Prioritizing Cost-Effective Dust Mitigation at the Salton Sea

This report was submitted in partial fulfillment of the requirements for the degree of Master of Environmental Science and Management at the Bren School of Environmental Science & Management, University of California, Santa Barbara.

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The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project is a year-long activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Group Project Final Report is authored by MESM students and has been reviewed and approved by:

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Abstract

The Salton Sea, the largest lake in California, is projected to shrink in size over the next thirty years, exposing potential dust-generating playa. In 2003, the Quantification Settlement Agreement (QSA) was signed, quantifying certain Colorado River water rights and mandating new agricultural to urban water transfers, decreasing inflows to the Sea. The QSA required an environmental mitigation program, including 15 years of mitigation water to slow the shrinking of Sea until 2017. With mitigation water deliveries now over, dust mitigation is required to meet air district rules for dust control at the expanding playa. This research project reviewed case studies of dust control methods and the legal background of dust control liability. Surface roughening and vegetation enhancement were identified as the most cost-effective suitable dust control methods at the Sea. Liability falls onto landowners under Imperial County rules, but California and the QSA water agencies also have certain responsibilities for dust control. A dust model was developed to predict the most dust-emissive areas of future exposed playa, accounting for dust generation potential of soil types and frequency of high wind events. A cost-effectiveness score was then calculated to prioritize areas of mitigation with highest emissivity and lowest costs. Areas with fine soils and high winds along the eastern and southern shores of the Sea were identified as top priority. Mitigation costs were estimated by landowner for both suitable recommended methods and currently approved methods. If approved by the air districts, suitable recommended methods employed across all future exposed playa offer a nearly threefold cost savings over currently approved methods.

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List of Acronyms

BACM - Best Available Control Measure
CARB - California Air Resources Board
CVWD - Coachella Valley Water District
DCM - Dust Control Measure
EPA -United States Environmental Protection Agency
GBUAPCD - Great Basin Unified Air Pollution Control District
ICAPCD - Imperial County Air Pollution Control District
IID - Imperial Irrigation District
JPA - Joint Powers Authority
LADWP - Los Angeles Department of Water and Power
MWD - Metropolitan Water District
NAAQS - National Ambient Air Quality Standards
$PM_{2.5}$ - Particulate Matter, 2.5 microns or smaller
PM_{10} - Particulate Matter, 10 microns or smaller
QSA - Quantification Settlement Agreement
SCAQMD - South Coast Air Quality Management District
SDCWA - San Diego County Water Authority
SIP - State Implementation Plan
SSAQMP - Salton Sea Air Quality Mitigation Program
SSMP - Salton Sea Management Program

1. Executive Summary

Introduction

The Salton Sea was created in 1905 through an engineering failure of a canal on the lower Colorado River, causing the river to spill into the Salton Basin. Given that it is a terminal lake with no natural inflow or outflow, the level of the Sea is highly dependent on agricultural flow from Imperial Valley farms. The Quantification Settlement Agreement (QSA) water transfers which began in 2003 to help reduce the state's water demand on the Colorado River, include implementation of agricultural conservation that reduces agricultural runoff to the Salton Sea. During the first 15 years of the QSA water transfers, mitigation water was transferred to the Salton Sea by the QSA water agencies to keep lake levels and salinity stable. Mitigation water deliveries stopped at the end of 2017, and it is predicted that the lake level will decline at faster rates. As the drying sea continues to expose more and more playa, soils will be exposed that could potentially contribute to dust storms, and high winds in the area could transport particulate matter to populated parts of Imperial and Riverside Counties. Of most importance are particulate matter less than 10 microns in diameter, which have specific regulations in California as part of National Ambient Air Quality Standards (NAAQS), which were created by the federal Clean Air Act.

Purpose and Goals

The purpose of this project is to model emissivity at the Salton Sea as the shoreline recedes and to recommend a dust control strategy that will cost-effectively mitigate predicted dust emissions. Another goal is to understand the legal framework regarding dust mitigation in order to determine potential liability of relevant parties to implement dust control projects at the Salton Sea.

Methods

In order to determine the best dust control strategies to implement at the Salton Sea, a comprehensive survey of dust control measures (DCMs) utilized at dried lake beds and other dust-emitting locations was conducted. The measures used at Owens Lake in California were especially important to this review, as the situation at Owens Lake is the most comparable to the Salton Sea.

Furthermore, a legal review was conducted to better understand the legal framework regarding dust control liability at dried lake beds. Again, Owens Lake was an important case to study, as its situation parallels that of the Salton Sea.

Lastly, a GIS model was created to determine how to cost-effectively control fugitive dust from the playas of the Salton Sea. This included a spatial analysis of the potential emissivity of exposed areas as well as the creation of a prioritization strategy. A Potential Dust Emissivity Score was given to all exposed areas and areas were then prioritized according to emissivity relative to cost of mitigation.

Overall Findings

1. Surface roughening and vegetation enhancement are best suited for dust mitigation at the Salton Sea, based on cost-effectiveness and suitability as determined by soil type.
2. Landowners may be primarily responsible for mitigating dust from exposed playa, according to local air quality management district regulations. The ICAPCD's regulations regarding responsibility are clearer than SCAQMD's regulations, introducing uncertainty as to who may ultimately pay for dust control over the long term.
3. Our Dust Emission Model calculates relative emissivity of future exposed playa. Each area of land is given a score to determine relative emissivity. The southeastern and southwestern regions of the Sea are the most emissive, partially due to higher winds in the southern part of the Sea as well as the soil types present.
4. A prioritization score was calculated to rank areas that should be targeted first, in order to achieve a cost-effective dust mitigation strategy. A higher score represents a higher cost-effectiveness for dust mitigation.

Recommendations

Based on the research and modeling conducted, we recommend the following:

- The areas modeled to be high prioritization areas should be remediated first in order to mitigate the highest amount of dust for the lowest cost.
- Surface roughening and vegetation enhancement should be the primary methods used for dust control at the Salton Sea.
- The State of California should pursue public-private partnerships to ensure that non-IID and non-federal landowners have the resources to mitigate dust emissions and comply with relevant air quality regulations.

2. Objectives

This project evaluates measures for dust emission control at the Salton Sea. We recommend cost-effective DCMs, determine parcel ownership of potential dust-emitting land, and investigate the legal framework surrounding land ownership, dust emission, and the declining lake level to provide information that may be useful for liability determinations.

Specifically, this project aims to:

1. Develop a survey of DCMs around the world and their costs, and determine which measures would be best to implement at the Salton Sea.
2. Examine legal dimensions to determine financial obligations and dust mitigation liability.
3. Model the dust emission potential of future exposed playa at the Salton Sea.
4. Identify cost-effective dust control strategies at the Salton Sea.

3. Significance of the Project

The Salton Sea is the largest lake in California, created accidentally when a flood caused the Colorado River to break through an irrigation canal and fill the Salton Basin. The lake has no natural inflow, so lake levels have been highly dependent on the runoff from surrounding agricultural land.

In 2003, the Quantification Settlement Agreement (QSA) was enacted to reduce the state's water demand on the Colorado River. The resulting QSA water transfers require farming conservation methods that reduce agricultural runoff to the Salton Sea, reducing a major source of its inflow. For the first 15 years of this agreement, mitigation water was supplied to the Salton Sea by the QSA water agencies to make up for the loss to the lake. However, now that the mitigation water transfers have stopped, lake levels are expected to drop in the coming years. With reduced inflows and constant evaporation, the lake will shrink more quickly, exposing the dry lake bed.

High winds create particulate matter dust emissions ($PM_{2.5}$ and PM_{10}) contributing to poor air quality in the area. These fugitive dust emissions are hazardous to human health and contribute to respiratory diseases such as asthma. Imperial County, which is currently designated as a severe nonattainment area for PM_{10}, also currently has the highest rate of hospitalization for asthma (Orlando, Smalling, and Kuivila, 2008). As the shoreline recedes, there is potential for emissive dust to be created from exposed areas. If DCMs are not implemented, the approximately half million residents living in the region, including people in both Imperial and Coachella Valleys, could be affected by these hazardous dust emissions.

With the end of the 2017 now past, the issue of responsibility of dust mitigation becomes imminent. As discussed later in this project, Imperial County air quality regulations mandate that landowners are liable for dust control and its associated costs. Major landowners in the area include Imperial Irrigation District (IID), the Torres Martinez Desert Cahuilla Indian Tribe, and the federal government. Additionally, a minority of private landowners, including local farmers, own some land around the Sea as well.

The purpose of this project is to draw data-driven conclusions that can be used for policy recommendations and air quality implementation strategies for controlling dust emissions at the Salton Sea. This includes a comprehensive survey of successful air quality control projects around the world as well as an investigation of who could potentially be responsible for dust control on exposed playa. The survey of dust emission control projects determine strategies proven to be successful in other dry lakes. Strategies that have not yet been proposed at the Salton Sea are also considered. The legal framework review identifies regions around the world that have faced similar environmental liability situations and analyzes their mitigation efforts. With a recommendation in place for dust control methods, the project aims to start the elaborate process toward controlling fugitive dust emissions from the Sea and preventing the decline in air quality for thousands of residents living in the surrounding region.

4. Background

4.1 Summary

Covering approximately 375 miles in Riverside and Imperial counties, the Salton Sea is the largest lake in California. Located within the Salton Sink in the lowest part of the Salton Trough, it has been historically filled with water on an occasional basis. Most notably, it took the form of ancient Lake Cahuilla, which disappeared sometime around 500 years ago (Hurlbert, 2007). Presently, the Salton Sea exists due to an engineering accident in 1905 which caused the Colorado River to flow into the Salton Basin for two straight years before the breach was repaired (University of Redlands, 2007). Both the Alamo and New Rivers originate in Mexico and feed into the Sea from the south, and consist mostly of agricultural runoff. The Whitewater River feeds into the Sea from the north, with Headwaters in the San Bernardino Mountains.

The over 9 billion square-foot saline Salton Sea currently acts as a large habitat for many different migratory bird species and is a stop on the Pacific Flyway. It is also home to the Desert Pupfish, an endangered species. Questions loom regarding the QSA and any impacts it may have on the Sea. The QSA was enacted in 2003 and heavily reduced California's use of the Colorado River, restricting the state's allotment to its historical allocation of 4.4 million acre-feet per year, based upon the Colorado River Compact of 1922. Also associated with the QSA, legislation was passed in 2003 that required the development of an overall restoration plan for the Salton Sea by the State of California.

The water transfer agreement between San Diego County Water Authority and Imperial Irrigation District, a major part of the QSA, allows the state to control its Colorado River water consumption by transferring water from agricultural regions in Imperial County to urban areas in the San Diego region. To mitigate the environmental impacts from the water transfers, the Water Authority, Coachella Valley Water District (CVWD), and Imperial Irrigation District have all contributed funding under the QSA Joint Powers Authority (JPA) toward dust control and other projects to protect the Sea's future. This sets the stage for the state to live up to its obligation to implement a long-term restoration program at the Salton Sea.

As the mitigation water for the QSA water transfers ended in 2017, the Salton Sea's elevation will steadily recede, exposing playa with potential to contribute fugitive dust (PM_{10}) that is known to cause asthma and other health concerns to nearby residents. The Imperial Irrigation District, the State, and the federal government are all landowners of areas around the Sea that are projected to be exposed. Local farmers also own land in the area. Imperial County air quality regulations put the onus of dust control on the landowner. Moving forward, responsibility of dust control, associated mitigation costs, and the degree to which land should be remediated will all depend upon a number of potential hydrologic, environmental, and legal factors. A timeline of major events regarding the Salton Sea is below in **Table 4.1**.

Table 4.1 - Salton Sea Timeline

1905 - Colorado River flood creates current Salton Sea
1911 - Imperial Irrigation District forms
1922 - Colorado River Compact agreement
1950 - Salton Sea second most popular recreation spot in California
1975 - 500,000 tourists per year
1986 - California issues selenium advisory
1993 - Salton Sea Authority formed
2003 - Quantification Settlement Agreement enacted
2017 - Mitigation water requirement for water transfers end
2017 - State's SSMP 10-Year Plan created - includes habitat and dust control projects through 2028
2021 - 200,000 acre-feet transferred from IID to SDCWA

4.2. Quantification Settlement Agreement of 2003

The QSA was created to help reduce California's use of Colorado River down to its 4.4-million-acre foot apportionment. The parties involved in the QSA are IID, SDCWA, and several other federal, local, and state water agencies. As a result of the QSA, California can creatively stretch its limited Colorado River resource by allowing urban areas to fund water conservation efforts in the Imperial Valley in exchange for use of the conserved water. Of the state's 4.4 million acre-feet allocation, 3.1 million acre-feet is apportioned to IID (SDCWA, 2017). Under the QSA, SDCWA funds agricultural conservation measures in Imperial Valley, and the conserved water produced is transferred from IID to San Diego.

The QSA defines specific water transfer quantities and obligations between the designated parties. IID provides up to 200,000 acre-feet of water per year to San Diego - through water conservation measures in Imperial Valley - for up to 75 years. In return, SDCWA pays a premium price for the conserved water as well as provides $30 million to IID to mitigate socioeconomic impacts from the water transfer and an additional $50 million to fund capital projects by IID. As of 2017, SDCWA pays $641 per acre-foot, where the price is scaled to increases in the Implicit Price Deflator (IPD) index for personal consumption expenditures (SDCWA, 2017).

The QSA JPA, made up of SDCWA, IID, CVWD, and the State of California, was established to fund the comprehensive environmental mitigation program required for the QSA water transfers. The QSA JPA has funded the delivery of mitigation water to the Salton Sea from 2003 to 2017, as well as the approved air quality mitigation program. The air quality program has installed six air quality monitoring stations and pilot projects to test the most effective way to address potential

QSA impacts to the Sea when mitigation water deliveries end at the end of 2017 (SDCWA, 2017). To date, the QSA water agencies have spent over $100 million on QSA environmental mitigation programs and projects.

4.3. State of California Salton Sea Management Program

The State of California's Salton Sea Management Program (SSMP) is in development and details several project phases to protect air quality and ecosystem values at the Salton Sea. The Phase I Plan is a 10-year phase that will guide State actions to expedite construction of habitat and dust suppression on areas of playa that have been or will be exposed at the Salton Sea by 2028 (State of California, 2017). The SSMP Phase I Plan includes milestones for 29,800 acres over the initial 10 years that were memorialized by the State Water Resources Control Board on November 7, 2017.

The SSMP has the goal of developing projects to protect or improve air quality, wildlife habitat, and water quality as necessary to minimize human health and ecosystem impact at the Salton Sea in the mid-term. While currently guided by the Phase I Plan, the SSMP is a longer-term process that has been developed and will be implemented by the State of California (State of California, 2017). The Phase I Plan aims to protect public health and wildlife by focusing on the north and south ends of the Sea where playa exposure is expected to be greatest and availability of agricultural return flows facilitate lowest cost habitat and air quality project development (State of California, 2017). The plan also includes a process for identifying management strategies for implementation in later phases.

5. Dust Control Measures Review

5.1. Survey of Dust Control Measures

There are many lakes around the world that have experienced either partial or complete drying. This comprehensive survey gathers information about the treatment of these dried lake beds and provides insight into the types of dust control strategies available. This will help in determining which methods are the most cost-efficient to implement at the Salton Sea. Aside from looking into dried bodies of water, dust control strategies at locations other than lakes have also been examined, such as those at construction sites and on unpaved roads. It is worthwhile to look into to see if these strategies could potentially help reduce dust at the Sea.

In researching dried lakes around the world, Owens Lake in California appears to be by far the most relevant case study, in large part because dust control has been implemented there for over 15 years (GBUAPCD, 2016). Additional case studies around the world were also researched to find additional dust control methods; however, most of these locations are not implementing dust control yet, are just beginning to experiment with strategies, or are looking towards Owens Lake for guidance on dust mitigation. It seems that Owens Lake has set the standard for dust emission control for other areas also experiencing problems with dust emissions.

5.2 Dust Control Strategies at Owens Lake

5.2.1 Best Available Control Measures (BACM)

In 1990, the Great Basin Unified Air Pollution Control District (GBUAPCD) approved three "Best Available Control Measure" (BACM) dust control methods for the Los Angeles Department of Water and Power (LADWP) to use at Owens Lake (GBUAPCD, 2016). These include shallow flooding, managed vegetation, and gravel blankets.

Shallow Flooding and Intermittent Ponds

Shallow flooding has been used to control nearly 80% of all exposed playa at Owens Lake (LADWP, Owens Lake Master Project, 2013). This involves flooding expansive "cells" of exposed lakebed with water a few inches deep, when the water percolates into the soil, gets recirculated and is used again. A variation on this technique involves flooding these cells a few feet deep, and then allowing them to drain down before refilling them (Austin, 2012). Flooding requires pumps and pipes and a large amount of water, - at Owens Lake about 95,000 acre-feet of drinking water per year. According to GBUAPCD, if 75% of the emissive area contains standing water and saturated soil, 99% of dust emissions are decreased. However, given that the terms of the QSA stipulate that water transfers will accelerate starting in 2018, the massive size of the Salton Sea (it covers ten times the area of Owens Lake), and the cost of implementing and maintaining shallow flooding, shallow flooding is not likely to be a reasonable dust mitigation option at the Salton Sea, unless the goal is to create habitat for migratory bird species as well. At

Owens Lake, shallow flooding and the creation of intermittent ponds inadvertently recreated habitat for water-birds. Because it is quick to implement (once the necessary infrastructure is in place), dust mitigated through shallow flooding accounts for 79% of the total treated area at Owens Lake (LADWP).

Managed Vegetation

Another dust control method approved by GBUAPCD is the use of managed vegetation to decrease the amount of dust blown into the air (GBUAPCD, 2016). For this method, native saltgrass is planted in rows, in expectation that it will spread out and serve as a ground cover over the dust. Research by GBUAPCD indicates that if half of a dust-producing area contains either live or dead vegetation, dust emissions will decrease by 99%. They also found that to establish vegetation in the first year, it will take about 7 acre-feet of water per acre and in the following years, it will take approximately 2.5 acre-feet of water per acre per year to maintain half of that cover. Due to the high level of maintenance as well as water-use, only approximately 8% of the dry Owens lakebed has been treated using this method (GBUAPCD, 2016).

Gravel Blanket

The third available option that GBUAPCD allows LADWP to use to suppress dust is the creation of gravel blankets (GBUAPCD, 2016). Locally-sourced rock is shallowly spread over the dry lake bed to prevent wind from disturbing the dust underneath. Because of its high upfront cost of $30 million per square mile, LADWP has not utilized this method as much as other methods (LADWP). Using gravel also requires certain soil conditions that do not exist throughout the entire lakebed. The advantage of this method is that it requires almost no maintenance and therefore, no recurring costs.

5.2.2 Alternative Controls (Non-BACM)

In the mid-2000s, GBUAPCD allowed LADWP to use other non-BACM dust control methods on certain portions of the Owens Lake playa, with the expectation that if the non-BACM methods are successful at suppressing dust emissions, they could be eventually be defined as BACM for the purposes of dust control.

Moat & Row

The main non-BACM method currently employed by LADWP is called "moat & row" (**Figure 5.2.2**). This is a PM_{10} control measure characterized by an array of earthen berms (rows) about 5 feet high above the lake bed surface, flanked on either side by slope-sided ditches (moats) about 4 feet deep (GBUAPCD, 2016). The rows are topped with sand fences up to 5 feet high that increase the effective height of the rows. The moats are intended to capture moving soil particles, and rows are intended to physically shelter the downwind lake bed from the wind (GBUAPCD, 2016).

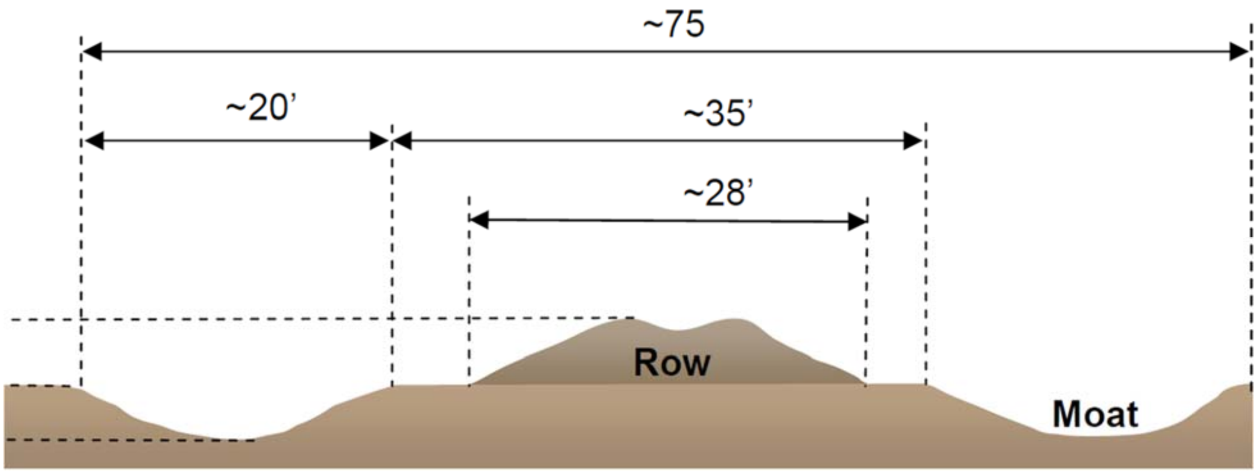

Figure 5.2.2 - Profile of moat and row with approximate dimensions (GBUAPCD, 2016)

The individual moat and row elements are constructed in a serpentine layout across the lake bed surface, generally parallel to one another, and spaced at variable intervals, so as to minimize the fetch between rows along the predominant wind directions (GBUAPCD, 2016). The purpose of this is to control emissions under the full range of principal wind directions. At Owens Lake, moat & row spacing varies from 250 to 1000 feet, depending on the surface soil type and the PM_{10} control effectiveness required (GBUAPCD, 2016). The PM_{10} control effectiveness of moat & row may be enhanced by combining it with other dust control methods such as vegetation, water, gravel, sand fences, or the addition of other features that enhance sand capture and sheltering or directly protect the lake bed surface from wind erosion. The effectiveness of the array can also be increased by adding moats and rows to the array, which reduces the distance between rows.

5.3 Other Potential Alternative Controls

Vegetation Enhancement

This measure consists of managed enhancement of existing vegetation in new playa areas. With the recession of the Salton Sea, plants already established along the shoreline may naturally expand where freshwater flows into the Sea, creating favorable growing conditions (IID, 2016). Species would likely include a mix of grasses, rushes, sedges, and shrub species. The expansion of these plant species toward the Sea could possibly remove the need for more costly and water-intensive measures. Additionally, hydrophytic vegetation could line the watercourses as they cross the playa.

Under this measure, vegetation should migrate down the playa with the shoreline, but vegetation densities might be unsustainable in certain areas without irrigation or artificial drainage (IID, 2016). To meet plant water demand, flood, pulse, or drip irrigation could be used. Fertilizers could also be added to irrigation water to encourage growth. Potassium, nitrogen, and phosphorus fertilizers are all potential options, which would also be strictly controlled to avoid excess application and potential eutrophic effects. If it appears that certain regions are not seeing growth after a period of time, they could be transitioned to different DCMs.

Tillage equipment would be used during construction, as well as for both the planting and maintenance of vegetation (IID, 2016). Tractors and backhoes would be necessary for both weed control and cultivation of the vegetation.

Surface Roughening

This DCM consists of roughening the land surface, typically with conventional tillage implements, depending on soil conditions and the target roughness (IID, 2016). The roughened surface is less susceptible to erosion due to the lifting of the boundary layer of moving air farther above the land surface, and due to the capture of mobile sand within the furrows created by the roughened surface. To maintain control over time, surface roughening may need to be repeated periodically as the land surface may be smoothed by erosion, sedimentation, and settling. Surface roughening is typically done with a tractor-drawn tillage implement, such as a disk or plow (IID, 2016). When necessary, water may be applied to restore soil structure so that re-tilling is more effective.

Dust control effectiveness is dependent on the geometric characteristics created by the tillage implement (IID, 2016). **Figure 5.3** below displays a conceptual schematic of the geometric parameters for a bull plow and a switch plow. Furrow depth, ridge height, and ridge spacing are functions of the implement. Interrow spacing is the spacing required between implement passes to achieve effective dust control. Surface roughening is expected to provide greater than 99 percent dust control effectiveness as long as the average ridge height within tilled areas is sufficient to arrest soil particle motion (IID, 2016).

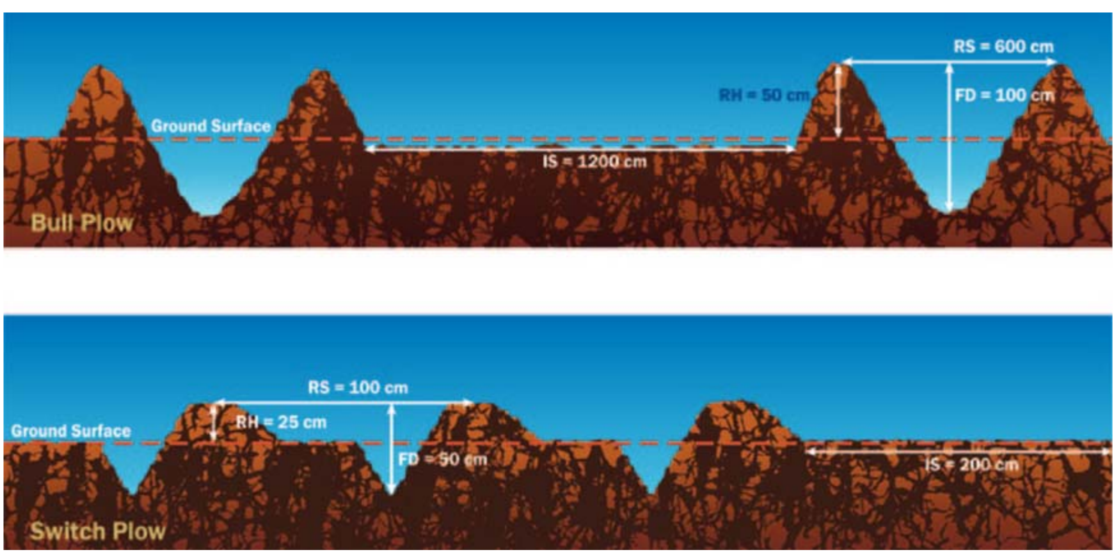

Figure 5.3 - Conceptual schematic of the ridge height (RH), ridge spacing (RS), furrow depth (FD), and interrow spacing (IS) for a bull plow and a switch plow (not to scale) (IID, 2016)

Vegetative Swales

This measure consists of earthen channels covered in vegetation, which are produced by creating pairs of berms approximately 50-60 feet apart, in a parallel manner (IID, 2016). Additionally, other pairs of berms adjacent to these are spaced anywhere from 200 to 500 feet from one another (IID, 2016). The purpose of these swales is to reduce the wind velocity at soil surface by obstructing its flow across the playa, leading to reduced emission downwind, as well as preventing sand from becoming mobile. These vegetated swales halt the sand and capture it underneath the vegetation, where it becomes trapped. Periodically, the surfaces of these swales will need to be wetted (either naturally or artificially), and need to form a crust to be effective. Swales also help reduce surface wind velocities due to sheltering of areas downwind of the swales (IID, 2016). This results in a large scale over which the swales can act as a dust control mechanism.

Evaporite Deposits / Brine Stabilization

An extensive evaporite deposit is located at the topographic low of Owens Lake and is adjacent to the dust control basins. Evaporites are natural salt and mineral deposits that remain after the evaporation of a body of water. Because this deposit is non-dust-emissive, it has been investigated as a potential replacement for the freshwater used in dust control (Groeneveld et al., 2010). The deposit consists of precipitated layers of sodium carbonate and sulfate bathed by, and covered with brine dominated by sodium chloride perennially covered with floating salt crust.

These floating crusts reduce evaporation to levels less than precipitation, thus ensuring that the evaporite body remains wetted at all times. Moving salts from an existing evaporite deposit to the dust control basins may, therefore, offer a viable replacement for the freshwater used for dust control on the dry lake bed (Groeneveld et al., 2010).

Using the adjacent non-dust-emissive natural evaporite deposit as a model, salt deposits created in the dust control basins could be engineered to contain equivalent layers: precipitated salts below, capped by a layer of salt-dominated brine. Salt crusts would form atop this supernatant brine layer to reduce annual evaporation to less than annual precipitation, thus ensuring that the engineered salt deposits would also remain wet and non-emissive (Groeneveld et al., 2010). Once established, the natural properties of salt deposits modeled upon the natural deposit may enable complete dust control with near zero additional fresh water.

Phytomelioration

The Aral Sea, which used to be the 4th largest lake in the world by surface area, is suffering a fate similar to Owens Lake (Usmanova, 2003). A method using vegetation is being employed at the dry sea floor surface to stabilize the dust. Research has been conducted to determine which salt-resistant plants, also called halophytes, are able to thrive on the salty dry seabed of the Aral Sea (Meirman et al., 2001). The process of cultivating halophytes in order to improve the productivity of soil and vegetation or to otherwise reduce dust storms is called phytomelioration.

An experiment at the Aral Sea found that sandy soils were more productive than clay soils in supporting phytomelioration and that using local or native species was more effective (Meirman et al., 2001). The growth of the species *Haloxylon aphyllum* was found to have the best results under certain conditions (Wucherer et al., 2012). If phytomelioration is to be used at the Salton Sea, native halophytes should be considered. Additionally, it would be important to look at the type of soil and salinity level of the soil where managed vegetation is to be planted in order to get the best results. Of course, this method requires some maintenance and infrastructure, just like shallow flooding.

5.4 Strategies at Non-Lakes

5.4.1 Dust Suppressants

Dust suppressants have historically been used to mitigate fugitive dust from construction sites and unpaved roads, such as earthen and gravel roads (Sanders & Addo, 1993). They also have the potential to be used on dried lake beds. The most common (as well as cost-effective) types of suppressants are hygroscopic salts like magnesium chloride ($MgCl_2$) and calcium chloride ($CaCl_2$), as wll as organic petroleum and non-petroleum products (such as bitumen emulsion and lignosulphonates) (Edvardsson, 2010). Suppressants act by agglomerating particles and essentially converting smaller particles into larger ones (CA DPR, 2012). This occurs by either creating moisture tension between fine particles (hygroscopic, such as with salts), cementing the particles (chemicals), or altering the surface chemistry (surfactants). Suppressants are widely used throughout the United States, with over 375,000 miles of public unpaved roads in the nation treated in some way (CA DPR, 2012). As of 1991, an estimated 75-80 percent of these suppressants used were hygroscopic (salts), 10-15 percent were petroleum based, and 5-10 percent were organic non-petroleum (Piechota et al., 2004).

Hygroscopic Salts (chlorides)

Hygroscopic salts like magnesium chloride and calcium chloride have been shown to be less toxic than petroleum-based suppressants, and magnesium chloride is considered non-toxic to aquatic life (Piechota et al., 2004, Edvardsson, 2010). With magnesium chloride in particular, impacts to water quality are very low and are below EPA thresholds (Goodrich et al. 2009, Shi et al. 2009). However, there are some concerns surrounding the impacts of both of these compounds on sensitive plant species, perhaps limiting their applicability (Bolander & Yamada, 1999). Because magnesium chloride and calcium chloride are salts and thus very water soluble, they also need to be reapplied on a yearly basis, and as such, operations and maintenance costs are higher in relation to capital costs (compared to other dust mitigation techniques) (Bolander & Yamada, 1999). Common product names for magnesium chloride include DustGard, Dust-off, and Chlor-tex, and common product names for calcium chloride include include Calcium Chloride Liquid, Calcium Chloride Flakes, Dowflake, and Liquidow.

Lignosulphonate (organic non-petroleum)
Many types of organic non-petroleum suppressants exist that have the potential to control dust emissions, including ligninsulfonate, tall oil, vegetable derivatives, and molasses. However, while ligninsulfonate has been extensively researched and studied, there is limited knowledge regarding the side effects of the other products, particularly any harmful impacts on aquatic habitats (Bolander & Yamada, 1999).

Lignin is the main component of lignosulphonate, and is a complex organic polymer found in wood cells which is typically removed from trees during the paper-pulping process (CA DPR, 2012). This polymer gives strength to wood cells, and to make it soluble, typically sodium, calcium, ammonium, or magnesium bisulfate is added during processing (CPWA, 2005). The most common product names for lignosulphonate are DC-22, Dustac, CalBinder, Lignin Sulfonate, Polybinder, and RB Ultra Plus.

One of the main benefits of this product is that it works well in dry conditions, and that it is typically cheaper than many types of chlorides (Sanders et al., 1994; WTIC, 1997). It is also very effective at keeping dust stable and in place, rather than emissive. However, it requires more frequent application than do chlorides (typically more than one application per year). It is quite brittle when dry, and can be broken up easily by large disturbances or very heavy rains (Edvardsson, 2010; WTIC, 1997). In aquatic environments, it has also been shown to retard the growth of fish (Piechota et al., 2004).

Bitumen Emulsion (organic petroleum)
Organic petroleum includes bitumen emulsion and mineral oils, which are produced from refined crude oil. These include products such as Vaseline. Unfortunately they have been shown to be much more expensive than other types of suppressants and thus not as economically feasible for widespread use (Edvardsson, 2010). They also have the potential to produce very strong environmental impacts, and thus are likely a poor choice for consideration (Lohnes & Coree 2002).

Polysaccharide (sugar) Solutions
Sugar solutions have also been tried and tested as dust suppressants, but due to their lack of effectiveness, are not feasible as mitigation strategies (Edvardsson, 2010).

5.5 Other Case Studies

Organizations looking to implement environmental mitigation at other locations, including the Great Salt Lake and Lake Urmia (Iran), have looked to Owens Lake to determine effective dust control methods (The Sheet, 2015).

Lake Urmia (Iran)

Lake Urmia, located in northwestern Iran, is another example of a desiccated endorheic saline lake that has been severely impacted by water diversions. It was once Iran's largest lake and one of the largest saltwater lakes in the world, but over the last fifty to sixty years, most of the rivers that feed into Lake Urmia have been dammed or diverted for the purposes of water consumption, energy demands, and irrigated agriculture (Moghaddasi et al., 2017). The lake's surface area dwindled from 5,000 km^2 twenty years ago down to just 500 km^2 in 2013 (UNDP, 2017). These anthropogenic impacts have led to the formation of sand dunes around the lake (Ahmady-Birgani et al., 2018).

Under various restoration efforts, it has now risen back to around 2,300 km^2 in area (although still shallow). These efforts included the release of water from dams, canal drainage to un-silt feeder rivers, and the implementation of more water-efficient irrigation practices in the farming communities that surround Lake Urmia (UNDP, 2017). Through United Nations Development Programme initiatives, integrated participatory crop management (IPCM) initiatives been implemented to reduce water consumption. These pilot projects have shown that water efficiency has increased by 35 percent (UNDP, 2014).

Due to the sheer size of Lake Urmia, which is over ten times the size of Owens Lake, restoration of water into the lake for dust control has been the main concern for officials, not dust emissions. However, in 2013 the Iranian government also created the Urmia Lake Restoration Program (ULRP). A goal outlined by the Program is the "Identification of dust source and stabilizing them," which specifically addresses dust control. Dust has also been identified as a source of human health concern in this region, through studies conducted on the lake (Alizade Govarchin Ghale et al., 2017). A 2014 "Roadmap" document created by the United Nations Development Programme recommends creating embayments for dust control, among other benefits such as recreation and habitat (Marden et al., 2014). This document also recommends characterizing the dust in terms of agricultural and human health impacts. In 2015, a delegation of Iranian scientists also visited Owens Lake to learn more about different dust mitigation techniques, with the hope of implementing them at Lake Urmia sometime in the future (The Sheet, 2015).

Great Salt Lake (Utah)

The Great Salt Lake in Utah is another example of a large endorheic saline lake at risk of desiccation. Since the arrival of pioneers in the 19th century, the lake surface has dropped by 11 feet in elevation and had reduced in volume by nearly 50 percent, exposing much of the lake bed (Wurtsbaugh et al., 2016). This has reduced the area of the lake from around 1,600 mi^2 when he pioneers arrived to only 1,050 mi^2 in 2015. Nearly 63 percent of the water depletion is attributed to agricultural use, with an additional 13 percent and 11 percent attributed to mineral extraction and municipal/industrial use, respectively (Wurtsbaugh et al., 2016). Because of this, the Great Salt Lake had been put at risk for increased level of fugitive dust.

The Bear River, which contributes about 60 percent of the freshwater inflow to the Great Salt Lake, is under consideration for diversion. The State of Utah is examining the construction of up to seven dams and a 50-mile pipeline to link the dams to urban water treatment centers (Weiser, 2016). If this project were to be implemented, it would likely greatly exacerbate the lake's decline and put the region even more at risk for potential dust emissions. The Great Salt Lake Advisory Council (GSLAC), created by the Utah State Legislature in 2010, is currently conducting studies on the potential for fugitive dust emissions at the Great Salt Lake (GSLAC, 2017). The Council is currently modeling how to implement an integrated water management plan, with the goal of determining the best way to maintain lake levels. As of yet, there are no large scale dust control projects in this region similar to those at Owens Lake.

Aral Sea

Over the last sixty years, the Aral Sea, located in Central Asia, has desiccated over 23 meters in depth, exposing massive amounts of seabed and splitting the Sea into distinct and separate sections (Zavialov, 2005). Once the fourth largest sea in the world at over 26,000 square miles in size, it is now broken into four smaller seas covering about 6,500 square miles, in total. Soviet irrigation projects that diverted the inflows to the lake caused the Sea to recede and led to collapse of the Sea's fishing industry, as well as created a new desert where the Sea once stood, called the Aralkum Desert.

Due to the sheer size of the exposed seabed and the extreme levels of salinization of its soils, the main goal of restoration efforts at the Sea is to increase sea levels to cover certain areas of the Seabed again, particularly around the North Aral Sea (Barghouti, 2006). The World Bank has provided loans to Kazakhstan to create dams to conserve and redistribute water into the North Aral Sea (World Bank, 2006). This northern region has been recovering slowly, with a sea level rise from about 30 meters to 40 meters (World Bank, 2005). The southern and larger part of the desiccated sea, on the other hand, is still desertified, and will likely remain that way for the foreseeable future. Planted vegetation has been considered as an option to combat the effects of desertification in the southern portion of the former sea, but periodic natural flooding of this region would likely destroy any vegetation that could be implemented for dust control.

There are no tangible efforts to implement large-scale DCMs in this region, in comparison to the efforts at Owens Lake and at the Salton Sea. Most efforts are focused on refilling portions of the Aral Sea for the purposes of restoring agriculture and fishing industries.

5.6 Summary of Strategies and Costs for Dust Control Measures

Table 5.6 - Dust Control Measure Costs (SSAQMP, July 2016)

Dust Control Measure	**Capital Cost (Per Acre)**	**Estimated O&M (% of Capital)**	**Total Cost ($2018)**	**Information Source**
Surface Roughening	400	75%	5,400	IID AQ Program to date
Moat and Row	14,000	10%	37,333	LADWP personal communication
Dust Suppressants	2,000	100%	35,333	Cargill (Magnesium Chloride)
Vegetation Enhancement	9,000	7.5%	20,250	IID AQ Program to date
Vegetative Swale	17,000	7.5%	38,250	IID AQ Program to date
Managed Vegetation	25,000	4.5%	43,750	LADWP personal communication
Shallow Flood	25,000	2.0%	33,333	LADWP personal communication
Brine Stabilization	21,000	0.25%	21,875	LADWP personal communication
Gravel Cover (2 inch thickness)	36,000	0.25%	37,500	LADWP personal communication
Gravel Cover (4 inch thickness)	48,000	0.25%	50,000	LADWP personal communication

Cost estimates are based on actual experience with dust control pilot projects at the Salton Sea and with LADWP projects at Owens Lake, with the exception of dust suppressants, which involve the use of products that can be priced and purchased (IID, 2016). However, these cost estimates are based on past projects that have only been implemented in a limited experimental capacity. Ultimately, design, construction, and engineering costs may be greatly affected by the unique location, climate and other characteristics of the regions in which the projects are implemented.

The literature review of terminal lakes revealed that only one terminal lake is applicable to this project - Owens Lake. The other case studies examined were not determined to be applicable to the Salton Sea because 1) The majority of actions taken at terminal lakes focus on retaining water to enhance lake/sea levels rather than mitigating dust emissions, and 2) many terminal lakes, such as the Aral Sea, the Great Salt Lake, and Lake Urmia, specifically refer to Owens Lake to forecast appropriate DCMs and associated costs.

Owens Lake shares similar features as the Salton Sea in regard to the air quality regulations that affect PM_{10}. Both bodies of water are obligated to maintain dust control using BACM, as defined by the EPA through their respective air pollution control districts. These measures include shallow flooding, gravel blankets, and managed vegetation. At both Owens Lake and the Salton Sea, the water agencies involved with dust control are implementing non-BACM pilot projects like surface roughening and vegetation enhancement, in the hopes that these methods will be approved by the EPA as BACM for the purposes of long-term dust control.

Both the LADWP, which is responsible for dust control at Owens Lake, and the parties to the QSA, who are taking proactive measures to control dust emissions at the Salton Sea, have used the same contractors for certain pilot projects. Due to the very similar nature of the projects being implemented, cost estimates for the technologies used at both of these bodies of water are therefore predicted to be similar, another reason why Owens Lake is the most relevant case study.

5.7 Dust Control Methods Best Suited for the Salton Sea

The purpose of the terminal lake literature review was to determine the most appropriate DCMs for implementation at the Salton Sea. The criteria for appropriate DCMs for use at the Salton Sea involved cost-effectiveness, suitability for Salton Sea playa, water use-effectiveness, and the minimization of potential environmental disturbances. The search was not limited to solely BACM techniques, which are defined by the two air pollution control districts that have jurisdiction over the Salton Sea. The BACM techniques were determined to be inappropriate for sole use at the Salton Sea because they were expensive, as in the case of gravel cover, involved a significant amount of water use, as in the case of shallow flooding, or had potential for indirect environmental harm, as in the case of chemical dust suppressants. Although Owens Lake mainly uses shallow flooding as a control measure, it is not appropriate to recommend a similar strategy for use at the Salton Sea because not nearly as cost-effective as the suite of experimental non-BACM techniques available for use at the Sea. The parties to the QSA also want to minimize the amount of water used for dust control, otherwise it would defeat one of the main purposes of the QSA, which is to conserve water so that it can be transferred from IID to SDCWA and CVWD.

Based on the best available dust control literature, results from IID DCM pilot studies, and consultations with USDA soil scientists, we have identified certain experimental non-BACM mitigation techniques that are suitable for use on certain soil classes (**Table 5.7a**).

Table 5.7a - Soil class and suitable mitigation techniques for use at the Salton Sea

Soil Class	Suitable non-BACM Mitigation Techniques
Fine-textured	Surface roughening; moat and row
Medium-textured	Surface roughening; moat and row; vegetation enhancement
Coarse-textured	Vegetation enhancement

Based on the above criteria, it was determined that the two most appropriate dust control mitigation techniques to be applied at the Salton Sea are surface roughening and vegetation enhancement. Both surface roughening and vegetation enhancement meet the water-effectiveness, cost-effectiveness, and environment sensitivity criteria, but are non-BACM DCMs. IID has been piloting both surface roughening and vegetation enhancement dust control studies in the Salton Sea since 2015 and is actively seeking approval from ICAPCD to become an approved BACM for dust control.

However, through the aforementioned review of dust control literature and results from IID DCM pilot studies, as well as through consultations with USDA soil scientists, surface roughening and vegetation enhancement have been determined to be suitable for implementation on only approximately 80% of future exposed playa (from 2018 - 2047). This is because there is some uncertainty regarding the effectiveness of each technology on each of the 5 soil classes at the Sea, and other similar types of dust control techniques might need to complement the main mitigation techniques used on each soil type in order to achieve dust control. Based on this analysis, and based on cost-minimization and a focus on non-BACM technologies, the remaining 20% of exposed playa should be treated with a combination of moat and row, vegetative swales, and managed vegetation DCMs.

The following non-BACM techniques were deemed appropriate to satisfy dust mitigation criteria for exposed regions that would not be appropriate for just “main” non-BACM measures (surface roughening and vegetation enhancement). **Table 5.7b** shows the relative usage of DCMs per area for each of the defined soil classes at the Salton Sea.

Table 5.7b - Relative use of dust control strategy by soil type per area

Soil Type	Surface Roughening	Moat and Row	Vegetation Enhancement	Vegetative Swale	Managed Vegetation
Fine	95%	5%	0%	0%	0%
Moderately Fine	90%	10%	0%	0%	0%
Medium	45%	10%	30%	10%	5%
Medium Coarse	40%	10%	35%	10%	5%
Coarse	0%	0%	70%	20%	10%
Shell	NA	NA	NA	NA	NA

6. Legal Review

6.1 Legal Review Background

The QSA has been litigated since its inception on the grounds of CEQA and California Water Code violations (Superior Court of California, 2018). A judge has ruled that the QSA will remain enforceable until at least 2047, when both the SDCWA and IID have the option to either end the agreement or extend it until 2077. The water conservation investment stipulations of the QSA have been met through efficient irrigation practices and capital improvement projects in IID. Some of these conservation methods can reduce agricultural runoff into the Salton Sea, contributing to declining shoreline levels. As the Sea shrinks, the exposed playa could produce increased dust, and mitigation responsibility may be called into question.

To help understand the legal ramifications surrounding dust control at the Salton Sea, it is helpful to review similar disputes. The legal scenario surrounding dust litigation is very unique, and there are not many relevant case studies to which it can be compared. One such dispute occurred at Owens Lake, in California. Many real-world dust mitigation scenarios worldwide use the Owens Lake situation as a reference, including those related to dried sea/lake beds. This section will provide a legal review of the Owens Lake case to determine its applicability to the Salton Sea, and ultimately to understand what the legal scenarios surrounding dust control obligations could be. Throughout this legal review, consultations with environmental lawyers were held periodically to clarify legal terms and to improve technical understanding of the complexities surrounding the Owens Lake case, and how it could potentially be applied to the Salton Sea.

6.2 Owens Lake Legal Review

Owens Lake is a 110-square-mile mostly dry saline lake on the eastern slope of the Sierras Nevada, and over the last century has become the single worst source of air pollution in the United States (GBUAPCD, 2013). Although air quality was an issue in the area for much of the 20th century as a result of actions by the Los Angeles Department of Water and Power (LADWP) to divert water from the Owens Valley, it was not specifically addressed by them until 1983. A timeline is provided below.

6.2.1 Owens Valley Water History: 1900 - 1983

- 1905: City of Los Angeles began to acquire both the land and water rights in Owens Valley to secure a reliable water source for its growing population (ICWD, 2008).
- 1913: Los Angeles exported 300,000 acre feet per year of water from Owens Valley via diversions from the Owens River (Pomfret, 2006).

- 1924: The land around Owens Lake had been completely exposed as a result of these water diversions (ICWD, 2008)
- 1933: Los Angeles had purchased 85% of the valley's residential and commercial property and 95% of the valley's farm and ranch land (ICWD, 2008).
- 1938-1950s: Los Angeles began selling properties in valley towns directly back into private ownership but without the associated water rights.
- 1970: Los Angeles built a second aqueduct to convey water to the city via three new sources of water: groundwater pumping from Owens Valley, decreased irrigation in Owens Valley, and increased diversions from Mono Basin (ICWD, 2008).
- Throughout the 1970s: There were legal disputes between LADWP and Inyo County, where Inyo County challenged LADWP's aqueduct construction and groundwater pumping via the 1972 enacted California Environmental Quality Act (CEQA) (Pomfret, 2006).
- 1982: A Memorandum of Understanding (MOU) between Inyo County and LADWP announced the intention of both parties to work together to identify and recommend methods to meet the needs of both the Valley and Los Angeles. Although the 1982 MOU established joint LADWP and Inyo County committees to balance the water needs of both agencies, suits were ongoing and air quality was not legally addressed until 1983.

6.2.2 Passage of SB 270

As of 1982, Los Angeles owned the water rights to continue to divert water from Owens Valley and continued groundwater pumping even with CEQA challenges brought forth by Inyo County. The main legal challenges concerned the ability of Los Angeles to pump groundwater in Owens Valley, but in the early 1980s legal attention shifted to air quality restitutions. In 1983, the California Superior Court ruled that the "Public Trust Doctrine" applies to LADWP's diversions from streams that flow into Mono Lake (ICWD, 2008). SB 270 (Health and Safety Code section 42316) was passed, which authorized GBUAPCD to require the City of Los Angeles to provide reasonable mitigation of air quality impacts associated with its water management. SB 270 is important because it established that LADWP was solely financially responsible for dust mitigation in the area although LADWP does not own any land in the area, only the associated water rights.

6.2.3 Implications of SB 270

Although SB 270 was enacted in 1983, mitigation measures in Owens Valley did not commence until 1998. From 1983 to 1998 the terms of SB 270 were explored: USGS studies were performed to determine the appropriate dust control techniques to be applied, and where along Owens Valley they should be applied to allow air quality to reach a "reasonable" level. The reasonable level is defined as by EPA's PM_{10} attainment goals. In 1998, Los Angeles agreed to flood, spread gravel, or seed the lake bed of 20 square miles of Owens Valley to mitigate dust at a projected cost of $400 million (New York Times, 1998). Throughout the 2000s, LADWP sued and counter-sued GBUAPCD over mitigation responsibilities. A federal judge threw out LADWP's 2013 countersuit against GBUAPCD regarding dust mitigation liability. It was ruled that it does not matter who owns or manages the land, but rather liability falls on whoever is responsible for creating the dust pollution by diverting the water that would otherwise feed the lake (Sierra Wave, 2013). Los Angeles is now ultimately responsible for mitigating dust via native vegetation, gravel blankets, and flooding with shallow sheets of water (with allowance for a few experimental moat-and-row pilot projects) (**Figure 6.2.3**). They must treat 53.4 square miles to meet the National Ambient Air Quality Standards (NAAQS), with overall project costs having already exceeded $1.2 billion (GBUAPCD, 2016).

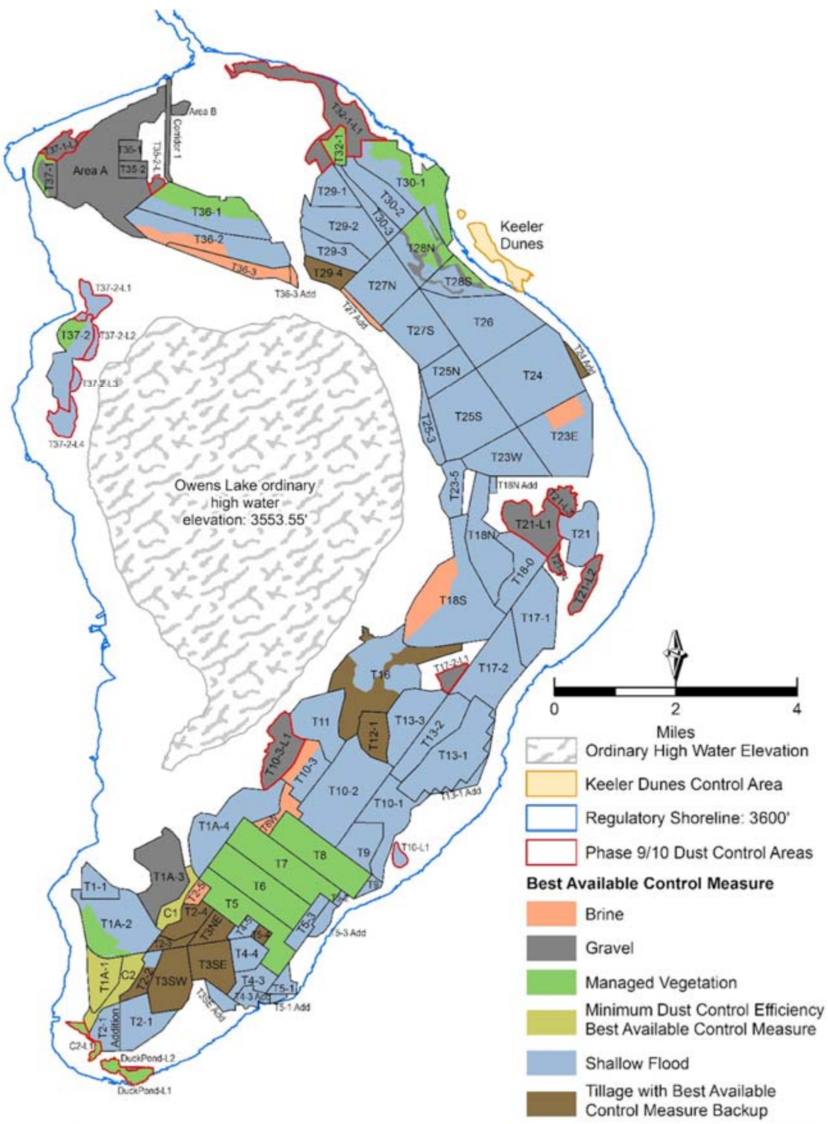

Figure 6.2.3 - Current Dust Control Measures Implemented at Owens Lake by LADWP (GBUAPCD, 2016)

6.3 Salton Sea Case Overview

Imperial County has been in severe nonattainment for federal and state 24-hour standard levels for PM_{10} (150 μg/m^3 and 50 μg/m^3, respectively) since the 1980s (Arb.ca.gov, 2014). A variety of factors contribute to the existing poor air quality in the region and there are concerns about potential impacts from playa exposed at the Salton Sea. Given the air quality issues, it is important to understand the water rights, land ownership, QSA, and ICAPCD rules to begin to understand the legal framework.

6.3.1 QSA Stipulations

Under the terms of the QSA, SDCWA receives up to 200,000 acre-feet of water per year from IID, and CVWD receives up to 103,000 acre-feet of water per year from IID. Because of the potential for environmental impacts to the Salton Sea related to the QSA-stipulated water transfers, the JPA was formed to allow all relevant parties joint decision-making powers and joint funding obligations toward environmental mitigation (SDCWA, 2003). The four relevant parties are SDCWA, IID, CVWD, and the State of California (through the California Department of Fish & Game). The JPA has a funding obligation limited to $287 million over the life of the agreement to implement required mitigation measures associated specifically to impacts from the QSA water transfers. As per Article IX of the Quantification Settlement Agreement Joint Powers Authority Creation and Funding Agreement (a side agreement to the QSA), any mitigation funding required beyond the $133 million limit (in 2003 dollars) will be borne solely by the State of California.

6.3.2 Relevant ICAPCD and SCAQMD Rules and Regulations

The Salton Sea lies within both ICAPCD and South Coast Air Quality Management District (SCAQMD) boundaries, and is thus subject to air regulations from two different jurisdictions. These regulations exist to ensure that California's SIP is in line with the EPA's NAAQS. ICAPCD Rule 800 requires control of "fugitive dust," defined as any "particulate matter" released into the air from any activity other than motor vehicle exhaust or stack emissions from stationary sources, and it applies to any man-caused condition (ICAPCD, 2012). Rule 800 section C.32 defines a "person" as any individual or legal entity. Rule 804 establishes that the "person" who owns the land is responsible for ensuring dust mitigation to limit visible dust emissions to less than 20% opacity.

Similar to the ICAPCD rules, SCAQMD Rule 403 ("Fugitive Dust") applies to "any activity or man-made condition capable of generating fugitive dust," including any portion of the earth's surface "which has been...uncovered...or otherwise modified from its undisturbed natural soil condition, thereby increasing the potential for emission of fugitive dust" (SCAQMD, 2005). Soil can be considered "undisturbed" if it has been restored to its natural state, paved (or covered by a permanent structure), or has a certain percentage of sustained vegetative ground cover (SCAQMD, 2005). "Fugitive dust" is defined as any solid particulate matter that becomes airborne from any activity other than an exhaust stack (SCAQMD, 2005).

Specifically regarding liability, Rule 403 states that "no person shall cause or allow the emissions of fugitive dust...such that the dust remains visible in the atmosphere beyond the property line of the emission source" (SCAQMD, 2005). It also states that "no person shall cause or allow PM_{10} levels to exceed 50 micrograms per cubic meter when determined...as the difference between upwind and downwind samples collected on high-volume particulate matter samplers or other U.S. EPA-approved equivalent method for PM_{10} monitoring." Unlike the ICAPCD rules, the SCAQMD rules are less clear regarding liability for the owners of exposed parcels, and instead state that no *person* shall allow the emissions of fugitive dust through their activities. Because of this, it is unclear whether or not Rule 403 is explicitly tied to land ownership. The phrasing of this rule creates uncertainty regarding which party would be specifically liable for dust control.

ICAPCD's and SCAQMD's respective rules regarding dust control strategies and onus of fugitive dust responsibility are, on the surface, similar enough that there is no need to tailor the dust mitigation strategy to the geographic scope of air pollution control district regulations.

6.4 Conclusions about Salton Sea Dust Liability

The SCAQMD rules do not appear conclusive regarding liability for QSA-related dust mitigation, but Rule 804 of the ICAPCD seems to imply the onus for dust mitigation is on the landowner (ICAPCD, 2016). In regard to the Owens Lake case, the federal judge's ruling on the 2013 LADWP countersuit that dust mitigation liability is on the party responsible for diverting water from Owens Lake, rather than on the landowners surrounding Owens Lake, could potentially be an indicator of liability for the parties to the QSA.

Because of significant differences surrounding the facts and circumstances, it is difficult to apply the results of the Owens Valley case directly to the Salton Sea. The contexts surrounding the Salton Sea and Owens Lake are different in several key ways: statutes, cause of sea recession, water outlets, and confounding factors. The main difference between the Owens Lake and Salton Sea cases is that there is a specific statute, SB 270, which explicitly places liability for dust control mitigation on LADWP. No similar statute exists to explicitly state the liability of any one QSA party for mitigation liability at the Salton Sea.

Additionally, whereas LADWP effectively drained Owens Lake by using its water rights to divert the lake's direct inflow (the Owens River), the parties to the QSA have instead indirectly caused a long-term reduction in the level of the Salton Sea by preventing agricultural runoff that would otherwise flow into the Sea. This adds multiple layers of complexity not present in the Owens Lake case. Furthermore, the QSA water transfers involved an extensive environmental review and analysis under modern environmental laws that did not exist for Owens Lake. The resulting environmental mitigation obligations include the control of air quality impacts under an approved air quality program, which was formed in response to the requirements of the Environmental Impact Report (EIR) produced for the QSA.

Moreover, there are other previous water transfer agreements and non-QSA factors that have undoubtedly had some impact on the level of the Salton Sea over time. This includes a large 1988 water transfer agreement between IID and the Metropolitan Water District of Southern California (MWD). This agreement is similar in scope to the QSA water transfers, where MWD paid for various canal linings and conservation measures within IID's jurisdiction, with the conserved water being transferred to MWD (IID, 1988). The total annual amount of water conserved and transferred under this agreement is 105,000 acre-feet/year. It is uncertain how the impacts from this and other agreements can be discerned and accounted for in determining mitigation liability at the Salton Sea. **Table 6.4** summarizes the legal dimensions of both the Owens Valley and Salton Sea cases.

Table 6.4 - Comparison of Owens Valley case to the Salton Sea

	Owens Valley	**Salton Sea**
Story	As a result of water transfers to a major metropolitan area, the lake level recedes, and dust emissions surpass NAAQS.	Air quality issues (severe nonattainment for PM_{10} NAAQS) existed before water transfer stipulations in 2003, and are a function of both water transfer related and non-water transfer factors.
Statutes	SB 270 explicitly defines LADWP as liable for dust control. In 2013, a federal judge ruled that the party responsible for causing the lake recession should be liable for dust control.	ICAPCD Rule 804 Section E.1 implies that the onus for dust control is on the landowner. SCAQMD Rules 403 and 403.1 are not as clear regarding landowner liability.
Cause of Sea Recession	The City of Los Angeles diverted water from the Owens River, which directly fed into the Owens Lake.	QSA-stipulated agricultural conservation in Imperial County has reduced runoff into the Salton Sea.
Land Ownership	The City of Los Angeles does not own any land in the Owens Valley.	Both IID and CVWD, JPA members, own land at the Sea.
Water Rights	The City of Los Angeles owns the water rights for Owens Valley.	Out of California's yearly entitlement of 4.4 million acre-feet of Colorado River water, IID is allocated 3.1 million acre-feet.
Drainage Basin	Owens Valley and Owens Lake is the direct drainage basin of the source of Los Angeles's water, the Owens River.	The Salton Sea is a federally designated agricultural sump. Inputs to the Sea are agricultural drainage water.
Confounding Factors	It is clear that LADWP's pumping of groundwater in Owens Valley and diverting water from the Owens River directly influenced the Sea level recession in Owens Lake.	Although the QSA water transfers directly influence the reduction in the level of the Salton Sea, other non-QSA factors and previous water agreements also impact the Sea.

6.5 Legal Review Summary

The QSA has been upheld by the Sacramento Superior Court on all fronts, including its analysis of air quality impacts and mitigation (Chine, 2013). This means that the defined air quality mitigation program approved in the environmental analysis for the QSA water transfers will continue to be implemented, including on-the-ground dust control projects. But in the case of the Salton Sea, there are certain existing air quality regulations that put the onus of dust control on the landowner. There is also the responsibility of the State of California to restore the Salton Sea beyond the environmental mitigation requirements of the JPA, as per the recently adopted stipulated order by the State Water Resources Control Board (SWRCB, 2017). With all of these potential liabilities at the Salton Sea, it is important to examine similar case studies to have a better understanding of dust control liability in other scenarios.

An in-depth investigation of the legal framework surrounding LADWP's responsibility to mitigate dust at Owens Lake found that Health and Safety Code section 42316 mandates that LADWP implement DCMs. At the Salton Sea, ICAPCD and SCAQMD regulations determine potential liability for remediation. ICAPCD Rule 804 requires the landowner to control fugitive dust, whereas SCAQMD regulations are less clear regarding mitigation responsibility. From the information gathered, it is likely that the onus of dust control at the Salton Sea will be on the landowners, at least within Imperial County. As mentioned previously, the QSA, JPA, and the State of California also have dust control responsibilities.

Because IID is a member of the JPA, they have a stable budget for them to use to implement dust control on IID-exposed land. The JPA water agencies have an official funding obligation of $133 million (in 2003 dollars), or $287 million in nominal dollars. The JPA funding must be spent on dust mitigation at the Salton Sea on land that is exposed solely due to the water transfers, also known as QSA-exposed land. Through the end of fiscal year 2017, the members of the JPA have expended approximately $119 million of their total obligation (**Appendix A**). Once the water agencies' funding is exhausted, the State of California is responsible for paying any QSA water transfer environmental mitigation costs that exceed the official $287 million obligation.

Although the JPA must spend $133 million on mitigation over the duration of the QSA, it is impossible to forecast specific expenditures for each and every year of the agreement. The payment schedule for both SDCWA and CVWD is due to end in fiscal year 2026, and payments from IID are due to end in fiscal year 2036 (**Appendix A**). These annual contribution amounts may vary over time, as the JPA has the power to reschedule the timing of the payment schedule, and could possibly revise it.

The State of California is also taking steps to control dust at the Sea, starting with their 10-year Plan under the SSMP, which includes a requirement of 29,800 acres of dust control and habitat creation projects from now through 2028. However, there is uncertainty regarding how other non-QSA parties and landowners, such as the Torres-Martinez Desert Cahuilla Indians and other private owners, will target fugitive dust given the lack of a funding mechanism and no direct access or input regarding expenditure of JPA funds.

It is unclear how landowner liability under the SCAQMD and ICAPCD air quality rules will interact with the mitigation responsibilities of the environmental mitigation program of the QSA and the State's acreage requirements under the SSMP.

7. Analytical Methods

7.1 Dust Emission Model

7.1.1 Summary

The purpose of the Dust Emission Model is to determine the areas of the Salton Sea that will be exposed in the future and which of those areas have the highest potential to emit dust. The Dust Model combines predicted sea level elevations, bathymetry of the Sea, soil types and their relative emissivity, wind speed, and land ownership to create a Potential Dust Emissivity Score for each type of soil within a parcel. This is done for the playa that is exposed every five years beginning in 2018 and ending in 2047. A higher score value indicates a higher potential for that unit of land to be emissive. Emissivity is primarily based on an area's soil type and percent of days when winds are over 15 mph. This Potential Dust Emissivity Score is used as a factor in determining which land areas to remediate in order to cost-effectively reduce dust emissions from exposed playa.

7.1.2 Dust Model Inputs and Data Sources

Several data sources were used as inputs to develop the Dust Model. They are outlined and explained in **Table 7.1.2** below.

Table 7.1.2 - Summary of model inputs and data sources to Dust Model

Input	Description	Source
Future Sea Surface Elevations	Predicted future surface elevations of the Salton Sea. Obtained from Salton Sea Air Quality Mitigation Program and verified with the SALSA model.	IID, 2016; SALSA model - CH2M Hill, 2014
Bathymetry	Underwater elevation profile (topography) of land currently beneath sea surface. Combined with future sea surface elevations, future exposed land area can be mapped.	USGS, 2010
Soil Type	Soil classification of shallow subsurface sediments. Describes the texture of the soil (shell, course, fine, etc.) Produced for a 2004 Bureau of Reclamation commissioned survey by Quester Tangent (acoustic sampling) and Salton Sea Authority (soil sampling).	Bureau of Reclamation, 2004
Relative Soil Emissivity	The relative potential of different soil types to emit dust when exposed to wind.	Peter Fahnestock, USDA - NRCS, 2018
Wind Speed	Percent of days when wind was above 15 mph out of a multiyear period. This is considered the threshold for producing dust storms in this model.	CARB, (2014-2018)

7.1.3 Predicting Future Sea Playa Exposure

The first portion of the Dust Emission Model requires forecasting the new shoreline and where the future exposed playa will be located. Future exposed playa was predicted by combining future sea surface elevations with high resolution bathymetry. The elevation component was obtained from CH2M Hill's Salton Sea Analysis (SALSA) Model. The SALSA Model can predict the future sea level and salinity at the Salton Sea over many years given inputs such as water inflows and outflows, QSA mitigation water, and wetland restoration project areas.

A range of estimates (mean, 5th and 95th percentiles, etc.) are produced for each output parameter. Mean elevations from Imperial Irrigation District's 2016 Salton Sea Air Quality Mitigation Program (SSAQMP) (see **Figure 7.1.3a** for graphic, and **Appendix B** for details) were selected as Dust Model inputs and were verified by running the SALSA model with similar inputs. Although significant uncertainty exists with any forecasting, the SALSA model has been tested since its creation in 2006 against actual playa exposure, and has proven to accurately predict playa exposure through 2015 (IID, 2016).

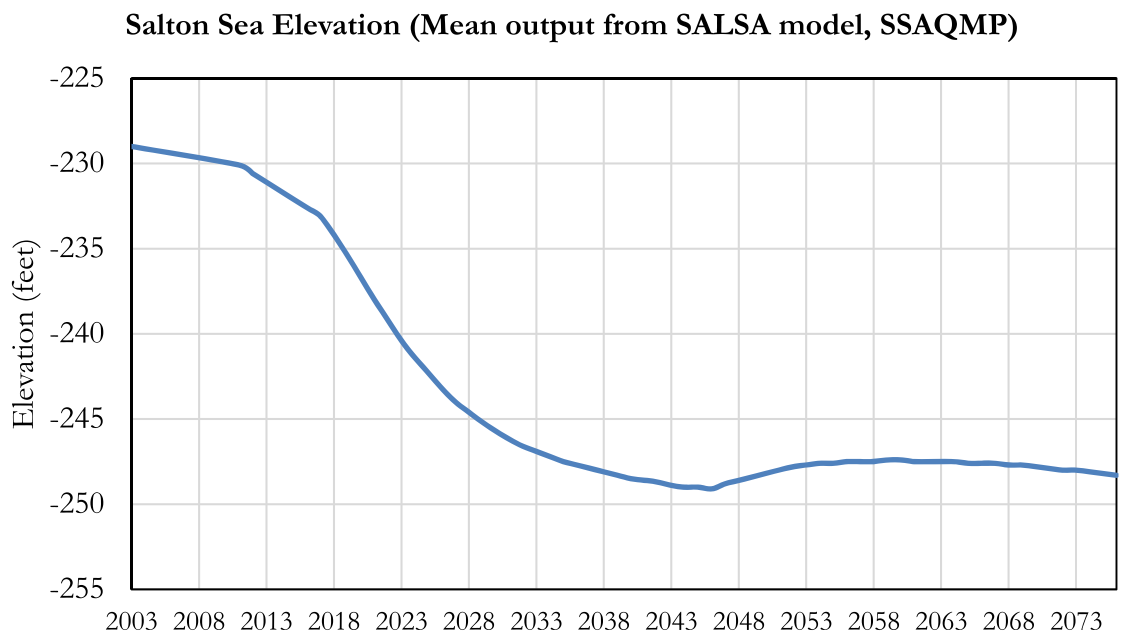

Figure 7.1.3a - Mean elevations from Imperial Irrigation District's 2016 Salton Sea Air Quality Mitigation Program

Additionally, the SALSA model returns the fraction of land exposed due to QSA versus non-QSA sources, allowing for QSA vs non-QSA costs to be calculated. Non-QSA factors included in the SALSA model include uncertainty in flows from Mexico, Coachella Valley, and local watersheds, hydroclimatic variability influencing runoff and drainage, and climate variability influencing evaporation. Because the whole Sea is declining, exposing the highest elevations first regardless of the reason for decline, it is impossible to say whether any physical piece of land is exposed due to QSA or non-QSA factors. Thus, all figures in this report which show future playa exposure do not reflect the actual spatial location of QSA and Non-QSA playa. Due to the nature of yearly exposure processes, each year will contain a "mix" of non-QSA and QSA playa exposure, determined by the proportion expressed from the SALSA model output.

The SALSA model assumes that the QSA water transfers will end in 2047, whereas the option exists to extend the transfer agreement until 2077, so the SALSA output is generated through 2077. The SALSA model output reveals that the Sea level stops declining after 2046 and remains nearly constant until 2077 (CH2M Hill, 2014). This is because the salinity concentration at the Sea becomes so high that the evaporation rate decreases and the Sea stabilizes (CH2M Hill, 2014). Therefore, only elevations out to 2046 were considered for the Dust Model. 2047 was selected as the final year in the Dust Model and uses the same elevation value as 2046.

Bathymetry data was obtained from a 2010 USGS survey using LiDAR laser surveying. The bathymetry shows the elevation of the Sea floor. As the Salton Sea shrinks to lower elevations, the contours of the Sea will become the new shoreline. Using ArcGIS, the bathymetry was combined with the future predicted sea surface elevations to determine the new shorelines, as well as the total future exposed playa area, at five-year intervals from 2018 to 2047[1]. See **Figure 7.1.3b** below for a map of future exposed playa by five-year intervals from present to 2046.

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[1]Five-year intervals were selected due to resource constraints. Further analysis could attempt to determine annual intervals. If following exact five-year intervals, the final year should be 2048, however the elevation does not change significantly from the peak in 2046 onward, as the Sea becomes too saline to evaporate at a rate faster than inflows. Given that sea levels are not changing after the year 2046, the year 2047 was selected as the final year because this is when the QSA stipulations could terminate if both SDCWA and IID do not agree on an extension to 2077.

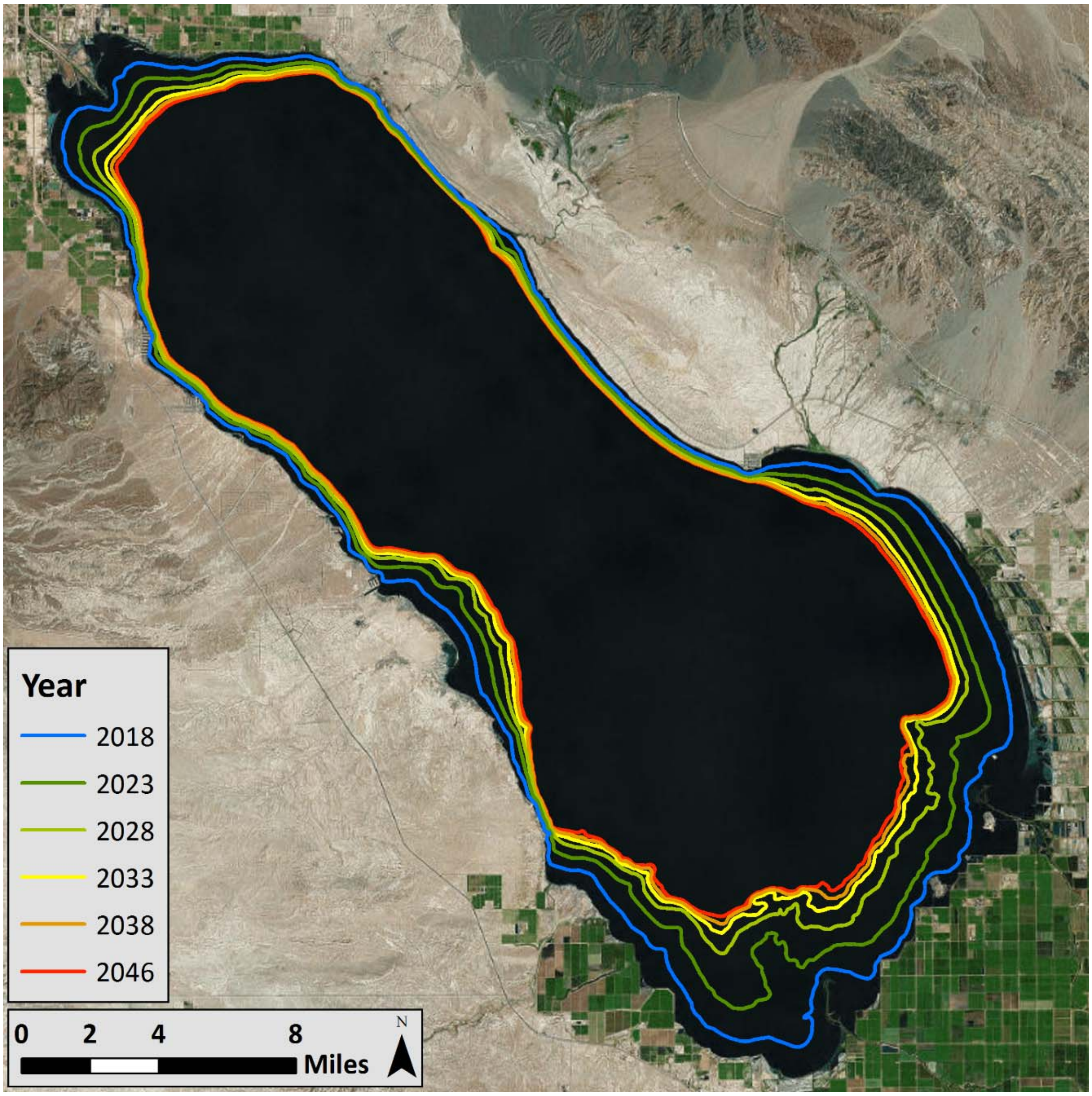

Figure 7.1.3b - Map of future shorelines and exposed playa, 2018-2046

7.1.4 Determining Soil Type of Future Exposed Playa and Relative Emissivity

Soil type is a key indicator of the potential to emit dust. A soil type GIS map layer was obtained from the IID. This layer was produced by a 2004 Salton Sea Authority soil sampling survey, with the aid of acoustic sounding by Quester Tangent for the Bureau of Reclamation. This soil layer contains information on the type of soil currently beneath the Sea that is expected to be exposed in the future, composed of approximately 7,000 soil polygons of continuous soil types, with an average area of approximately 4.5 acres per polygon. See **Figure 7.1.4** below for a map of soil types. Soil types include shell, coarse textured, moderately-coarse textured, medium textured, medium-fine textured, and fine-textured. These different soil types correspond to different relative potentials to emit dust and different suitabilities for alternative mitigation techniques. Generally, fine soils are more likely to emit dust compared to coarse soils.

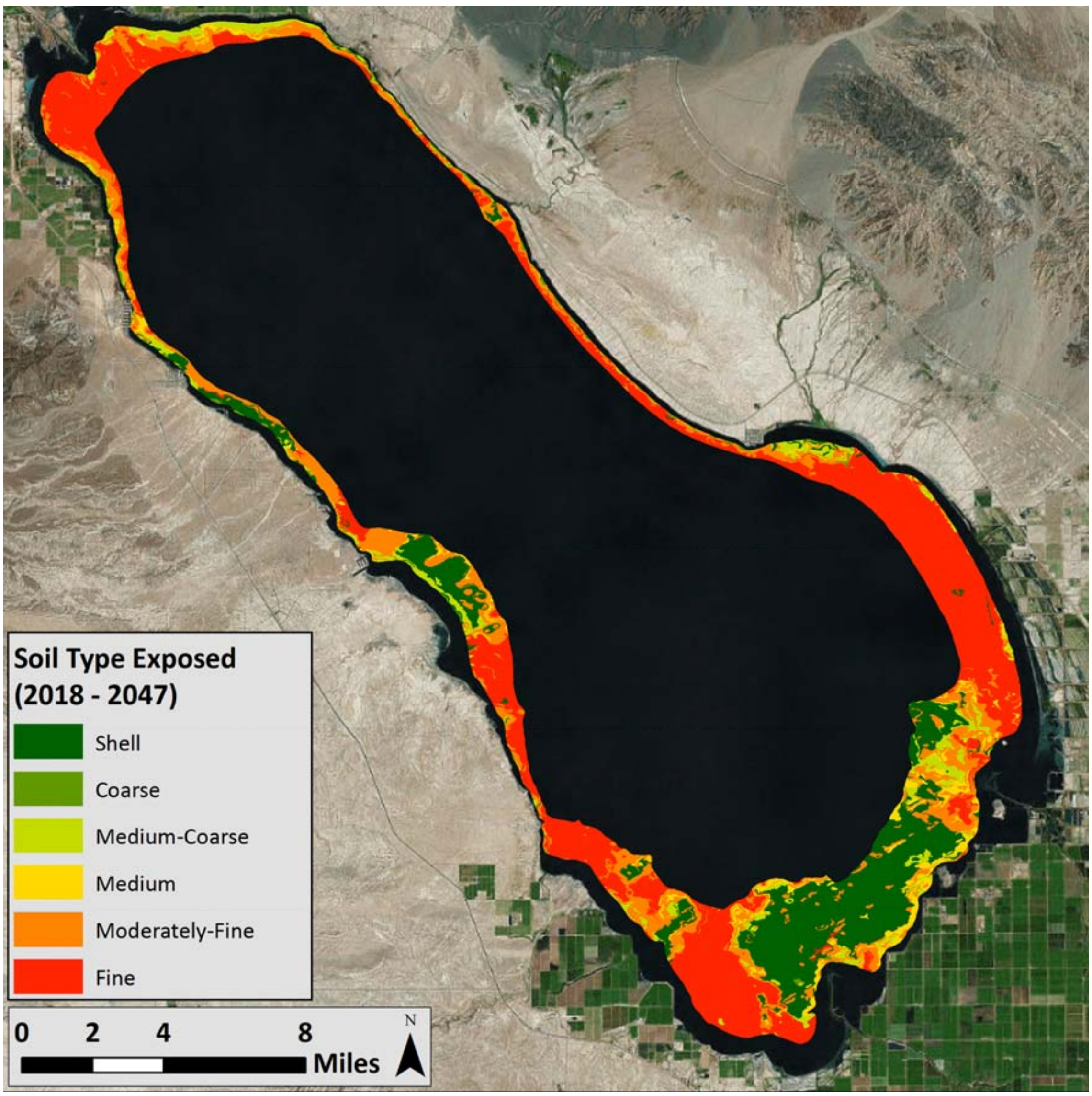

Figure 7.1.4 - Map of soil classification for future exposed playa

There are intrinsic properties of the soil that facilitate the transport of airborne dust and PM_{10}, which include the particle size, concentration of carbonates, organic matter concentration, and coarse fragment concentration. These soil characteristics were determined from the USDA-NRCS, which created a PM_{10} potential interpretive model to evaluate a soil's potential as a source of PM_{10} airborne particulates. An overview of the model is described in **Table 7.1.4a**.

Table 7.1.4a - Soil characteristics and their potential contribution to PM_{10} airborne particulates. Characteristics with positive contributions are sources and/or catalysts to PM_{10} emissions, while negative contributions represent impediments to PM_{10} emission. (USDA-NRCS, 2002)

Soil Characteristic	Contribution to PM_{10} Potential
Particle Size	+85%
Carbonate Concentration	+15%
Organic Matter Concentration	-40%
Coarse Fragment Concentration	-60%

The model assumes that the area being affected is dry, bare, smooth, and has a long distance that is exposed to wind, all characteristics that are consistent with future exposed playa at the Salton Sea. Peter Fahnestock of USDA used the model to forecast the four intrinsic soil characteristics for the identified six soil classes. The detailed methodology used for this determination is in **Appendix C**, but conceptually the process related the amount of PM_{10} energy contained in each soil class (silt and clay concentrations) to the potential wind erodibility of each soil class.

In addition to intrinsic soil characteristics, climate factors can affect the potential emissivity of soil. Saltation from wind is a major climate factor influencing emissivity potential. In addition to wind, another dust-generating disturbance can come from human activity, such as the use of off-roading all-terrain vehicles (ATVs). Because human activity is difficult to forecast spatially, and ICAPCD laws prohibit off-roading vehicles on public lands, human activity as a source of dust generation was not considered in the Dust Model.

Based on the soil and climate factors, the relative potential to emit dust by soil type can be determined (see **Table 7.1.4b** below for outline of dust emission factors). Shell soils have a value of 0, meaning that no dust will be generated from shell soil types. Coarse soils are set to a baseline value of 1, with each other soil type scored relative to coarse soil. For example, a value of 3.6 for fine soils means that under the same wind conditions, there is predicted to be 3.6 times as much dust generated from a fine soil type compared to a coarse soil.

Table 7.1.4b - Soil type class and relative potential to emit dust

Soil Type Class	Relative Potential to Emit Dust
Shell	0
Coarse	1
Medium Coarse	1.5
Medium	1.8
Moderately Fine	2.7
Fine	3.6

7.1.5 Modeling High Wind Events

Wind is a major contributor to dust emissions. A combination of fine-textured soils and high winds creates a high potential for dust storms (IID, 2016). As such, it was necessary to determine how windy areas of future exposed playa might be. Wind data was obtained from a publicly available searchable database from the California Air Resources Board (CARB). CARB data included wind speed, wind direction, and other meteorological factors such as temperature. Six primary weather stations were selected for this analysis, based on their proximity to the Salton Sea. Additionally, two secondary weather stations were selected to supplement the wind data and improve interpolation results. The weather stations and their locations are listed in **Table 7.1.5** below:

Table 7.1.5 - Weather station names and locations

Name	Location	County	Latitude	Longitude	Proximity
Torres - Martinez	Northwest	Riverside	33.51831	-116.07538	Primary
Salton Sea Park	Northeast	Riverside	33.50896	-115.91954	Primary
Bombay Beach	Mid-East	Imperial	33.35264	-115.73419	Primary
Sonny Bono	Southeast	Imperial	33.17638	-115.6231	Primary
Naval Test Base	Southwest	Imperial	33.16923	-115.85593	Primary
Salton City	Mid-West	Imperial	33.27275	-115.90062	Primary
Westmorland	South of Sea	Imperial	33.03239	-115.62362	Secondary
Niland - English Road	East of Sea	Imperial	33.21349	-115.54514	Secondary

Daily wind data from these eight sites over several years (2014-2018) was downloaded and processed into a usable form for the model. The wind speed and direction changes from day to day, or even hour to hour, so a single metric for each station was desired. The percent of days with an average wind speed above 15 mph was selected as the wind speed metric. Fifteen mph represents the threshold where dust storms are likely to form (USGS, 2002), so this was considered more useful than other metrics, such as average wind speed. Since the goal of this model was to determine the potential of exposed playa to emit dust, rather than determine where dust might travel, wind direction was not considered. Similarly, since predicting dust storm intensity was not a goal, average wind speed was not calculated. Instead, by accounting for the percent of days over 15 mph, the model predicts how often a given area is likely to emit dust.

The wind data processing produced eight data points along the perimeter and near the Sea with values of percent of days with winds above 15 mph. In order to determine the frequency of high wind events at future exposed playa locations where no wind stations currently exist, interpolation was necessary. ArcGIS's "Kriging" tool (Gaussian process regression) was selected as the interpolation method. This interpolation process filled in the gaps between the eight data points, predicting what values are likely at any given location based on proximity to known points. The result produced a map layer of predicted wind (percent of days above 15 mph) across the entire Salton Sea. See **Figure 7.1.5** below for a map of wind stations and interpolated frequency of high wind events.

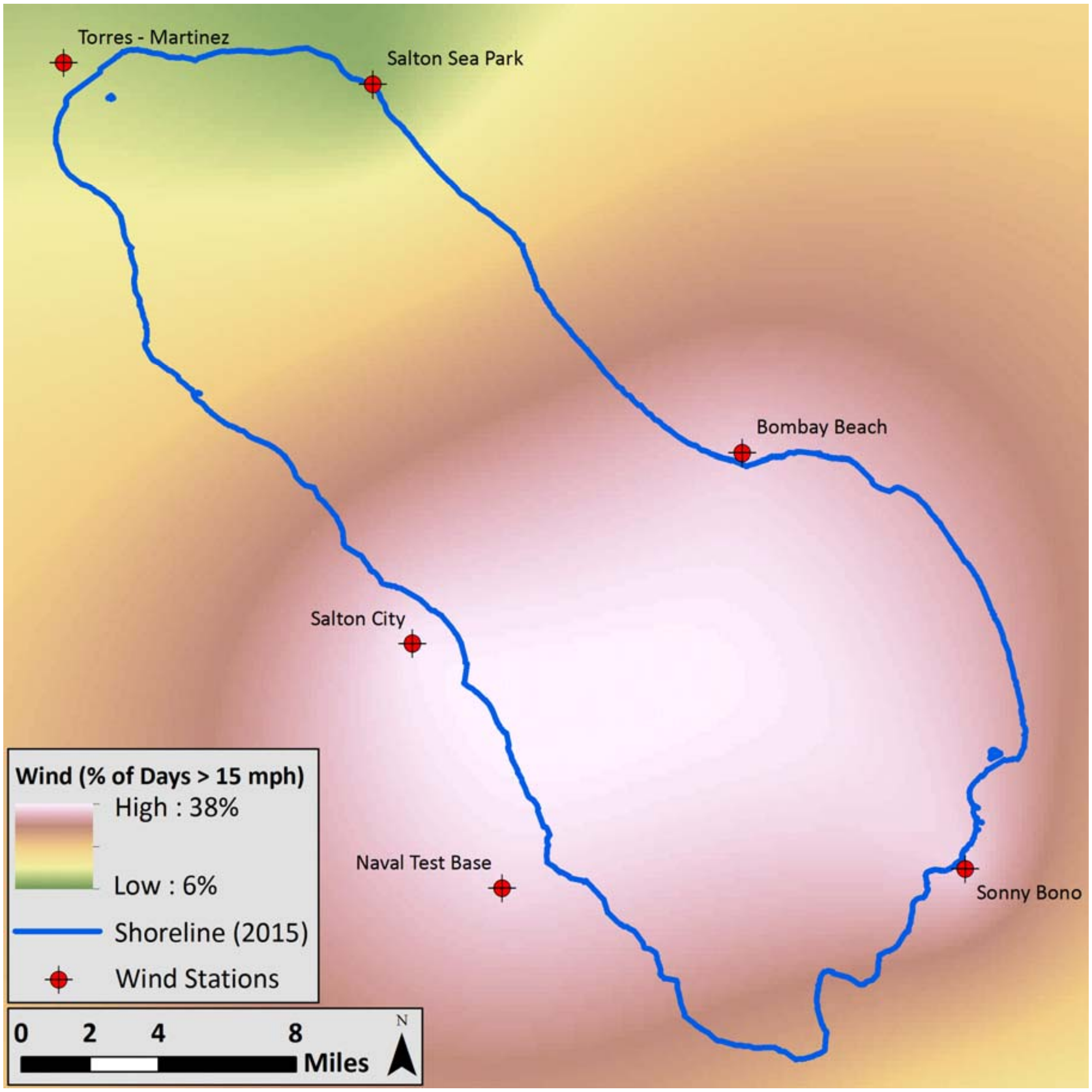

Figure 7.1.5 - Map of wind stations and interpolated frequency of high wind events

7.1.6 Overlaying Information

To produce a useful table for analysis of wind and soil type, the wind map layer needed to be overlaid with the soil layer. A spatial join with ArcGIS attached wind data to soil polygons so that each soil polygon was assigned the value of the closest point from the wind point layer. The parcel layers from Imperial and Riverside Counties were intersected onto this soil-wind layer to determine land ownership of these soil polygons. Additionally, lands to be mitigated by the State of California were traced and intersected as well, for later consideration of remediation costs. This intersection further divided soil polygons into smaller sub-polygons, since the same soil polygon could be overlapped by two or more parcels owned by different agencies. To analyze emissivity of exposed playa at five-year points, this combined soil-wind-parcel layer was clipped to sea level elevations at 2018, 2023, 2028, 2033, 2038, 2043, and 2047. At each five-year point, the area of each of the soil-wind-parcel sub-polygons was calculated for to enable area-based cost calculations for each of the land owners.

7.1.7 Calculating the Potential Dust Emissivity Score

A Potential Dust Emissivity Score was calculated to define the most emissive areas of the Salton Sea. The goal was to achieve a score which allowed land areas to be ranked in order of emissivity, rather than to calculate metrics such as emission rates or ambient dust concentrations. See **Figure 8.1** in the results section for a map of the most emissive areas.

To calculate Potential Dust Emissivity Score, the values for Relative Potential of Soils to Emit Dust, described above, were assigned to the corresponding soil type of each sub-polygon and then multiplied by the wind score. This multiplication results in scores which are highest for areas with both high winds and fine soils. Because both factors in this calculation (Relative Potential of Soils to Emit Dust and frequency of high wind events) have cardinal properties, the result is meaningful as well, and scores can be compared relative to each other. This means that a moderate Potential Dust Emissivity Score could be achieved as a result of a combination of either frequent winds and low dust emission potential or infrequent winds and a high dust emission potential, depending on the exact values of each factor. The result was added to the map layer, creating a spatial dataset in which each soil polygon has information for area, landowner, and Potential Dust Emissivity Score - the ultimate goal of the Dust Model. The complete Dust Model was then exported to a spreadsheet for further analysis and manipulation. The following section explains the methodology for prioritizing which areas to remediate to achieve PM_{10} attainment cost-effectively.

7. 2 Mitigation Prioritization Model Methodology

7.2.1 Summary

The most cost-effective way to reduce PM_{10} emissions to standards required by the ICAPCD and SCAQMD is to remediate the most emissive, least costly areas of land. To determine those areas, a Prioritization score was calculated for each sub-polygon and then ranked from highest to lowest. This score is created by dividing the Potential Dust Emissivity Score by the cost per acre of using the mitigation technique assigned to the specific soil type. Therefore, areas with higher Potential Dust Emissivity Scores and lowest cost to mitigate per acre are identified as a priority for cost-effectively reducing fugitive dust. Although the JPA has a remaining obligation of approximately $150 million for dust control mitigation on QSA-exposed land, annual expenditures for projects are uncertain, and it is also uncertain at what specific year the State of California would be obligated to provide funding to cover QSA-exposed land. Because of these uncertainties, it is important to recommend a cost-effective approach to dust mitigation at the Salton Sea.

7.2.2 Mitigation Prioritization Inputs and Data Sources

The following inputs were used to develop the Mitigation Prioritization Model. They are outlined and explained in **Table 7.2.2** below.

Table 7.2.2 - Summary of model inputs and data sources to Mitigation Prioritization Model

Input	Description	Source
Potential Dust Emissivity Score	A score calculated based on soil type and wind. A higher score indicates a higher potential for that area to be emissive.	Dust Model Methodology (See method section above)
Suitable Mitigation Technologies	Dust control methods suitable for fine-, medium-, and coarse-textured soils.	Table 3-8 (IID, 2016)
Mitigation Costs	An estimation of the capital and O&M costs per acre for dust control measures.	Table 3-9 (IID, 2016)
Land Ownership	Land parcel data for Imperial and Riverside Counties. Includes parcel owners, contacts, land use, and other related information.	Riverside County 2017; Imperial County 2011
State Remediation	Land to remediated by the State of California under the 10-year plan.	Salton Sea Management Program, 2017

7.2.3 Calculating Weighted Average Costs of Applicable Dust Mitigation Controls

DCM cost figures are obtained directly from the SSAQMP, as well as through consultation with IID (**Table 5.6a**). The cost was provided in two parts, the upfront capital cost, and the annual operation and maintenance (O&M) cost to sustain the technique as an effective DCM.

Given that these DCMs will need to be maintained to satisfy dust control requirements of the air pollution control districts, the O&M cost was assumed to be incurred into perpetuity.

The discount rate (r) was specified as 6% because this is the rate adopted for all financial projections, per the terms of the QSA JPA Creation and Funding Agreement. The costs were calculated using the following formula:

$$PV\ Capital\ Cost = \frac{C_n}{(1+r)^n}$$

$$PV\ O\&M\ Cost\ =\ (\frac{C * \alpha}{r})\ /\ (1+r)^n$$

$$PV\ of\ Total\ Dust\ Mitigation\ Cost = PV\ Capital\ Cost + PV\ O\&M\ Cost$$

Where:
C = capital cost
r = discount rate
n = year index (2018 is year 0)
α = % of capital required for annual O&M

The cost of DCMs and the proportion of DCM usage per soil class, two key factors provided by section 5 of this report, are inputs into the present value of total mitigation cost equation. For reference, **Table 5.6** provides the specific capital and O&M cost figures for each identified DCM, and **Table 5.7b** indicates the most suitable proportion of mitigation techniques to be used at the Salton Sea, depending on soil class. The total cost per suitable DCM was multiplied by their relative proportion of usage per soil type to produce **Table 7.2.3**, highlighting the weighted average mitigation cost per soil class per area. Costs are incurred as the Sea recession, which was modeled in five-year time intervals beginning in 2018, so future DCM implementation costs to mitigate future exposed playa needed to be discounted to 2018 dollars. Although all mitigable land will require a combination of DCMs for achieving dust mitigation, **Figure 7.2.3** shows the dominant, or highest proportion of, DCM used by area.

Figure 7.2.3 - Dominant mitigation strategy by area

Table 7.2.3 - Mitigation cost per acre by soil type using recommended DCMs

Soil Class	Weighted Average Total Mitigation Cost
Fine	$6,997
Moderately Fine	$8,593
Medium	$18,251
Medium Coarse	$18,993
Coarse	$26,200
Shell	$0

7.2.4 Prioritizing Areas for Dust Mitigation

A Prioritization score was created by dividing the Potential Dust Emissivity Score by the cost per acre of mitigating that specific type of soil by soil polygon:

$$Prioritization\ Score = \frac{Emissivity\ Score}{Cost\ per\ Acre\ (\$)\ of\ Chosen\ Dust\ Control\ Method}$$

Therefore, if an area has a potential to be highly emissive but can be remediated with the least costly dust control method, it will have a relatively high Prioritization score. The scores were then ranked from highest to lowest, with the highest score having the highest priority. This was repeated for each of the five-year intervals. Areas that were designated as being the responsibility of the State and areas with shell were not considered areas to be mitigated. Therefore, they received a Prioritization score of zero and were not included in the priority map. This analysis only considered the recommended dust control mitigation measures identified in **Table 5.7b**, surface roughening, moat & row, vegetation enhancement, vegetated swales, and managed vegetation.

7.2.5 Dust Mitigation Cost Scenario Analysis

To quantify the potential costs of dust mitigation through 2047, the Prioritization Model was converted from providing a Prioritization score at the soil polygon resolution to providing a score per parcel under four different scenarios:

1. Recommended DCM, prioritize IID land (based on the stated goal of the QSA parties)
2. Recommended DCM, prioritize most cost-effective parcels
3. BACM only, prioritize IID land
4. BACM only, prioritize most cost-effective parcels

The methodology for determining the recommended dust control strategy is detailed in section 7.2. The BACM-only dust control measures were described in the dust control literature review, and the cost per soil class is shown in **Table 7.2.5**. Methodology for determining the specific BACM to be used and in what ratio per soil class was based on the SSAQMP, and consultations with IID, and is detailed in **Appendix D**. The soil polygon prioritization scores were averaged by parcel and weighted based on the relative percentage of land the soil polygon represented in the parcel, with shell and areas designated for State projects given a prioritization score of zero.

Table 7.2.5 - Mitigation cost per acre by soil type using BACMs

Soil Type Class	Total Cost (Capital + O&M)
Fine	$34,167
Moderately Fine	$38,750
Medium	$42,188
Medium Coarse	$42,500
Coarse	$42,708
Shell	$0

With the prioritization score by parcel identified, the model was run to determine the cost of mitigating all potentially emissive parcels from 2018-2047 per five-year time period and for both the recommended and BACM-only dust control scenarios. Using the results of the SALSA model, QSA-exposed land per five-year period was used to determine the specific amount of land that the JPA is liable to mitigate. As of the start of the 2018 fiscal year, the JPA still has approximately $153 million left in its payment schedule to fund both administrative and dust control implementation related activities at the Salton Sea, but actual annual expenditures are uncertain. Prior JPA budgets are not a good indicator of future budgets because prior budgets had significant funding allocated towards mitigation water, which ended in 2017. Given this uncertainty, and yearly JPA-specific obligations could not be determined, so it is not possible to model how to best spend the remaining funding available to the JPA.

Instead of a budget-based model, the model input was land exposed by QSA or non-QSA factors. QSA exposed land is required to be mitigated by the JPA and then by the State, but it is impossible to determine which parcels are specifically exposed by QSA vs. non-QSA sources. The relative amount of land exposed from the water transfers, obtained from the SALSA model, as a proportion of total land exposed, was determined to be liable by the JPA and then by the State. Because QSA land is legally obligated to be mitigated, the model determined the most cost-effective way to treat the total acreage of QSA exposed land per time period, under both the recommended and BACM only dust control scenarios. Additionally, because IID is the implementing agency of the environmental mitigation program, IID-owned land was prioritized for mitigation, with other landowners targeted based on cost-effectiveness. IID was also targeted because there would be no associated transactions costs with mitigating the land, since it is already owned by a member of the JPA. In contrast, to mitigate dust on non-IID land, there may be significant transaction costs or the need to obtain special permits. An alternative scenario was run to determine how the QSA versus non-QSA costs would be allocated for both the recommended and BACM-only dust control scenarios in a situation where IID land was not prioritized, but rather the most cost-effective parcels were mitigated first, regardless of land ownership.

8. Results

8.1 Dust Emission Model Results

The result of the Dust Emission Model is depicted graphically below (**Figure 8.1**), where darker red areas are the most emissive. The most emissive areas are those which are subject to the most frequent strong winds, and which have the soils with the highest potential to emit dust. The eastern shore, south of Bombay Beach, contains highly-emissive areas, as does the southern shore of the Sea, west of the New River. The northern shore of the Sea, while composed of fine-textured soils, is not subject to as frequent high wind events, and therefore has a lower modeled emissivity than fine soils in the southern portion.

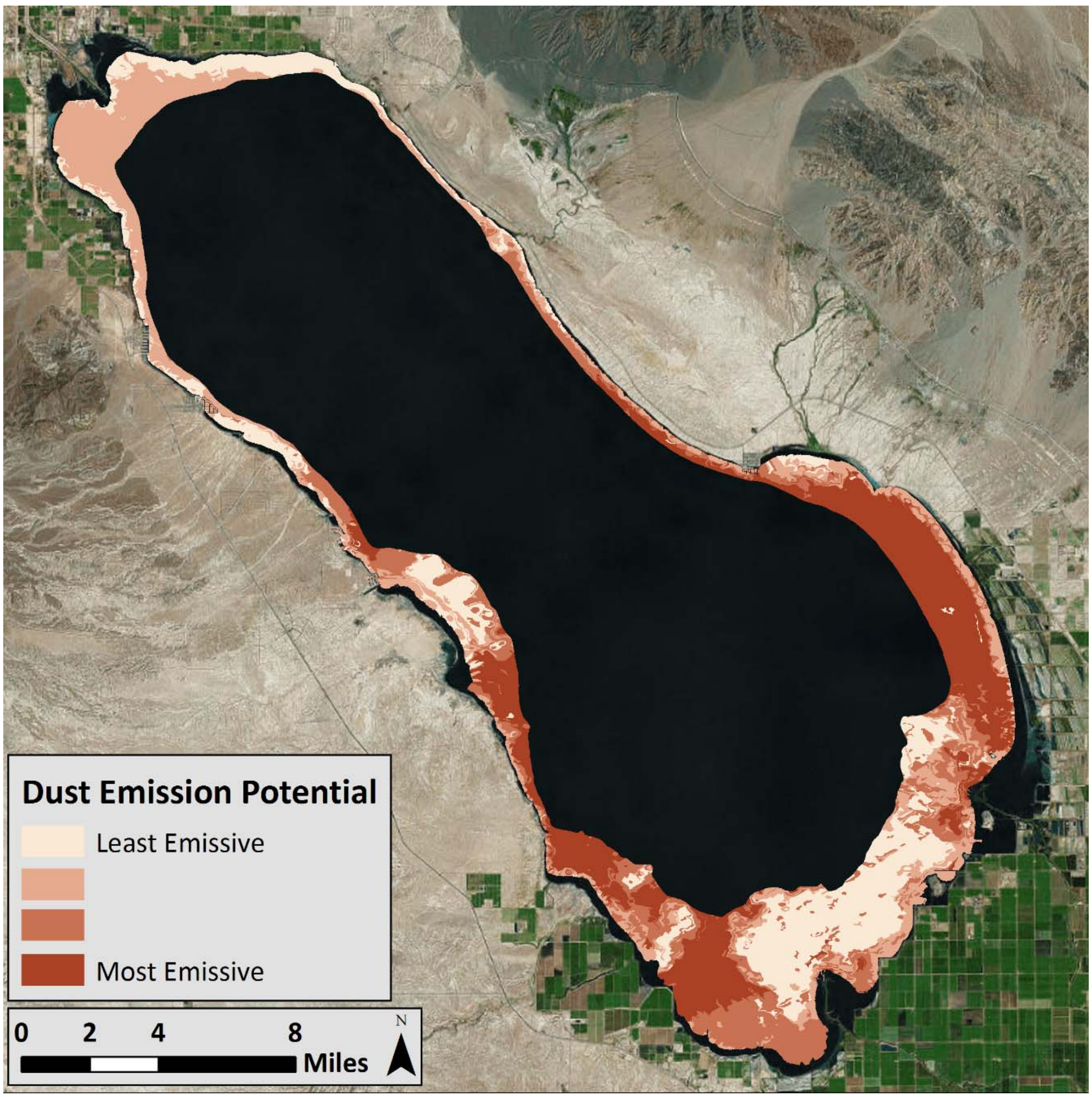

Figure 8.1 - Map of potential dust emission

8.2 Mitigation Prioritization Results

The result of the mitigation Prioritization Model are shown in **Figure 8.2**. The results reveal that the highest priority areas for dust control mitigation are in the southern portion of the Sea, specifically the southwest and the southeast. These areas are the highest priority because they have the highest amount of emissivity potential per cost of mitigation.

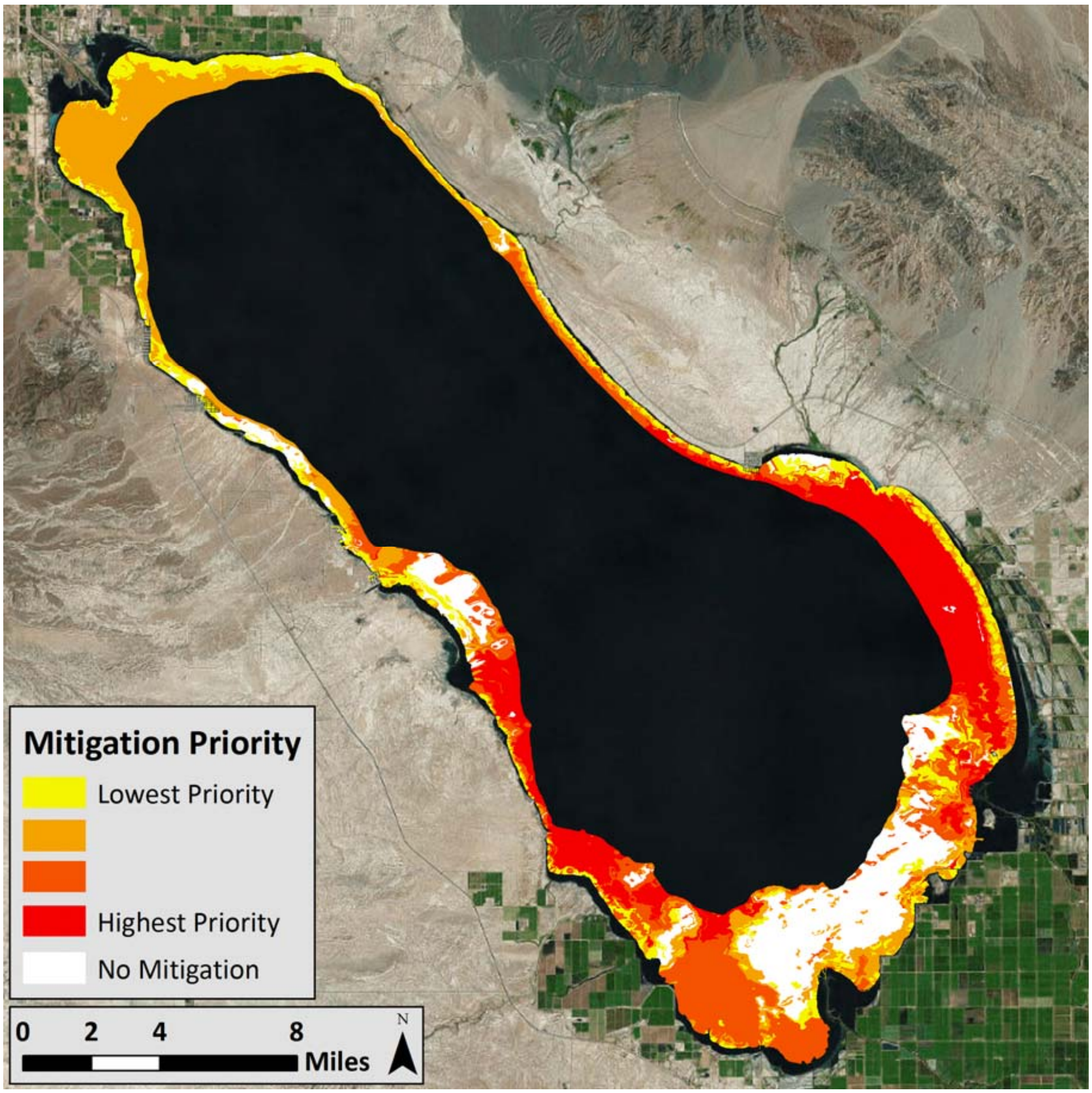

Figure 8.2 - Map of dust mitigation priority by cost-effective ranking

8.3 Scenario Analysis Results

The results of the scenario analysis show that the cost of mitigating all exposed parcels from 2018 to 2047 using the recommended DCMs is approximately $325 million ($2018). Mitigation costs rise to over $1 billion ($2018) when using BACM-only DCMs. Costs per landowner for using recommended DCMs is detailed in **Figure 8.3a**. These costs are calculated into perpetuity, considering the continuation of O&M costs. Results show that IID and the federal government will be bearing most of the costs for dust mitigation, with some substantial costs being borne by CVWD, tribal and private landowners, and municipalities ("Other"). In 2047, there is virtually no cost because the Salton Sea's lake level stabilizes and no significant amount of land is further exposed after this year. Cost per landowner for only using BACM are in **Figure 8.3b**. **Figure 8.3c** compares the two scenarios. Total cost per landowner follows the same ordinal ranking from highest total cost to lowest total cost whether using the BACM or recommended DCMs, with IID paying the most for dust mitigation, followed by Federal, Tribal, Private, CVWD, and "Other". However, in the BACM DCM scenario the time period with the highest total cost is 2019-2023 ($415 million), while the period with the highest total cost for the recommended scenario is from 2003-2018 ($114 million). It is interesting to note that mitigating the dust using BACM only DCMs for all playa exposed from 2019-2023 is more expensive than treating all playa exposed from 2003-2047 using the recommended DCMs.

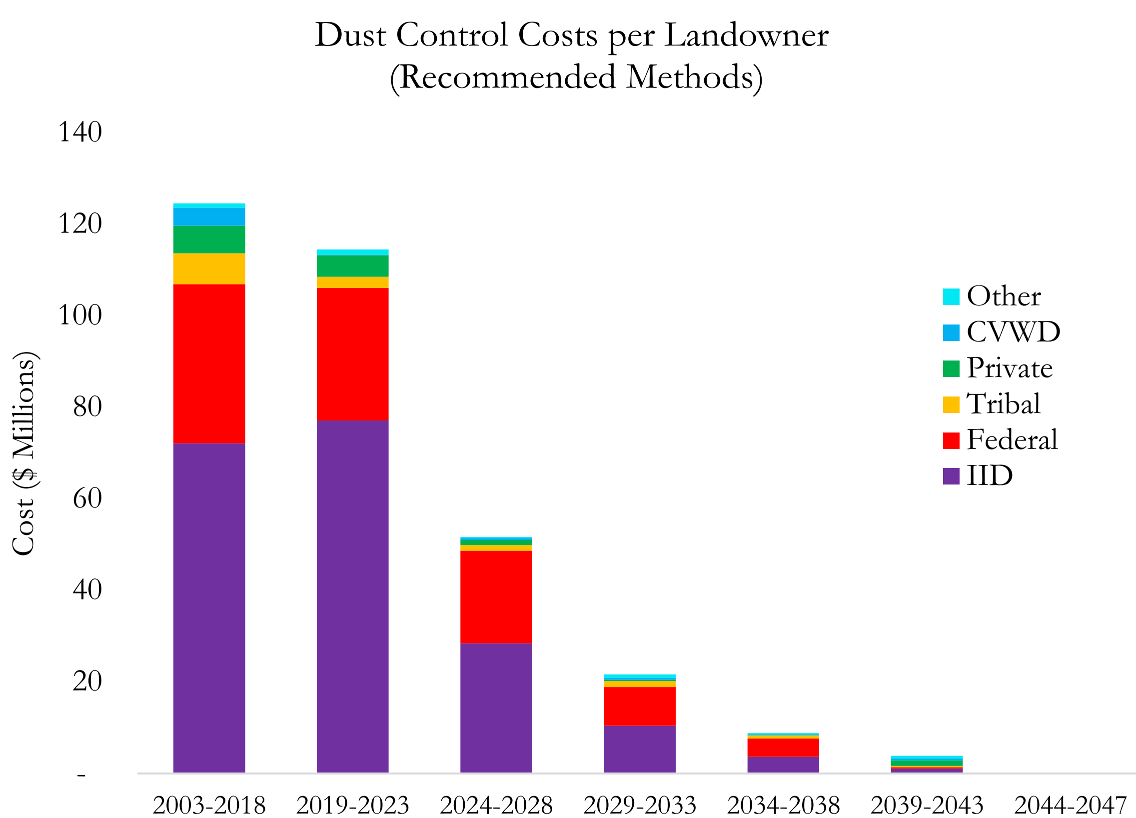

Figure 8.3a - Dust control costs by landowner using recommended DCMs, 2003-2047

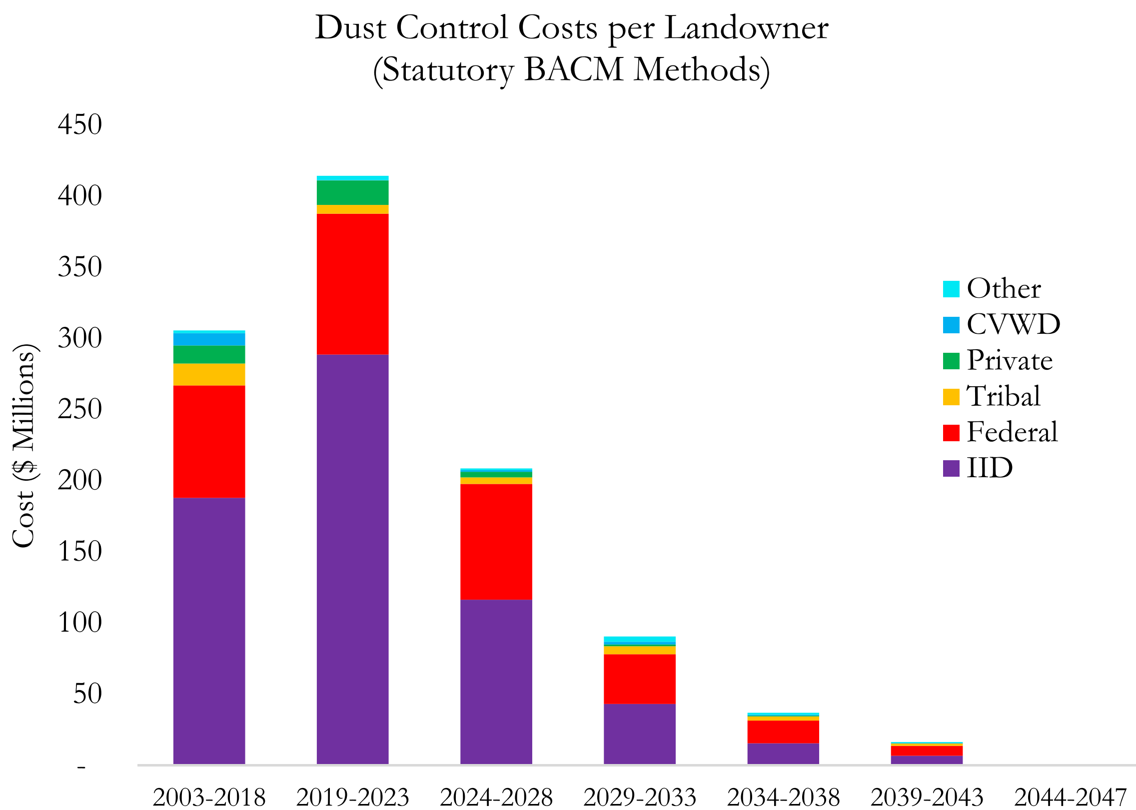

Figure 8.3b - Dust control costs by landowner using statutory required BACM DCMs, 2003-2047

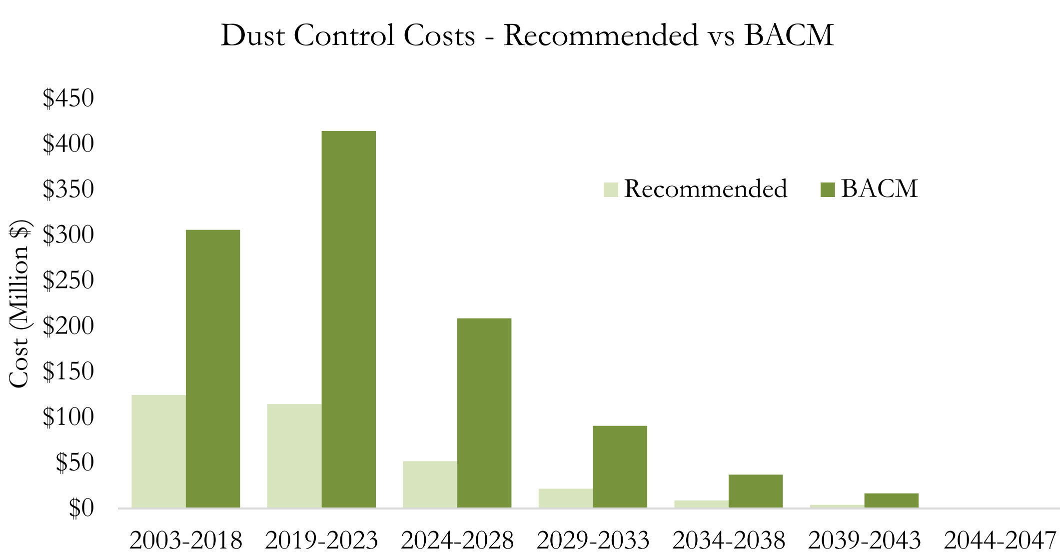

Figure 8.3c - Comparison of BACM vs Recommended dust control costs

As determined by the SALSA model, an average of 73% of the land exposed from 2018-2047 is from QSA sources. Cumulative QSA land exposure by year from 2012 to 2047 is displayed graphically below in **Figure 8.3d**, and the QSA versus non-QSA land exposure areas for selected time periods between 2003 and 2047 are depicted below in **Table 8.3**.

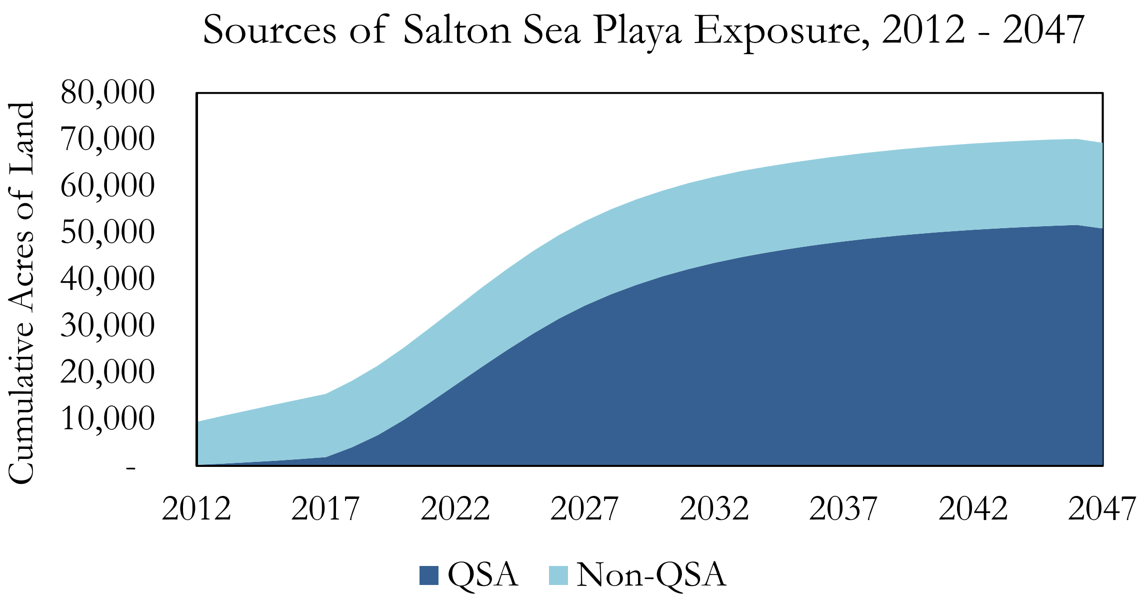

Figure 8.3d - Proportion of land exposed from QSA sources from 2012 - 2047. Annual data was not available before 2012 for QSA sources (before SALSA model was developed), however, non-QSA sources are included for that time period.

Table 8.3 - Area of land exposed from QSA sources from 2003 - 2047. The rightmost column included the cumulative total for 2003-2047.

Time Interval	**2003-2018**	**2019-2023**	**2024-2028**	**2029-2033**	**2034-2038**	**2039-2043**	**2044-2047**	**2003-2047 (Total)**
QSA exposed land (acres)	3,972	17,179	15,613	7,952	4,055	2,156	5	**50,932**
Non-QSA exposed land (acres)	14,263	2,753	1,267	204	0	72	0	**18,383**
% QSA	22%	86%	92%	97%	100%	97%	100%	**73%**

Results from the scenario using recommended DCMs and prioritizing IID-land first versus a pure cost-effective mitigation approach did not reveal a significant difference in costs between the two scenarios. The total cost of mitigating QSA exposed land prioritizing IID-land first was about $187.7 million, while the total cost using a cost-effective approach was about $186 million.

9. Discussion

9.1 Discussion of Results

From the results of the Dust Emission Model, the future exposed playa to the southeast and southwest are predicted to have the highest potential to emit dust. In general, the southern end of the Sea is windier, making the fine-soiled sections of the southern end the most emissive. Additionally, the eastern shore to the south of Bombay Beach contains large areas with fine soils and high winds, creating expansive and highly emissive regions. Large areas near the southern end of the Sea, although windy, contain coarse soils or shells. These areas were not determined to be as emissive. Finally, although soils near the north end of the Sea are often fine in texture, the lower prevalence of high wind events reduces the overall Potential Dust Emissivity Score for this area.

The results of the Prioritization Model indicate that the future exposed playa in the regions to the southeast and southwest should be targeted first for dust control. By mitigating these areas first, the JPA environmental mitigation program can achieve the greatest amount of dust control to satisfy the QSA mitigation requirements for the least amount of money. Interestingly, the priority areas have nearly identical spatial overlap with the most emissive regions of the exposed playa. This is because the soil types associated with the most emissive regions, fine-textured soils, are also the types best suited for low-cost dust control techniques.

The fact that the most emissive soils are also the cheapest to mitigate makes the funding allocation for dust control more straightforward, and places a greater emphasis on forecasting wind. Though one area might have a more emissive soil type, and thus be cheaper to mitigate compared to other areas, if that particular area is not expected to experience frequent high wind events (compared to areas that have expensive soil types to mitigate), the decision of where exactly to control dust becomes less clear. The Prioritization Model accounts for all three factors: soil class type, cost of mitigation per soil class type, and frequency of high wind events, to help make spending decisions more effective.

The total costs of the recommended dust control strategy, whether prioritizing IID-owned land first, or purely prioritizing the most cost-effective land first, remain the same because of the assumption that all land will be mitigated. There is, however, a difference between the two scenarios in the cost to mitigate *all* land exposed by QSA sources. Through 2047, the cost difference between the two prioritization strategies is less than $2 million, which represents only 1% of total mitigation costs for QSA-exposed land. This difference is small because during many of the five-year periods analyzed, the QSA has significant mitigation requirements. It was determined that over 90% of land is exposed by QSA sources across multiple five-year periods.

When the mitigation requirement for QSA-exposed land is such a high percentage of all exposed land, prioritizing between the two scenarios becomes less insightful.

The State's SSMP 10-Year Plan defines two major regions in which the State of California will implement dust mitigation and habitat restoration activities around the Salton Sea - the southern and eastern shores, and to a lesser extent, the northern tip. **Appendix E** shows the specific areas in which these projects are planned. The State's projects will take place on land in the northern part of the Sea that is, generally, in the lower 50th percentile of priority for dust control. Although this is not the most cost-effective way to achieve dust mitigation results, the State's plan may be helpful for landowners who might not have a secure source of funding for dust control efforts. A significant amount of land in the northern part of the Sea is owned by non-JPA parties, including tribal, private landowners, and municipalities. State projects in the north might be more beneficial for these specific landowners, rather than targeting the most cost-effective lands in the south, where IID can use JPA funds toward mitigation. Furthermore, the purpose of State projects does not solely include dust control, but habitat restoration as well, which would not necessarily be required in areas that are cost-effective in terms of dust mitigation. Results from the Prioritization Model indicate that a significant amount of land in the southern portion of the Sea does not require dust mitigation, and thus State efforts in the south should be focused on the identified higher-priority regions.

Aside from State project areas, there are also regions of the Salton Sea that may have potential to generate geothermal power. If geothermal companies invest in these lands as they become exposed, liability may fall upon them to mitigate dust from these lands, thereby reducing the overall amount of exposed playa to incorporate into this analysis, as JPA funding would not go toward these lands. **Appendix F** shows areas in which there is geothermal energy potential overlaid over recommended mitigation strategies.

9.2 Limitations and Uncertainty

Despite using the best available data, it is impossible to forecast results that reflect future outcomes with complete certainty. The main areas of uncertainties of the underlying data and potential limitations of analysis are described below.

9.2.1 Soil Type

A major influence on the emissivity of a parcel of exposed playa is the soil type and characteristics. We utilized the best available survey from USGS, which used an array of soil sampling and acoustic sounding to predict relevant surface sediment characteristics. However, wave action, new sediment action, and new shell formation may alter some soil characteristics over the timeframe of our modeled playa exposure. As new playa is exposed, its actual emissivity will be measurable using a portable in-situ wind erosion lab, which will likely be more useful for actual mitigation guidance than a predictive model.

9.2.2 Hydrology Forecast, Climate Change, and Overall Playa Exposure

The timing and location of future playa exposure is a function of the hydrologic response of the Salton Sea to external forces including inflows, diversions in Mexico, salt loads, and evaporation rates. There is substantial uncertainty in forecasting these conditions over the length of the QSA, but we utilized the best available model, the SALSA model, to simulate the effects of the water transfers on Salton Sea elevation, salinity, and exposed playa.

Hydrological forecasts are inherently tied with changes in global climate. Forecasted temperature and precipitation changes were calculated from median computed values from 112 future climate projects from 16 different climate models under three emission scenarios. Per the forecasts, annual temperatures are projected to continue an accelerated increase throughout the century. Annual temperatures are projected to increase by over 2.7 °C by the end of century relative to the reference climate period (1985). SALSA model projections of annual precipitation do not exhibit strong consensus, with some projections showing future decreases and some showing future increases, but median values are unchanged from the reference climate period.

The SALSA model provides a probabilistic range of estimates of future Sea elevations. The mean elevation for each year was selected for use in the playa exposure model. The 95% confidence interval for Salton Sea elevations ranges from less than 1 foot around the mean to approximately 2 feet from the mean predicted elevation for later years. Given the shallow profile of the Sea in certain areas, small elevation changes can result in large differences in area exposed. While this uncertainty will affect the total area exposed, and therefore the total mitigation costs, it does not affect the predicted emissivity of future exposed land, nor does it affect any prioritization scores.

9.2.3 Wind

Wind data was available for six weather stations around the Salton Sea. While this is a good spatial resolution for weather stations, the area is large, and gaps remain. Interpolation was used to fill in those gaps. Local wind conditions may be erratic, and difficult to predict; therefore, actual wind conditions may be different than modeled. Furthermore, a standard threshold of 15 mph was used for dust generation. Some studies have cited higher wind speeds as necessary for dust generation, which would alter the spatial distribution of high wind events and lower the overall frequency.

9.2.4. Potential Dust Emissivity Score

The Potential Dust Emissivity Score is not a substitute for in situ emissivity measurements. It is intended to provide planning level management decisions. The score was calculated by multiplying the frequency of high wind events with the relative dust emission factor of each soil, giving each component of the score a weight of 0.5. If calculations incorporated weighing more importance on wind than soil emission factor or vice versa, results could vary.

9.2.5 QSA Time Scale

The QSA guarantees SDCWA the right to purchase water from IID until 2047, with the option to extend to 2077. Our model is assuming the scenario where the QSA will be extended to 2077, where the effects of the water transfer, and other non-QSA factors, including water conservation measures and climate change become more uncertain from the large time scale.

9.2.6 Mitigation Costs

The types and associated costs of mitigation strategies are critical for determining overall costs. A mix of mitigation strategies were provided for each soil type. However, in practice, certain DCMs may be more suitable and the actual mix of DCMs appropriate for use may vary from the recommendations. Furthermore, costs for each strategy were obtained from Owens Lake and Salton Sea pilot projects. These costs are likely to be fairly accurate, but unexpected changes in costs could emerge as these pilot projects are scaled up, altering the total costs of mitigation. Furthermore, long-term costs may vary more than those predicted in short-term pilot projects, due to unpredictable circumstances that could require more or less maintenance.

9.2.7 Other Sources of Dust Generation

Wind and soil type were the only factors considered for dust generation. However, human-induced factors often play a large part in creating dust. Although not allowed on areas of the Salton Sea, ATVs have contributed to dust emissions due to lack of enforcement. Accounting for ATV usage could increase the predictive capability of this dust model.

10. Conclusions & Next Steps

10.1 Recommendations

The end of the mitigation water requirement in 2018 all but guarantees the shrinking of the Salton Sea. Sustaining the Sea's water level will likely be infeasible due to water limitations as well as impacts of climate change. Although the shoreline's recession cannot be prevented, an effective plan for remediating dust will substantially reduce negative health impacts on the hundreds of thousands of residents of Riverside and Imperial counties.

After conducting a survey of existing dust control methods, investigating the potential liability for mitigating dust, modeling the emissivity of future exposed playa at the Salton Sea, and determining high-priority areas to remediate, the following is recommended:

1. The QSA JPA mitigation program should first remediate the areas specified as High Prioritization as shown in **Figure 8.2**, and then target less prioritized areas as allowed under their budget in order to mitigate the highest amount of dust for the lowest cost.
2. Implement surface roughening for the majority of fine- and medium-textured soils and vegetation enhancement for the majority of medium- and coarse-textured soils, with moat and row, vegetative swales, and managed vegetation filling in the remaining areas.
3. The State should pursue public-private partnerships to ensure that private, tribal, and other landowners not party to the JPA will have the resources to mitigate dust emissions and comply with relevant air quality regulations.

10.2 Review of Project Findings

In order to recommend dust control strategies to implement at the Salton Sea, a literature review of dust control projects was conducted and determined that surface roughening is best suited for fine- and medium-textured soils and vegetation enhancement is best suited for medium- and coarse-textured soils.

Furthermore, the legal framework for mitigation responsibility was analyzed, finding that landowners will likely be responsible for mitigating dust from exposed playa. However, this responsibility is clearer for ICAPCD than SCAQMD, whose regulations regarding mitigation requirements are less clear. It is uncertain how the air pollution control district rules will interact with the State's restoration plan and the JPA mitigation requirements.

A Dust Emission Model was created and shows the relative emissivity of future exposed playa. A map visually displays this in **Figure 8.1**. Each area of land is given a Potential Dust Emissivity Score, which determines how emissive land parcels are relative to each other. Southeast and southwest areas of the Sea are the most emissive, partially due to higher winds in the southern part of the Sea as well as soil types present.

Using the Potential Dust Emissivity Score, suitable mitigation methods and associated costs, and land ownership data, a Prioritization score was created for each exposed area. A higher score represents a higher cost-effectiveness to remediate. **Figure 8.2** shows how land areas are prioritized according to the Prioritization score.

10.3 Next Steps

With these recommendations in place, this report hopes to help guide decision-making that will substantially reduce dust emissions and prevent harm to residents around the Salton Sea. While the best available data was used, analysis could be improved given more comprehensive and accurate data, when it becomes available.

Below are recommendations for future research:

- Obtain more comprehensive data regarding soils, specifically in reference to the chemical composition. Determine if there are spatial trends in chemical composition of soils. The main deposited chemical is thought to be selenium, and it would be helpful to know its concentration distribution throughout the sea, and what other chemicals are present in current and future exposed playa.
- Integrate the results of air modelling into analysis to forecast the geographic scope of dust emissions.
- Explore the potential for private-public partnerships to see if cost-effective mitigation can be implemented on non-QSA land.
- Understand the EPA's process of approval of non-BACM DCMs. Under ICAPCD Rule 804, both the pollution control district and EPA must approve the DCM. Although IID is in the process of seeking ICAPCD approval, it would be helpful to explore the methods and time frame for EPA approval, which will ultimately allow the non-BACM projects to be developed on a large scale.
- Determine the minimum scale of dust mitigation projects to help inform management decisions. The analysis in this report was presented at both the soil polygon and parcel level, but mitigators may prefer to enact dust control projects on a smaller or intermediate scale.

By taking these steps and thinking about these questions going forward, a more accurate analysis of dust emissions and mitigation costs can be conducted.

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Appendix A

Summary of mitigation contributions by water agency and remaining payment schedule

Summary of Mitigation Contributions by Water Agency

AGENCY	CONTRIBUTIONS THROUGH FY 2017	FY 2018 CONTRIBUTIONS
CVWD	$ 43,860,295	$ 5,695,516
IID	$ 29,391,162	$ 5,761,221
Water Authority[1]	$ 58,563,292	$ 8,664,667
Total Agency Contributions	**$ 131,814,749**	**$ 22,433,882**

Water Agency Remaining Payment Schedule

	CVWD		IID		WATER AUTHORITY		TOTAL PAYMENTS	
Year	Due 12/31	Due 7/1	Due 12/31	Due 7/1	Due 12/31	Due 7/1	By Calendar Year	By Fiscal Year
2017	$ 5,531,599	$ 500,000	$ 1,987,469	$ 4,250,000	$ 8,314,814	$ 1,850,000	$ 22,433,882	$ 24,912,833
2018	$ 5,195,516	$ 500,000	$ 2,261,221	$ 3,500,000	$ 6,914,667	$ 1,750,000	$ 20,121,404	$ 22,433,882
2019	$ 745,350	$ 1,000,000	$ 2,473,610	$ 2,800,000	$ 1,060,053	$ 1,750,000	$ 9,829,013	$ 20,121,404
2020	$ 738,869		$ 2,726,346	$ 1,825,000	$ 1,050,836	$ 850,000	$ 7,191,051	$ 9,829,013
2021	$ 2,697,555		$ 2,885,115	$ 1,500,000	$ 3,801,632		$ 10,884,302	$ 7,191,051
2022	$ 2,706,745		$ 3,309,240		$ 1,517,597		$ 7,533,582	$ 10,884,302
2023	$ 2,733,006		$ 4,746,284		$ 1,221,837		$ 8,701,127	$ 7,533,582
2024	$ 151,876		$ 4,888,673		$ 1,345,439		$ 6,385,989	$ 8,701,127
2025	$ 565,131		$ 5,035,333		$ 1,047,693		$ 6,648,157	$ 6,385,989
2026			$ 5,186,393				$ 5,186,393	$ 6,648,157
2027			$ 5,341,985				$ 5,341,985	$ 5,186,393
2028			$ 5,502,244				$ 5,502,244	$ 5,341,985
2029			$ 5,130,911				$ 5,130,911	$ 5,502,244
2030			$ 5,308,589				$ 5,308,589	$ 5,130,911
2031			$ 5,322,392				$ 5,322,392	$ 5,308,589
2032			$ 4,556,924				$ 4,556,924	$ 5,322,392
2033			$ 6,005,020				$ 6,005,020	$ 4,556,924
2034			$ 5,643,731				$ 5,643,731	$ 6,005,020
2035			$ 5,143,974				$ 5,143,974	$ 5,643,731
2036								$ 5,143,974
Total	$ 21,065,647	$ 2,000,000	$83,455,454	$13,875,000	$ 26,274,569	$ 6,200,000	$ 152,870,670	$ 177,783,503

Appendix B

Mean sea surface elevations from IID's 2016 Salton Sea Air Quality Mitigation Program

SALSA Model Output - Mean Elevations, 2003-2076, SSAQMP, 2016

Year (2003-2043)	Elevation	Year (2044-2076)	Elevation
2003	-229	2044	-249
2011	-230.1	2045	-249
2012	-230.6	2046	-249.1
2013	-231.1	2047	-248.8
2014	-231.6	2048	-248.6
2015	-232.1	2049	-248.4
2016	-232.6	2050ta	-248.2
2017	-233.1	2051	-248
2018	-234.2	2052	-247.8
2019	-235.4	2053	-247.7
2020	-236.7	2054	-247.6
2021	-238	2055	-247.6
2022	-239.2	2056	-247.5
2023	-240.4	2057	-247.5
2024	-241.4	2058	-247.5
2025	-242.3	2059	-247.4
2026	-243.2	2060	-247.4
2027	-244	2061	-247.5
2028	-244.6	2062	-247.5
2029	-245.2	2063	-247.5
2030	-245.7	2064	-247.5
2031	-246.2	2065	-247.6
2032	-246.6	2066	-247.6
2033	-246.9	2067	-247.6
2034	-247.2	2068	-247.7
2035	-247.5	2069	-247.7
2036	-247.7	2070	-247.8
2037	-247.9	2071	-247.9
2038	-248.1	2072	-248
2039	-248.3	2073	-248
2040	-248.5	2074	-248.1
2041	-248.6	2075	-248.2
2042	-248.7	2076	-248.3
2043	-248.9		

Appendix C

Salton Sea predicted future exposed soil type: PM_{10} emission "potentials"

Prepared by Peter Fahnestock, USDA - NRCS

Assumptions:

1. The soils are considered to be in a naturally dry state. There is no apparent moisture in the surface layer.
2. The CaCO3 content and any salts are consistently present or absent across all Soil Type classes. They are not considered to have any additional effect on the rating as the act equally on all soil classes.
3. The ratings do not take into account soil disturbance. The soils are assumed to be in the same state of disturbance.
4. Organic matter/carbon is present in insignificant amounts and thus is not considered in rating.
5. The soils are rated on a "gravel-free" basis. There are no rock fragments present on the surface or in the surface layer.
6. PM_{10} is entirely composed of silt and clay particles and all silt and clay particles are equally likely to be involved in emissivity.

Method:

1. I fit specific soil textures to each of your Soil Type classes.
2. Based on textures, I assigned "I values" (Wind Erodibility Index) in tons/acre/yr to each of the soil classes.
3. I converted the I values to a relative scale between the classes. I suppose this could be thought of as a comparison of the relative amount of wind erosion each class generates based on the others.
4. Based on textures in each class, I determined the range of silt and clay percentages for each texture in the class. I generated mean values for each texture and subsequently for each soil class.
5. I added the silt and clay means for each class together to create a "silt + clay" number for each class. In actuality, this becomes my "best-guess" for the combined silt and clay percentages in each class.
6. I took this silt + clay number and multiplied it to the relative I value number (from #3 above). I was attempting to relate the amount of PM_{10} energy contained in each soil class (the silt + clay number) to the potential erodibility energy (the converted I value) of each class.
7. Finally, I normalized the numbers from #6 relative to each other to get a magnitude of PM10 emissivity potential for each class. The numbers look kind of as I would expect based on the simplistic model I laid out.

Appendix D

Relative use of dust control method by soil type per area - BACM

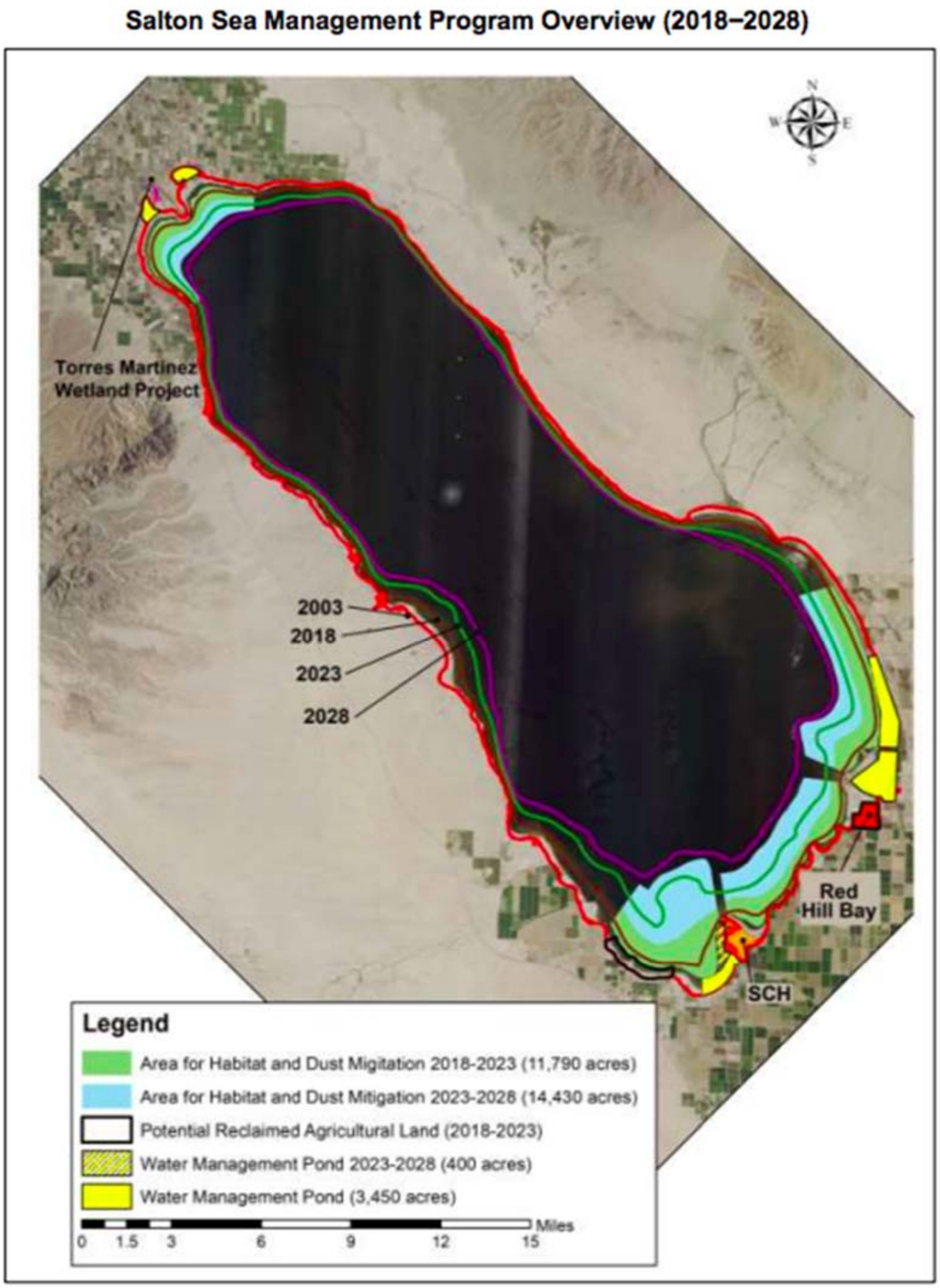
The dust control literature review and legal review identified the statutory approved BACM DCMs: shallow flooding, gravel cover, chemical dust suppressants, and managed vegetation. The proportion of DCM usage per soil class type needed to be computed for BACM only DCMs to appropriately compare the BACM only versus recommended DCM scenarios. The BACM only scenario was developed with the same criteria as the recommended scenario: cost-effectiveness, suitability for Salton Sea playa, water use-effectiveness, and the minimization of potential environmental disturbances. Based on the best available dust control literature, results from Owens Lake, and consultations with USDA soil scientists, a blended ratio of DCM per soil type was developed below.

Relative use of dust control strategy by soil type per area - BACM

Soil Type	Shallow Flooding	Gravel Cover - 2 in.	Chemical Dust Suppressants	Gravel Cover - 4 in.	Managed Vegetation
Fine	80%	20%	0%	0%	0%
Moderately Fine	45%	5%	0%	0%	50%
Medium	15%	0%	0%	0%	85%
Medium Coarse	12%	0%	0%	0%	88%
Coarse	10%	0%	0%	0%	90%
Shell	NA	NA	NA	NA	NA

Appendix E

California state mitigation and restoration projects from SSMP 10-Year Plan



Appendix F

Map of geothermal areas and recommended mitigation strategies