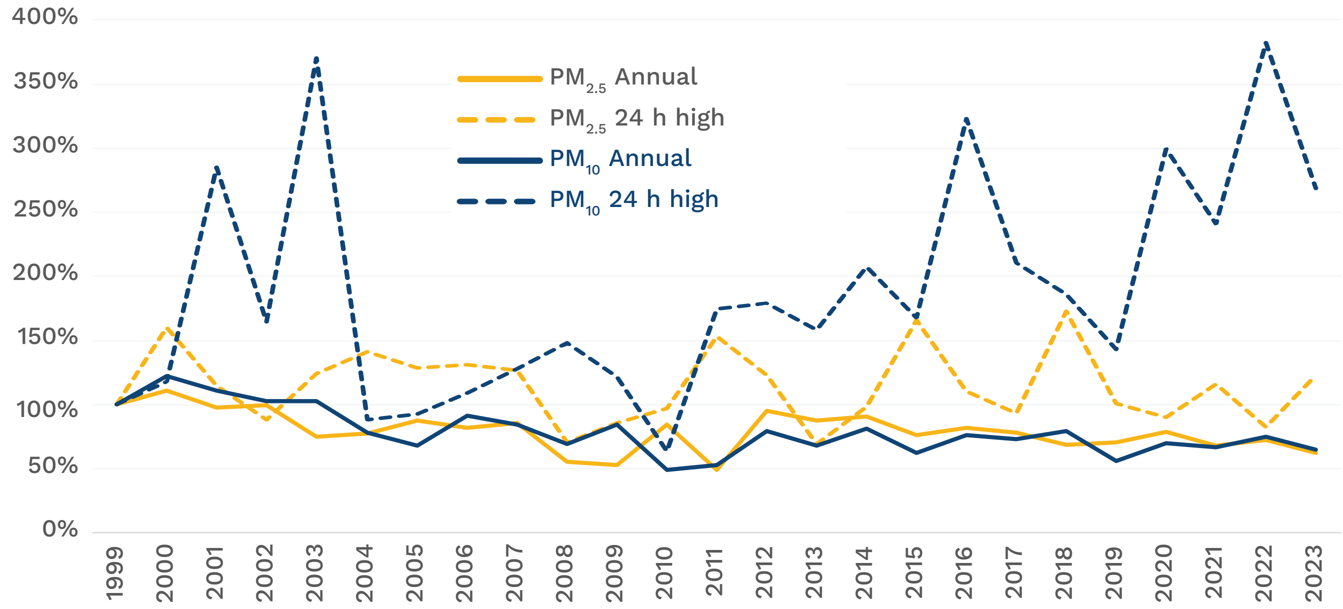
Appendix
Variability in PM Concentrations

As discussed in Chapter 4, pollutant emissions and subsequent concentrations vary dramatically across time and place in the Salton Sea region, complicating efforts to control emissions and protect public health. In this appendix, we provide a more detailed description of average and peak PM_{10} and $PM_{2.5}$ concentrations in the region to highlight the magnitude of this variability. Figure A-1 shows relative percentage changes in the reported annual average and maximum 24-hour average $PM_{2.5}$ and PM_{10} concentrations in the Salton Sea Air Basin, for the period 1999 (the earliest available $PM_{2.5}$ data) to 2023, using 1999 as the base year. Average annual $PM_{2.5}$ concentrations decreased from 15.2 $\mu g/m^3$ to 9.5 $\mu g/m^3$ over the period shown, while average annual PM_{10} concentrations decreased from 77.8 $\mu g/m^3$ to 50.4 $\mu g/m^3$. However, the maximum 24-hour average concentrations show considerable annual variability and differing trends between $PM_{2.5}$ and PM_{10} values. While maximum 24-hour average concentrations peaked for PM_{10} in 2003 and again in 2022, at about 850 $\mu g/m^3$ — almost quadruple the 1999 concentration — the maximum 24-hour average $PM_{2.5}$ concentration in 2022 was about 18% *lower* than the 1999 concentration of 52.5 $\mu g/m^3$.

FIGURE A-1. Changes in Annual Average and Maximum 24-hour Average PM Concentrations in the Salton Sea Air Basin, 1999–2023



Source: CARB's iADAM Air Quality Trends Summaries

January typically has the lowest average monthly PM_{10} emissions of the calendar year. Table A-1 shows average daily PM_{10} concentrations in January for the years 2017–2023, to reflect “baseline” or low ambient conditions. As we note in Chapter 5, many factors affect the conversion of pollutant *emissions* from various sources into *concentrations* in the atmosphere, and the subsequent detection of such concentrations by monitoring stations. In its annual reports, IID identifies the 10 highest emissions days for the Salton Sea playa and provides average hourly PM_{10} concentrations[109] for each of these peak emissions days. We compiled reported values for the peak emissions day for the years 2016–2023 in Table A-2 (from both IID’s and CARB’s datasets) to show the variability between the “baseline” values shown in Table A-1 and the peak emissions day value for each year. Many of the stations did not report data for various periods, noted as “no data” in the tables. Unfortunately, none of the monitoring stations reported data for January 2016. As discussed in Chapter 7, these peak emissions can drive acute health risks for people exposed to these concentrations (values are color-coded based on the AQI index shown in Table 11).

TABLE A-1. Average Daily PM_{10} Concentrations in January for 2017–2023 - (all values in µg/m³)

YEAR	2017	2018	2019	2020	2021	2022	2023	AVERAGE JANUARY PM_{10} MEASUREMENTS 2017-2023
Brawley	no data	44.1	26.9	30.4	31.2	33	26.6	32
Calexico	36.1	75.1	46.4	66	53	58.9	45.8	54.5
El Centro	no data	41.3	30.1	36.9	33.6	37.7	29.5	34.8
Niland	no data	no data	18.1	17.6	19.9	23.7	18.7	19.6
Westmorland	no data	36.4	21.7	28.1	29.6	30.2	26.6	28.8
Bombay Beach	18.5	9.8	12.2	8.9	15.9	no data	10.9	12.7
Naval Test Base	39	16.3	26.9	15.3	no data	12.8	12	20.4
Salton City	21.6	41	26.3	10.2	no data	no data	17.1	23.2
Salton Sea Park	16.9	41	15.3	12.3	11.9	no data	15.6	18.8
Sonny Bono	21.9	6.8	24	12.4	5.8	no data	17.3	14.7
Torrez-Martinez	13.7	12.7	18.2	15.1	11.8	no data	no data	14.3
Mecca	no data	no data	no data	no data	no data	35.8	27	31.4

Values above are color-coded according to the AQI Index shown in Table 11

Source: CARB’s AQMIS tool and IID for daily PM_{10} data

109 We calculated the daily PM_{10} concentration from the reported average hourly concentration as a simple average of the 24 hourly values.

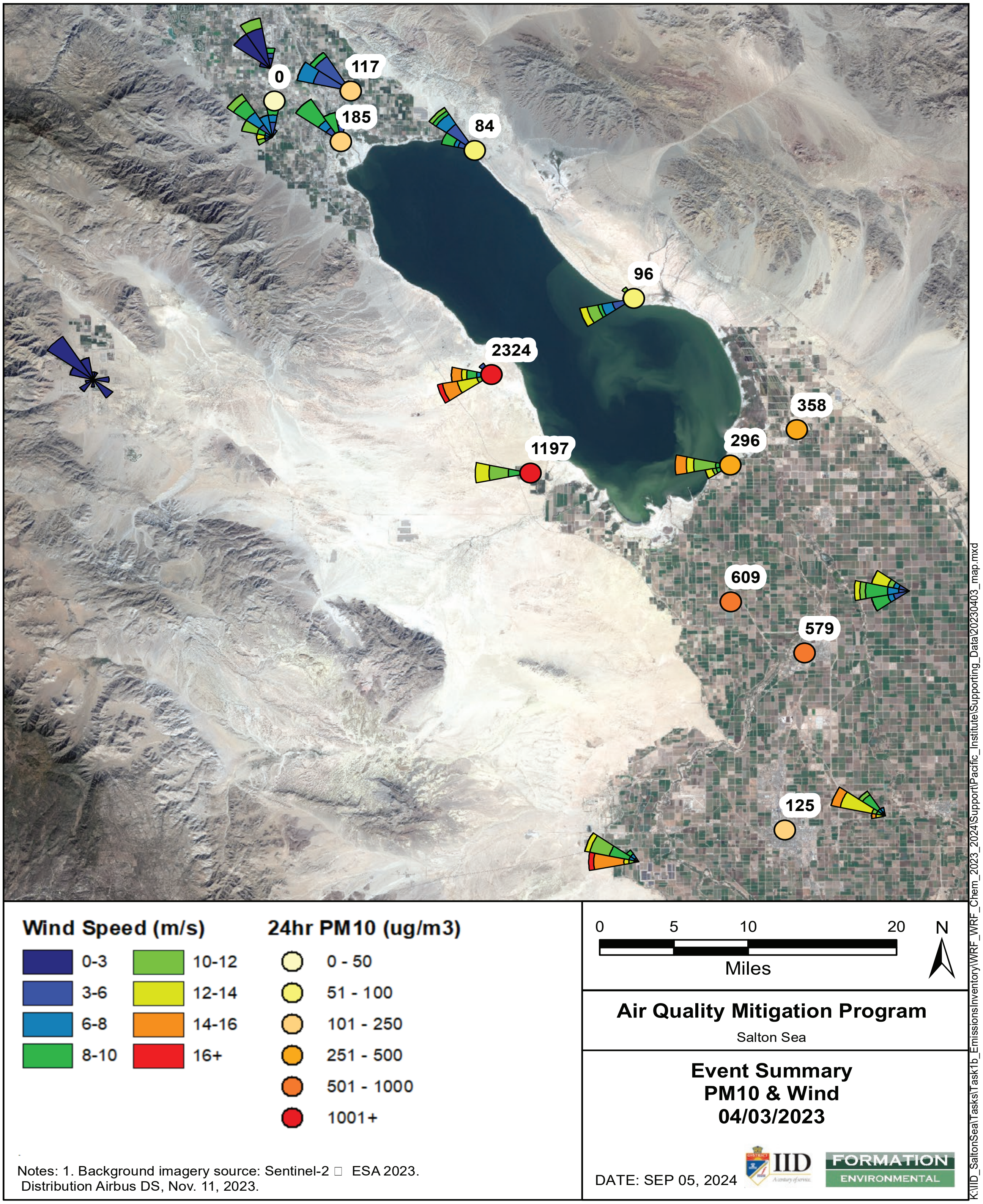
TABLE A-2. Average Hourly PM_{10} Concentrations on Annual Peak Emissions Days, 2016–2023
(all values in µg/m³)

YEAR	2016	2017	2018	2019	2020	2021	2022	2023
Date of Peak Emissions	**Dec. 16**	**May 6**	**Apr. 19**	**Apr. 9**	**Jun. 5**	**Mar. 25**	**Mar. 5**	**Sept. 30**
Brawley	No data	No data	342	100	124	53.3	131	521
Calexico	240	410	185	97.0	108	44.3	64.8	197
El Centro	No data	No data	156	91.2	96.6	29.1	42.6	152
Niland	No data	No data	156	93.4	141	60.0	120	294
Westmorland	No data	297	193	77.4	145	67.0	163	418
Bombay Beach	140	568	27.4	55.2	70.4	43.0	35.6	90.2
Naval Test Base	1,250	422	300	109	189	95.6	256	147
Salton City	1,010	1,190	260	138	106	645	594	1,940
Salton Sea Park	No data	48.4	22.8	52.7	51.7	23.6	13.6	111
Sonny Bono	691	162	107	32.1	55.5	11.3	103	223
Torres-Martinez	132	32.7	117	No data	250	No data	27.1	289
Mecca	No data	No data	No data	No data	No data	No data	No data	No data

Values above are color-coded according to the AQI Index shown in Table 11. Values are rounded to three significant figures.

Source: CARB's AQMIS tool and IID for hourly PM_{10} data

FIGURE A-2. April 3, 2023, Wind Speeds and PM_{10} Concentrations



Source: IID, 2024

Figure A-2 shows recorded wind speeds[110] and PM_{10} concentrations at multiple monitoring stations around the Salton Sea on April 3, 2023, the peak emissions day in IID's 2022–23 monitoring period (note that emissions on September 30, 2023, in the subsequent monitoring year, were even higher). Figure A-2 shows the wide variation in maximum reported PM_{10} concentrations and wind speeds in areas around the Salton Sea. The maximum reported PM_{10} concentration near Salton City, on the west side of the lake, was more than 20 times higher than the maximum reported concentration near Bombay Beach, on the east side of the lake, and more than 12 times higher than the maximum reported concentration at the Torres-Martinez monitoring station, on the north side of the lake. Note also the differences in wind speed and direction between the north and west sides of the lake on that day. The Salton City monitoring station is one of six established by IID in 2010 that monitor hourly average mass concentrations of PM_{10} and $PM_{2.5}$ and include standard instruments for measuring air quality and other meteorological information. The Salton City station is located near the western shore of the Salton Sea, east of Anza-Borrego Desert State Park, and north of the largest alluvial fan in the Salton Sea Basin. This fan is made up of sediment deposited from the Arroyo Salada, Tule Wash, and San Felipe Creek (IID 2024a). During high-wind events, strong westerly winds blow sand and sediment from the western desert and alluvial fan eastward over the Salton City station, across the Salton Sea, and to communities in the Imperial and Coachella Valleys (IID 2024a).

The day with the highest PM_{10} emissions, or the peak emissions day, of a calendar year, typically occurs in the spring between March and May, though peak emissions days can occur at other times of the year. Monitoring stations on the western side of the Salton Sea, at the Salton City and Naval Test Base stations, regularly report the highest PM_{10} concentrations. About 60% of the total annual emissions occur during the 10 highest emissions days in a given year, a pattern that is consistent year-to-year (IID 2024a).

In 2016, 2017, and 2023, PM_{10} concentrations on peak days were dramatically higher than other years. On May 6, 2017, PM_{10} reportedly reached concentrations of 5,548 $\mu g/m^3$ at Salton City and 985 $\mu g/m^3$ at Calexico. Concentrations at these sites were more than 100 times higher than their respective January averages but were much lower than the peak emissions day in 2023. On September 30, 2023, the average hourly PM_{10} concentration was 1,939 $\mu g/m^3$ at Salton City (the highest recorded hourly value, not shown on the chart, was 12,493 $\mu g/m^3$ at 5:00 pm). This is nearly 13 times higher than the federal NAAQS 24-hour average for PM_{10}, 38 times higher than the California 24-hour average, and 113 times higher than the January average PM_{10} concentrations recorded at Salton City in the same year.

From 2018–2022, PM_{10} concentrations were relatively lower, even on peak emissions days. For instance, in 2020, the highest average hourly PM_{10} measurement (recorded at Torres-Martinez, with a value of 249.51 $\mu g/m^3$) was 16 times higher than the January 2020 PM_{10} concentrations (which was an average of 15.13 $\mu g/m^3$ at Torres-Martinez), 1.6 times higher than the federal NAAQS 24-hour average standard, and five times higher than California's 24-hour average standard.

110 Wind speeds are shown in meters/second (m/s); one m/s = 2.2 mph, while 14 m/s = 31 mph.

Even in these relatively low years, the reported January average PM_{10} concentrations are higher than California's 24-hour average PM_{10} concentration standard. At the Calexico station, the January average PM_{10} concentration was higher than the state 24-hour average in four different years.[111] That is, even at the time of the year that typically has the lowest PM_{10} emissions, the Salton Sea Basin can still exceed California's air quality standards in at least one measurement or air quality station.

FIGURE A-3. Dust Storm Recorded by the Salton South IID Roundshot Camera on September 30, 2023

Stations at Bombay Beach, on the eastern shore of the Sea and downwind from Salton City, and the Sonny Bono station, on the southeastern shore of the Sea and downwind from Naval Test Base,[112] recorded higher PM_{10} concentrations as well. Figure A-3 shows images of the dust event on September 30, 2023, from IID's Roundshot cameras at Salton South and Vail Drain, both on the southeast side of the Salton Sea. Large amounts of dust can be seen blowing across the Sea during the highest peak emissions day since 2016.

111 Average January values at the Calexico station were higher than the state 24-hour average in 2018, 2020, 2021, and 2022.

112 The Naval Test Base station, also located to the west of the Salton Sea and to the south of the Salton City station, did not record PM_{10} concentrations between 10:00 am and 8:00 pm on September 30, 2023, when the Salton City station recorded the highest values of up to 12,493 μg/m³. Instead, an "Excessive PMC Noise" error was logged for those hours.

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