THE POTENTIAL FOR FUGITIVE DUST PROBLEMS AT THE SALTON SEA IF WATER LEVELS ARE LOWERED SIGNIFICANTLY FROM CURRENT CONDITIONS

SUMMARY OF A SALTON SEA SCIENCE OFFICE WORKSHOP, LA QUINTA, CALIFORNIA, APRIL 3-4, 2002.

FINAL PANEL REPORT ON FUGITIVE DUST ISSUES

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LIST OF ACRYNYMS

EIR	Environmental Impact Report (a state/local agency document)
EIS	Environmental Impact Statement (a federal agency document)
IID	Imperial Irrigation District
$PM_{2.5}$	Fine Particulate Matter
PM_{10}	Inhalable Particulate Matter
SDCWA	San Diego County Water Authority
SIP	State Implementation Plan
U.S. EPA	U.S. Environmental Protection Agency

INTRODUCTION

The Salton Sea Science Office convened a workshop on April 3 – 4, 2002 to address the potential for air quality impacts associated with sediments that would be exposed following any significant reduction in water levels at the Salton Sea. Implementation of a water transfer agreement between the Imperial Irrigation District (IID) and the San Diego County Water Authority (SDCWA) could lead to significant reductions in water levels at the Salton Sea. A variety of other water supply and water conservation issues and some actions associated with the Salton Sea restoration project could produce other reductions in Salton Sea water levels.

The IID and the SDCWA have approved an agreement for long term transfer of conserved water from the Imperial Valley to San Diego county. Under this agreement, IID and its agricultural customers would conserve water and sell it to SDCWA for at least 45 years. Either agency could extend the contract for another 30 years beyond the initial term. Deliveries of water in the first year of the contract would total 20,000 acre-feet, with subsequent deliveries increasing in annual 20,000 acre-foot increments until a maximum annual delivery of between 136,000 and 200,000 acre-feet is reached. The transfer agreement sets an initial cap on water transfers at 200,000 acre-feet per year, but also requires that deliveries to SDCWA reach a minimum of 136,000 acre-feet per year. IID and SDCWA could expand the maximum annual water delivery amount by another 100,000 acre-feet (to 300,000 acre-feet per year) after the tenth year. The water transfer agreement encompasses voluntary water conservation by Imperial Valley farmers, and expressly prohibits land fallowing to produce water for transfer.

The State Water Resources Control Board must approve the transfer as being consistent with California Water Code Section 1011 and with state constitutional requirements that water be used reasonably and beneficially. The U.S. Bureau of Reclamation must approve such matters as a change in the water diversion point from Imperial Dam to Lake Havasu, as well as matters relating to water accounting under the Colorado River Compact.

A Draft EIS/EIR for the water transfer project has been released and is currently in the public comment period. The Draft EIS/EIR for the water transfer assumes that a variety of other factors (which are not defined clearly) will result in additional reductions in water inflow to the Salton Sea beyond those associated with the water transfer project itself. The combination of the water transfer project and other factors are estimated by the water transfer EIS/EIR to result in exposure of up to 66,000 acres of currently submerged lakebed at the Salton Sea (50,000 acres due to the proposed water transfer and 16,000 acres due to other factors).

Estimates of the lakebed area that would be exposed by any specific water inflow reduction depend in part on the baseline lake surface elevation that is assumed. Different parties have estimated the potentially exposed area using lake surface elevations ranging from –227 feet (the current lake surface elevation) to –335 feet (the baseline lake surface elevation used in the Draft EIS/EIR). Panel member Tim Krantz notes that alternative estimates of the area that could be exposed by the IID water transfer program range from 54,000 acres to 71,000 acres. Salinity control projects associated with the Salton Sea restoration project and other water conservation actions might produce still further water level reductions at the Salton Sea. The panel has not attempted to resolve the differing estimates of the area that might be exposed by implementation of the IID water transfer agreement, but notes that all estimates involve a large area (78 to 111 square miles).

The air quality workshop was preceded by a tour of the Salton Sea on April 2, 2002. Most members of the panel were able to attend the tour. A public workshop session was held on April 3, 2002 at the Imperial Irrigation District offices in La Quinta, CA. The public workshop session included a series of presentations by various panel members. These presentations covered a variety of topics including:

- A brief overview of the Salton Basin and the formation of the Salton Sea;
- The current surface water hydrology of the Salton Sea;
- Potential water level reductions associated with the proposed water transfer project;
- State and federal ambient air quality standards for suspended particulate matter;
- Federal air quality management planning requirements;
- Dust storm processes and air quality management programs at Owens Lake;
- Processes that transfer dissolved salts from groundwater to the soil surface;
- Groundwater hydrology of the Salton Sea basin;
- Current studies of wind erosion processes in desert areas;
- Monitoring of gaseous pollutant and particle deposition at Salton Sea restoration project test sites;
- Dust storm processes at Mono Lake; and
- Soil crusting as a factor affecting wind erosion processes.

The public workshop presentations were followed by a general discussion among panel members. The facilitated panel discussion focused on the potential for wind erosion problems at the Salton Sea; identification of data gap issues and potential areas for future research; and general approaches to mitigating fugitive dust problems. The panel discussion was followed by a general question and comment session from the audience. Most workshop panel members met again at the La Quinta City Hall on April 4, 2002 to develop a generalized outline of topics and discussion points to be covered by this white paper. A preliminary draft of this paper was circulated to panel members for review and comment in late April. A revised draft of the paper was circulated to panel members and outside peer reviewers for additional comment in late May 2002. This final version of the panel report reflects comments provided by the panel and outside peer reviewers.

The remainder of this paper is organized into 6 major sections, as follows:

- Background information on PM_{10} standards and associated air quality management issues;
- A discussion of major factors that determine the potential for wind erosion problems;
- Comparisons between the Salton Sea and other areas (Owens Lake, Mono Lake, and Laguna Salada);
- A summary of the panel's major conclusions;

- Data gap issues identified by the panel and potential areas for future research; and
- A brief discussion of options for mitigating fugitive dust problems

Included at the end of this paper are the following figure and table attachments:

- Figure 1: a satellite photo of the Salton Basin with the prehistoric shoreline of Lake Cahuilla;
- Figure 2: a map of estimated sediment texture conditions for the Salton Sea lakebed;
- Figure 3: a map showing the locations of existing air quality and meteorological monitoring stations in the Salton Sea Air Basin;
- Figure 4: three photos of a local dust storm event observed by staff of the Salton Sea Science Office along the south shore of the Salton Sea;
- Figure 5: a graph illustrating the range of particle size collection efficiencies that are possible under PM_{10} sampling equipment certification procedures; and
- Table 1: a comparison of various features and environmental conditions at the Salton Sea, Owens Lake, Mono Lake, and Laguna Salada.

Figures 1 and 2 were produced by The Redlands Institute using satellite photos and Salton Sea Database GIS information. Both figures include potential shoreline configurations for the Salton Sea under alternative water inflow reduction scenarios. The photo base of Figure 1 provides a very useful overview of topographic and land use features of the Salton Sea basin, and indicates the size of existing upland areas that have natural soils derived from historic lakebed sediments. Figure 2 uses color coding to illustrate lakebed sediment texture conditions estimated from the limited bottom sampling analyses that have been conducted to date.

Figure 3 shows the locations of existing air quality monitoring stations, airport weather stations, and California Irrigation Management Information System (CIMIS) meteorological stations in the Salton Sea air basin. Air quality monitoring station locations are coded according to the operating agency (South Coast Air Quality Management District, Imperial County Air Pollution Control District, or Mexico). Many of the air quality monitoring stations also have meteorological towers. The National Weather Service monitors meteorological conditions at three airfields in the basin. The CIMIS meteorological stations are maintained by various participating agencies.

Figure 4 is a set of three photos illustrating a local dust storm event observed by staff from the Salton Sea Science Office. The dust source was a mudflat area along the present shoreline of the Salton Sea, west of Davis Road.

Figure 5 shows PM_{10} collection efficiency curves as a function of particle size. This figure is included to help illustrate the particle size range and fractional sampling issues associated with the definition of PM_{10}. These issues are important when trying to relate physical particle size assessments to fugitive dust emission rates and ambient air quality standards for PM_{10}.

The comparison table for Salton Sea, Owens Lake, Mono Lake, and Laguna Salada is incomplete with respect to Laguna Salada. The Laguna Salada area in Mexico was identified by the panel as an area that may be useful indicator of exposed lakebed conditions that could develop at the Salton Sea. The climatic and geologic features of the Salton Sea are likely to have more in common with the Laguna Salada area than with Owens Lake and Mono Lake.

PM_{10} STANDARDS AND ASSOCIATED AIR QUALITY MANAGEMENT CONSIDERATIONS

AMBIENT AIR QUALITY STANDARDS

The 1970 amendments to the Clean Air Act established the basic structure of current federal air quality programs, including the requirement that the U.S. Environmental Protection Agency (U.S. EPA) adopt various national ambient air quality standards. The first federal air quality standards were promulgated in 1971. California has an even longer history of setting ambient air quality standards under state enabling legislation, with the first state air quality standards being authorized in 1959. Federal ambient air quality standards are based on evidence of acute and chronic toxicity effects. State ambient air quality standards are based primarily on health effects data, but can reflect other considerations, such as protection of crops, protection of materials, or avoidance of nuisance conditions (such as objectionable odors). Several state ambient air quality standards are more stringent than the comparable federal standards or address pollutants that are not covered by federal ambient air quality standards. The numerical values of various ambient air quality standards have been changed several times. Ambient air quality standards for suspended particulate matter also have undergone changes in definition related to the size fractions of suspended particulate matter that are collected by sampling equipment.

In a general context, “ambient air quality” refers to air quality conditions in outdoor areas. In a regulatory and permitting context, “ambient air” normally has connotations implying outdoor locations where the public has or potentially may have access. Ambient air excludes work environments regulated by the Occupational Safety and Health Administration and other indoor locations. While the health implications associated with ambient air quality standards remain valid regardless of location, the standards themselves have no legal or regulatory application to indoor areas.

Suspended particulate matter represents a diverse mixture of solid and liquid material having size, shape, and density characteristics that allow the material to remain suspended in the air for meaningful time periods. The physical and chemical composition of suspended particulate matter is highly variable, resulting in a wide range of public health concerns. Many components of suspended particulate matter are respiratory irritants. Some components (such as crystalline or fibrous minerals) are primarily physical irritants. Other components are chemical irritants (such as sulfates, nitrates, and various organic chemicals). Suspended particulate matter also can contain compounds (such as heavy metals and various organic compounds) that are systemic toxins or necrotic agents. Suspended particulate matter or compounds adsorbed on the surface of particles can also be carcinogenic or mutagenic chemicals.

Current federal and state air quality standards for suspended particulate matter generally are designated as PM_{10} standards (for inhalable particulate matter) and $PM_{2.5}$ standards (for fine particulate matter). Public health concerns focus on the particle size ranges likely to reach the lower respiratory tract or the lungs. Inhalable particulate matter (PM_{10}) represents particle size categories that are likely to reach either the lower respiratory tract or the lungs after being inhaled. Fine particulate matter ($PM_{2.5}$) represents particle size categories likely to penetrate to the lungs after being inhaled. For most locations, $PM_{2.5}$ concentrations will be dominated by photochemically generated aerosols (sulfates, nitrates, and organic compounds) and aerosols which condense from gaseous compounds that reach vapor saturation as hot combustion emissions cool. Current state and federal regulatory programs focus on the PM_{10} standards since regulations for implementing the $PM_{2.5}$ standards have not yet been promulgated.

In addition to public health impacts, suspended particulate matter causes a variety of material damage and nuisance effects: abrasion; corrosion, pitting, and other chemical reactions on material surfaces; soiling; and transportation hazards due to visibility impairment.

Federal and state PM_{10} standards have been adopted for two averaging times: a 24-hour average and an annual average of the 24-hour values. The federal PM_{10} standards have been set at 150 micrograms per cubic meter as a 24-hour standard and at 50 micrograms per cubic meter as an annual arithmetic mean. The California PM_{10} standards have been set at 50 micrograms per cubic meter as a 24-hour average and at 30 micrograms per cubic meter as an annual geometric mean. The California Air Resources Board is considering revising the state annual average PM_{10} standard to 20 micrograms per cubic meter as an annual arithmetic mean, and is considering adopting an annual $PM_{2.5}$ standard of 12 micrograms per cubic meter as an annual arithmetic mean.

PARTICLE SIZE TERMINOLOGY

Size, shape, and density are important physical characteristics of suspended particulate matter. Particle dimensions can be discussed using many different units of measure. The most common size unit used in air pollution discussions is the micrometer or micron. There are 1 million microns in a meter and 25,400 microns in an inch; 1 micron is 0.001 millimeters or 0.00003937 inches. Human visual acuity varies between linear features and point features, with visual acuity for linear features being about three times greater than for point features. People with good vision typically can distinguish linear features (such as a hair) as thin as 50 microns, but can't distinguish isolated dust particles smaller than about 145 microns in diameter (smaller points against a high contrast background can be detected visually, but the eye cannot resolve their size).

Although particle size terminology implies a physical size measurement, most air pollution discussions of particle size are not based on the physical dimensions of suspended particles. In many cases, particle size terminology is merely used as a convenient shorthand for describing the aerodynamic behavior of suspended particles. Unfortunately, geologists, soil scientists, hydrologists, and atmospheric scientists often use different particle size definitions even when dealing with a common issue such as wind erosion and fugitive dust. Many of the particle size definitions used by earth scientists are based on measures of physical size. A sieve diameter usually is implied when large particles have been mechanically sorted into size categories. Particle size data derived from settling velocity analyses generally will be reported as sedimentation diameters. Particle size determinations based on microscopic examination may reflect any of several definitions, many of which are based on statistical analysis of particle image data. Particle size information provided by ambient air quality sampling instruments usually refers to the aerodynamic equivalent diameter.

THE DEFINITION OF PM_{10}

Particle size references used in ambient air quality standards refer to the aerodynamic equivalent diameter of particles. The aerodynamic equivalent diameter is not based on physical dimensions, but is based on the terminal settling velocity of a particle in still air. The aerodynamic equivalent diameter is the diameter of a sphere with a density of 1 gram per cubic centimeter that has the same terminal settling velocity as the actual particle.

PM_{10} is a fractional sampling of ambient particles that approximates the extent to which particles in various aerodynamic diameter ranges are likely to penetrate into the lower respiratory tract. The 10-micron component of the PM_{10} definition refers to a sampling instrument 50% collection efficiency measure, not an absolute particle size limit. When operated during wind speeds of 1-15 mph, an acceptable PM_{10} sampler must collect 45-55% of the mass of particles with aerodynamic equivalent diameters between 9.5 and 10.5 microns. In addition, the size-based collection efficiency curve derived for the sampler must pass a test for total particle mass collection. When the collection efficiency curve is applied to a standardized particle mass distribution, the calculated total mass of collected particles must be within 10% of the total mass calculated for the "ideal" PM_{10} sampler collection efficiency curve. The standardized particle mass distribution used for the mass collection test includes particle sizes ranging from less than 1 micron to 45 microns in aerodynamic diameter.

The Quality Assurance Division of the U.S. EPA Environmental Monitoring Systems Laboratory characterizes PM_{10} samplers as follows (Purdue, 1988): "PM_{10} samplers normally have a smooth, S-shaped sampling effectiveness curve dropping from near 100 percent to near 0 percent as the particle size increases from 1 to 50 micrometers. The 50 percent cutpoint specification has been established at 10 +/- 0.5 micrometers." Similarly, the Aerometric Data Division of the California Air Resources Board characterizes PM_{10} samplers as follows: "The PM_{10} sampler is designed to collect 50 percent of all particles 10 microns in aerodynamic diameter and collects a declining fraction of particles as diameter increases and an increasing portion of particles below 10 microns." Sampling effectiveness is actually measured in terms of particle mass, not particle numbers. The cutpoint diameter is the size where 50% of the ambient particle mass is collected (not 50% of the discrete particles).

FEDERAL AIR QUALITY PLANNING REQUIREMENTS

The status of an area with respect to federal and state ambient air quality standards generally is categorized as nonattainment, attainment, or unclassified. In the federal usage, initial designations are often made as either nonattainment or as unclassified. When designated in this manner, the unclassified designation includes attainment areas that comply with federal standards as well as areas for which monitoring data are lacking. Unclassified areas are treated as attainment areas for most regulatory purposes. When initially designated in this manner, formal attainment designations are used only for areas that transition from a nonattainment status to an attainment status. Areas that have been reclassified from nonattainment to attainment of federal air quality standards are automatically considered "maintenance areas" for the next 20 years. Both nonattainment and maintenance areas are subject to the Clean Air Act conformity requirements discussed below. Both the Coachella Valley and the Imperial Valley portions of the Salton Sea Air Basin have been designated as federal and state nonattainment areas in terms of the relevant PM_{10} standards.

The federal Clean Air Act requires each state to develop, adopt, and implement a state implementation plan (SIP) to achieve, maintain, and enforce federal air quality standards throughout the state. Deadlines for achieving the federal air quality standards vary according to air pollutant and the severity of existing air quality problems. The SIP must be submitted to and approved by the U.S. EPA. SIP elements are developed on a pollutant-by-pollutant basis whenever one or more of the federal air quality standards are being violated. The deadline for achieving the federal PM_{10} standards in the Imperial Valley portion of the Salton Sea Air Basin expired in 1994, but issues of pollutant transport from Mexico complicate air quality planning considerations in this area. In 2001 the U.S EPA concluded that the Imperial Valley would have attained the federal PM_{10} standards in 1994 if not for the impact of emissions originating in Mexico. The PM_{10} SIPs for both the Coachella Valley and Imperial Valley are currently being revised and updated. At present, neither the Imperial Valley nor the Coachella Valley PM_{10} SIPs consider potential consequences of lowered water levels at the Salton Sea.

Section 188(f) of the Clean Air Act allows the U.S. EPA to waive PM_{10} attainment deadlines for areas where nonanthropogenic sources (natural sources that are not influenced directly or indirectly by human activity) contribute significantly to violations of the PM_{10} standard. Examples of nonanthropogenic PM_{10} emission sources include volcanic eruptions, smoke from natural forest and range fires, windblown dust from undisturbed natural areas, and salt spray in coastal areas. The U.S. House of Representatives committee report on the 1990 Clean Air Act amendments specifically cited dust from Owens Lake and Mono Lake as examples of anthropogenic emissions because dust storms in those areas are ultimately caused by the human activity of diverting water from the streams feeding Owens Lake and Mono Lake (Stensvaag 1991). It is likely that any fugitive dust problems linked to lakebed areas exposed by reduced water inflows to the Salton Sea would be considered an anthropogenic air quality problem, not a natural event emission source.

CLEAN AIR ACT CONFORMITY REQUIREMENTS FOR FEDERAL AGENCIES

Section 176(c) of the Clean Air Act requires federal agencies to ensure that actions undertaken in nonattainment or maintenance areas are consistent with the Clean Air Act and with federally enforceable air quality management plans. The U.S. EPA has promulgated separate rules that establish conformity analysis procedures for transportation-related actions and for other (general) federal agency actions. Transportation conformity requirements apply to highway and mass transit projects funded or approved by the Federal Highway Administration or the Federal Transit Administration.

General conformity requirements are potentially applicable to most other federal agency actions, including funding and approval actions. The general conformity rule applies to federal actions occurring in nonattainment or maintenance areas when the total direct and indirect emissions of nonattainment pollutants (or their precursors) exceed specified thresholds. The emission thresholds that trigger requirements of the conformity rule are called *de minimis* levels. Emission sources that are not subject to direct or indirect federal agency control are excluded from Clean Air Act conformity reviews under the general conformity rule.

The U.S. EPA general conformity rule establishes a process that is intended to demonstrate that the proposed federal action:

- Will not cause or contribute to new violations of federal air quality standards;
- Will not increase the frequency or severity of existing violations of federal air quality standards; and
- Will not delay the timely attainment of federal air quality standards.

Compliance with the conformity rule can be demonstrated in several ways. Compliance is presumed if the net increase in direct and indirect emissions from a federal action would be less than the relevant *de minimis* level. If net emissions increases exceed the relevant *de minimis* value, a formal conformity determination process must be followed. Federal agency actions subject to the general conformity rule cannot proceed until there is a demonstration of consistency with the SIP through one of the following mechanisms:

- By dispersion modeling analyses demonstrating that direct and indirect emissions from the federal action will not cause or contribute to violations of federal ambient air quality standards;
- By showing that direct and indirect emissions from the federal action are specifically identified and accounted for in an approved SIP;
- By showing that direct and indirect emissions associated with the federal agency action are accommodated within emission forecasts contained in an approved SIP;
- By showing that emissions associated with future conditions will not exceed emissions that would occur from a continuation of historical activity levels;
- By arranging emission offsets to fully compensate for the net emissions increase associated with the action;
- By obtaining a commitment from the relevant air quality management agency to amend the SIP to account for direct and indirect emissions from the federal agency action; or
- In the case of regional water or wastewater projects, by showing that any population growth accommodated by such projects is consistent with growth projections used in the applicable SIP.

Dispersion modeling analyses can be used to demonstrate conformity only in the case of primary pollutants such as carbon monoxide or directly emitted PM_{10}. Modeling analyses cannot be used to demonstrate conformity for secondary pollutants such as ozone or photochemically generated particulate matter because the available modeling techniques generally are not sensitive to site-specific emissions.

Existing PM_{10} SIPs for the Salton Sea Air Basin do not consider the possibility of significant water level reductions at the Salton Sea. In addition, the existing PM_{10} SIPs do not recognize the various actions being considered for the Salton Sea Restoration Project. If pending PM_{10} SIP revisions do not address the potential for fugitive dust problems at the Salton Sea, then identification and mitigation of fugitive dust problems would have to occur on an incremental project-specific basis. Federal agency participation in the Salton Sea restoration project, water resources management projects, or other land management projects affecting the Salton Sea could be disrupted by difficulties in making the required Clean Air Act conformity determinations.

FACTORS THAT DETERMINE THE POTENTIAL FOR WIND EROSION PROBLEMS

Wind erosion involves a continuum of particle motions that normally are categorized as surface creep, particle saltation, and particle suspension. Surface creep is a sliding or rolling motion of particles across a surface. Particle saltation is a bouncing motion in which particles are lofted slightly into the air and carried a short distance downwind before falling back to the ground. Particle suspension implies lofting particles high enough into the air that they can be carried moderate to long distances before particle settling and deposition processes overcome turbulent motion forces that keep the particles suspended. Initial particle movement generally is by saltation. The ballistic impact of particle saltation helps initiate surface creep, additional particle saltation, and particle suspension. In terms of overall mass movement, most wind erosion occurs through particle saltation and surface creep. Air quality considerations focus on the smaller component of particle suspension.

A general understanding of physical forces associated with wind erosion processes can help explain the importance of topics that are frequently mentioned in field evaluations of areas where wind erosion is a concern. The wind erosion process represents a transfer of energy from moving air to sediment or soil particles at the ground surface. At the scale of individual particles, wind erosion is the result of several interacting forces, some of which induce particle movement and others which resist particle movement. Lift, shear, and ballistic impact forces induce particle movement while gravity, friction, and cohesion among particles resist movement. In this context, lift represents a difference in pressure between the top and bottom of a particle while shear represents a difference in pressure between the upwind and downwind sides of a particle. Lift represents forces that produce vertical motion and shear represents forces that produce horizontal motion. Gravity and cohesion among particle resist lift forces while friction and cohesion among particles resist shear forces.

A very thin nonturbulent layer of air always exists next to the ground surface. This layer, often called the laminar layer, is essentially a zone of calm air. The thickness of the laminar layer depends in part on the roughness of the ground surface. Horizontal shear forces only affect objects that extend above or are lifted above this laminar layer. Rough non-cemented surfaces and minor irregularities in smooth surfaces often result in some surface particles being perched partially or completely above the laminar layer. Sand-sized particles are often large enough to project above the laminar layer, and thus can be instrumental in the initiation of wind erosion processes.

Pressure differences that generate lift forces can be generated by vertical differences in wind speed or by vertical turbulence in the local wind flow. Air moving at higher velocity exerts less pressure than air moving at a lower velocity. Friction at the ground surface causes wind speeds to be lower near the ground than at greater heights above the ground. Vertical turbulence near the ground also produces temporary fluctuations in pressure that generate lift forces. In general, it takes less energy to keep a particle suspended once it is lofted above the laminar layer than it does to remove it from the ground surface in the first place. Consequently, short term wind gusts, episodes of strong vertical turbulence, and ballistic impact forces from saltating particles can all be important in producing particle suspension.

While much research focuses on the physics of wind erosion processes, a practical evaluation of the potential for wind erosion at a specific location needs to consider the following major factors:

- The physical characteristics of exposed soils and sediments;
- Substrate moisture conditions;
- Substrate crusting issues;
- Meteorological conditions; and
- Other modifying influences.

The substrate crusting topic in the preceding list involves various aspects of the other topic areas. It has been separated into a discrete topic for convenience and to avoid unnecessary repetition. The following paragraphs address these topics both as general considerations and in the context of the Salton Sea.

PHYSICAL CHARACTERISTICS OF EXPOSED SOILS AND SEDIMENTS

The characteristics of soil and sediment surfaces are a major determinant of how susceptible the material will be to wind erosion. One of the most important characteristics to consider is the mix of particle size categories in the material. For descriptive purposes, the mix of particle sizes can be characterized using standard soil texture categories. The standard particle size categories used for texture classification are clay particles (under 2 microns in sieve diameter), silt particles (2 to 50 microns in sieve diameter), and sand particles (50 to 2,000 microns in sieve diameter). The sand component is sometimes subdivided into fine sands (50 to 100 microns in sieve diameter), medium sands (100 to 500 microns in sieve diameter), coarse sands (500 to 1,000 microns in sieve diameter), and very coarse sands (1,000 to 2,000 microns in sieve diameter). The U.S. Department of Agriculture has grouped various mixes of clay, silt, and sand particle sizes into 12 soil texture categories (ranging from clays and silts for material strongly dominated by fine particles, through various loam categories for materials with broad mixes of clays, silts, and sand particles, to sandy categories for material dominated by sand sized particles).

Other factors that are important to consider include the extent of particle aggregation in the clay content of the material and the amount of organic material in the soil or sediment. Both of these factors tend to reduce the susceptibility of the material to wind erosion. The amount of non-erodible material (such as gravel or rocks) in surface layers, and the extent and nature of any particle cementing or crusting can be additional factors reducing the potential for wind erosion. As noted above, sediment crusting issues are discussed separately in a subsequent section.

Conditions at the Salton Sea. The best information on lakebed sediment texture conditions for the Salton Sea appears to be the data from LFR Levine-Fricke (1999). The 73 sediment samples collected by that study were clustered primarily in the southern part of the Salton Sea and near the Whitewater River Delta in the northern part of the Salton Sea. Relatively few samples were collected in the deeper waters of the Salton Sea. Few samples were collected between Salton City and San Felipe Creek on the west side of the Sea or between Salt Creek and the Wister unit of the National Wildlife Refuge on the eastern side of the Salton Sea. Figure 2 attached to this paper illustrates the sediment texture categories estimated from the LFR Levine-Fricke data.

The Whitewater River seems to be contributing predominantly silty sediments. The New and Alamo Rivers seem to be contributing a mix of sediment texture categories, with the Alamo River delivering more sandy sediments than the New River. Salt Creek seems to be contributing clay sediments. Predominantly clay sediment input also seems to be entering on the west side of the Salton Sea from intermittent creeks between Desert Shores and Salton City. A curved band of clay sediments appears to be accumulating across the Salton Sea between San Felipe Creek and Bombay Beach. Some of this may be due to direct input from San Felipe Creek, although current patterns in the southern part of the Salton Sea may be a major influence in this area, which includes the deepest portions of the Salton Sea. The intermittent creeks draining into the Salton Sea in the central parts of the western and eastern shores may be contributing sandy sediments to the area separating the northern and southern basins of the Salton Sea, but only a few sediment samples were collected in this area. The intermittent creeks from San Felipe Creek south to the New River seem to be delivering a mix of clay and silt sediments, although only a few sediment samples were collected in shallow water portions of this area. Intermittent creeks from Bombay Beach south toward the Alamo River also seem to be delivering a mix of clay and silt sediments. The shallow southern end of the Salton Sea shows a rather complex pattern of sediment texture categories. Beach areas around the Salton Sea have extensive accumulations of sands derived from barnacle shells and fish bones.

Soil texture conditions for upland areas around the shore of the Salton Sea have not been thoroughly mapped. The available soil survey for the Imperial Valley (U.S. Department of Agriculture Soil Conservation Service 1981) has a generalized map of soil conditions. Some of the mapping units have relatively uniform soil texture conditions while other mapping units have a mixture of texture conditions ranging from gravelly sand to silty clay. The general soil map in the Imperial Valley soil survey shows the immediate shoreline around the southern end of the Salton Sea as a fluviquent mapping unit. This mapping unit is described as “nearly level, poorly drained soils of undifferentiated texture in the lacustrine basin”. The northern end of the Salton Sea is poorly covered by existing soil mapping. In general, agricultural soils near the southern end of the Salton Sea have a high clay content.

SUBSTRATE MOISTURE CONDITIONS

The moisture content of exposed material has a strong influence on the susceptibility of the material to wind erosion. Soils and sediments that are moist at the surface are extremely resistant to wind erosion processes. The moisture can be derived from precipitation events, agricultural irrigation, groundwater, or proximity to surface waters. Soil and sediment texture conditions influence the vertical distribution of available moisture. Capillary action is greatest in fine sediments and least in sandy materials. The depth to saturated conditions, the extent of capillary action, and the chemistry of the interstitial water have important implications for the formation of surface salt deposits, calcium carbonate or gypsum deposits, and the cementing of soil or sediment materials. Weather conditions may impose seasonal changes, both in terms of overall moisture conditions and in the nature of any soluble or insoluble mineral deposits at or near the surface.

Conditions at the Salton Sea. Areas around the Salton Sea receive an annual average of about 2.5 to 3 inches of precipitation per year. Consequently, direct precipitation contributes only sporadically to soil moisture conditions. Groundwater conditions, agricultural irrigation, and proximity to surface water are the dominant influences on soil and sediment moisture conditions. The generally warm to hot air temperatures, along with low humidity and moderate winds, mean that soil surfaces are typically dry.

Because most water inflow to the Salton Sea comes from surface waters and agricultural drains, there has not been any extensive effort to map groundwater conditions in terms of depth to groundwater, groundwater flow rates, or chemical composition of groundwaters. Groundwater conditions around the Salton Sea have been categorized in terms of six subareas. The aquifer beneath and adjacent to the Salton Sea in these six areas generally is believed to be a regional groundwater discharge area, although the discharge rates are thought to be small due in part to the low hydraulic conductivity of the lacustrine sediments of former Lake Cahuilla. In general, groundwater in the Imperial Valley portion of the basin is more highly mineralized than groundwater in the Coachella Valley portion of the basin. Available information indicates that most of these areas have chloride type groundwater conditions. Groundwater in the southeastern part of the basin has high sulfate concentrations. Areas affected by sulfate type groundwater may be of special concern in terms of potential fugitive dust issues because efflorescent deposits of sodium sulfate salts can be very susceptible to wind erosion.

SUBSTRATE CRUSTING ISSUES

The development of surface mineral deposits and the cementing of surface soil or sediment layers has strong implications in terms of susceptibility to wind erosion. Soil cementing by calcium carbonate and gypsum (hydrated calcium sulfate) is an important phenomenon in arid areas, although it does not always happen at the soil surface. Where surface mineral deposits do form, the thickness, chemical composition, and mineralogical composition of the deposit are important. Calcium carbonate, gypsum, and sodium chloride deposits are relatively stable and protect underlying sediments from wind erosion. Sodium salts are much more soluble than calcium salts. Consequently, areas affected by sodium salt minerals may show distinct seasonal changes in the presence, geographic extent, and physical nature of the material.

Salt crusts only form where environmental conditions allow salt minerals to accumulate to significant concentrations in the surface zone of soils or sediments. In the absence of direct precipitation from a water body that has reached saturation conditions, the formation of surface salt deposits typically requires salt transfer from mineralized groundwater or from subsurface deposits of soluble salts that can be mobilized by soil moisture conditions. Where water transfer to the surface is slow, the process of forming mineral crusts or cementing of surface materials may not occur.

Where surface salt deposits do form, the process is a function of air and soil temperature, surface soil moisture (especially from precipitation events), the depth to saturated conditions, soil and sediment texture conditions affecting the range of capillary action, and the mineral content of the water in the sediments. Where the water table is relatively deep, precipitation events may be the major water source that mobilizes soluble salts in the upper soil horizons, allowing salt deposits to form through capillary action and evaporation at the soil surface. If salt deposits are dominated by sodium chloride, a hard cemented crust will form under all temperature conditions. Sodium chloride salt crusts are resistant to wind erosion. If salt deposits are dominated by sodium sulfate, sodium carbonate, or sodium bicarbonate salts, the physical character of the salt deposit will be sensitive to temperature and humidity conditions.

Salt deposits dominated by sodium sulfate, sodium carbonate, or sodium bicarbonate salts undergo complex mineralogical phase changes that are a function of substrate temperature and moisture availability. These salts are strongly hygroscopic, and undergo significant volume changes during mineralogical phase changes. The volume changes can disrupt the physical structure of a salt crust as well as the structure of soil or sediment materials that contain high concentrations of these salts. The physical characteristics of sodium sulfate, carbonate, and bicarbonate salt deposits can change from hard cemented crusts resistant to wind erosion to weak fragmented crusts susceptible to wind erosion, to anhydrous powders that are extremely susceptible to wind erosion. Sodium sulfate salts tend to form weak crusts or anhydrous powders at temperatures below 65 degrees F (18 degrees C), but will form hard cemented crusts at higher temperatures. Sodium carbonate and bicarbonate salts tend to form weak crusts or anhydrous powders at temperatures below 50 degrees F (10 degrees C), but will form hard cemented crusts at higher temperatures.

Panel member Dale Gillette noted that where a firm crust is formed, the thickness of the crust and the pressure needed to break it will determine how well it protects underlying sediments from wind erosion. As a practical field test, if the crust is at least 1 centimeter thick and requires more pressure to break than is required for breaking a Ritz cracker, then the crust will be highly resistant to wind erosion and will protect the underlying sediments. Such crusts also will be resistant to the ballistic impacts of saltating sand. Weaker crusts can be eroded by sand saltation, and thus offer only temporary protection from wind erosion. Panel member Dale Gillette also noted that if a rough cemented crust is formed, it can trap loose sediment particles in sheltered depressions, thus reducing the potential for suspension of that material.

Conditions at the Salton Sea. A variety of surface crusting conditions occur in areas around the Salton Sea, but there are few areas of extensive salt deposits comparable to those found at Owens Lake or Mono Lake. Areas of sodium chloride or sodium sulfate salts are likely to form near the immediate shoreline of the Salton Sea due to evaporation of intruding lake waters. But the shoreline zone affected by such processes normally would be relatively narrow. Sodium chloride salts would be expected to dominate many shoreline areas that have salt deposits. But powdery salt deposits (which might be sodium sulfate salts) also have been observed at times in various locations around the shore of the Salton Sea. The prospects for sulfate versus chloride salt formation may vary seasonally. Deposits of sodium carbonate or sodium bicarbonate salts are not expected at the Salton Sea because lake waters have very low concentrations of carbonate and bicarbonate ions. As with many desert areas, calcium carbonate and gypsum deposits occur in soils around the Salton Sea. There has been no comprehensive mapping of areas presently exhibiting different types of crusting or salt deposits. That makes it difficult to use current conditions as a basis for extrapolating to conditions that might develop on sediments exposed by the lowering of water levels in the Salton Sea.

METEOROLOGICAL CONDITIONS

Wind speed and wind direction patterns are of obvious importance to any assessment of wind erosion conditions. But other meteorological data such as seasonal temperature patterns, seasonal precipitation patterns, and seasonal evaporation rate patterns also are important. In some areas, relative humidity data, the frequency of fog events, and the frequency of dew formation could be important considerations.

The threshold wind velocity necessary to initiate wind erosion processes depends on the characteristics of exposed soil and sediment materials and the surface moisture content of those materials. Where the surface material is dry and there is no cementing or crusting of the materials, threshold wind velocities depend primarily on particle size and density characteristics. Typical threshold wind speeds are in the range of 15 to 20 mph as 10-meter equivalent wind speeds. Serious dust storm events generally require wind speeds over 20 mph. The World Meteorological Organization (1983) suggests 16 mph as a typical threshold wind speed for "everyday wind erosion" and 22 mph as a typical threshold wind speed for dust storm events.

Conditions at the Salton Sea. The California Irrigation Management Information System (CIMIS) operates a series of meteorological stations throughout agricultural areas of California, including the Coachella and Imperial Valleys. Several stations are located around the Salton Sea. Data archives from these monitoring stations have not been compiled and summarized in any comprehensive manner. Analysis of data from these stations needs to account for the fact that most wind monitoring instruments are on short towers, about 2 meters above ground level. This prevents direct comparison to data from conventional 10-meter towers. However, the CIMIS stations normally collect useful data on wind speed, wind direction, direct solar radiation, air temperature, and humidity levels. The available data allow an evaluation of atmospheric stability conditions, which in turn allows for conversion of measured wind speed data into equivalent 10-meter wind speeds. Other data from conventional meteorological stations are available, but these stations generally are not located near the shore of the Salton Sea.

Wind conditions at the CIMIS station in Salton City during 1997 and 1998 have been extrapolated to an equivalent 10-meter instrument height. The following tabular summary shows the frequency with which the extrapolated 10-meter hourly average wind speeds exceeded various threshold velocities.

Summary of Wind Speed Occurrence at the Salton City CIMIS Monitoring Site

Wind Speed Value Category	1997 Data	1998 Data
15 mph or higher	397 hours	407 hours
18 mph or higher	269 hours	229 hours
21 mph or higher	95 hours	56 hours
24 mph or higher	35 hours	23 hours
27 mph or higher	20 hours	8 hours
30 mph or higher	11 hours	1 hour

For the Salton City CIMIS site, extrapolated 10-meter wind speeds exceeded 21 mph 1.08 percent of the time in 1997 and 0.64 percent of the time in 1998. By comparison, wind speeds at Owens Lake typically exceed 20 mph about 11 percent of the time (958 hours per year) and typically exceed 30 mph about 1.1 percent of the time (97 hours per year).

OTHER MODIFYING INFLUENCES

A number of other factors also need to be considered when evaluating the potential for significant wind erosion. Particle saltation from adjacent areas can be important when a mosaic of crusted and uncrusted soil surfaces is present and at boundaries between large crusted and uncrusted areas. The size and shape of erosion-sensitive areas also can be a factor, especially when particle saltation originating within the erosion-sensitive area is important to the wind erosion process. The extent and rate of vegetation establishment on barren areas also is important, since vegetation can provide significant protection from wind erosion. Disturbance by human or animal activity can be an important factor that increases the frequency and magnitude of wind erosion events.

In some situations, upslope water erosion and subsequent sedimentation may be a source of loose, erdodible material on surfaces that are otherwise resistant to wind erosion. Flash flood events are a common source of silt and clay sediment deposition in desert basins. The sediments deposited by flash flood events are typically unconsolidated and susceptible to wind erosion even if the underlying ground condition is a cemented or crusted surface.

Conditions at the Salton Sea. Several areas around the Salton Sea are potential sources of sand that could be blown across areas exposed by reduced water levels. In general, desert vegetation around the Salton Sea is relatively sparse, with large areas having less than 20% cover. In addition, there are potential sand source areas along the Whitewater River at the north end of the Salton Sea, sand dune areas on the Salton Sea Test Base on the western shore of the Salton Sea, and other sand source areas in the Niland area near the southeastern corner of the Salton Sea.

The potential for vegetation establishment and the potential for disturbance by human activity are additional factors that need to be considered at the Salton Sea. In general, the rate of natural vegetation establishment on barren sediments in desert areas is very slow. High soil salinities will further retard the rate and extent of vegetation establishment on recently exposed barren sediments. Human disturbance increases the susceptibility of barren areas to wind erosion, and also can affect the prospects for vegetation establishment. Many shoreline areas around the Salton Sea appear to receive occasional disturbance from human access.

COMPARISONS BETWEEN THE SALTON SEA AND OTHER AREAS

Panel member presentations included overviews of conditions at both Owens Lake and Mono Lake. Owens Lake and Mono Lake are logical points of comparison because of their recognized fugitive dust problems. The high salinities of Owens Lake and Mono Lake naturally invite comparisons to the Salton Sea. Such comparisons are useful when they help explain important processes and mechanisms. Direct comparisons also are important where the similarities between areas clearly outweigh the differences. But caution must always be exercised when trying to extrapolate from one location to another.

One of the most important differences between the Salton Sea and conditions at Owens Lake or Mono Lake is likely to be the nature and extent of salt deposit formation. Sources and mechanisms for salt deposit formation at Owens Lake and Mono Lake appear to be absent or of minimal importance at the Salton Sea. The bulk of the Owens Lake salt deposit was formed by direct precipitation from the desiccating lake. The major salt beds that formed in the lowest part of the Owens Lake playa have a high water content and a high concentration of sodium chloride salts. That makes the major salt beds resistant to erosion. The outer portions of the Owens Lake playa are affected by efflorescent salts dominated by sodium carbonate, sodium bicarbonate, and sodium sulfate. These efflorescent salt minerals were the first salts to reach saturation conditions as Owens Lake dessicated, resulting in their precipitation on the outer portions of the playa. Additional efflorescent salts are contributed to the outer portions of the Owens Lake playa by mineralized springs and groundwater inflow. Significant portions of the eastern and southern sided of the playa experience seasonal formation of salt deposits dominated by sodium carbonate, sodium bicarbonate, and sodium sulfate salts. Most dust storms at Owens Lake originate from those portions of the playa.

In comparison to Owens Lake, water level reductions at the Salton Sea are unlikely to result in precipitation of dissolved salts which would be susceptible to wind erosion. Even with water inflows to the Salton Sea reduced by 500,000 acre-feet per year, sodium sulfate and sodium chloride concentrations in the Salton Sea would not reach saturation any time in the next 50 years.

In contrast to Owens Lake, most of the salt deposits at Mono Lake are produced by saline and alkaline groundwater inflows to the lake. Similarly mineralized groundwater inflow to the Salton Sea appears to be minimal. Localized areas of salt formation occur around the shoreline of the Salton Sea, and would be expected with any future reductions in water levels. But there is no indication that such deposits would affect large portions of exposed lakebed. The absence of any identifiable mechanism for formation of geographically extensive salt deposits is a major difference between conditions at the Salton Sea and those at Owens Lake or Mono Lake. Conditions other than highly erosive salt deposits are likely to dominate the fugitive dust issue at the Salton Sea. Wind erosion conditions at the Salton Sea are likely to be determined by general soil texture conditions rather than by the formation of efflorescent salt deposits.

Table 1 in the Attachments section of this paper presents an extensive comparison of conditions at the Salton Sea, Owens Lake, and Mono Lake. To the extent that information is readily available, the table also provides information on the Laguna Salada area of Mexico.

Another area that may have relevance to the Salton Sea is the blowsand area in the northern portion of the Coachella Valley. This area of natural desert sand deposits is an important contributor to PM_{10} problems in the Coachella Valley. Although the panel did not discuss this area, a cursory review of the Coachella Valley PM_{10} SIP suggests that there may be some similarities to the Whitewater River delta area at the Salton Sea.

SUMMARY OF MAJOR CONCLUSIONS

Surface soils in much of the Salton Basin are derived from lakebed sediments deposited in Lake Cahuilla and other inundations of the trough. Because inflows to the Salton Basin from the Colorado River entered from the south, the northern end of the Salton Basin shows less dominance of sediments derived from the Colorado River. Lakebed sediments currently submerged in the Salton Sea have had additional sediment and organic matter deposition since the present Salton Sea was formed. But in general, lakebed sediments that would be exposed by a lowering of water levels in the Salton Sea are likely to have texture conditions similar to adjacent shoreline areas. Locations where there are abrupt changes in local topographic features could be exceptions to this general expectation.

The variability of onshore conditions around the Salton Sea makes it almost certain that some areas of exposed lakebed sediments will have the potential for generating meaningful quantities of fugitive dust under some conditions. The Whitewater River delta area has a mix of sand and fine sediments which is conducive to wind erosion. Surface conditions in that area indicate that some localized wind erosion events have occurred. Clay sediments are more prominent in the southern shoreline areas, but river deltas add significant variability. Sand dune areas are found north of San Felipe Creek on the navy’s former Salton Sea Test Base site. Local geologic conditions (such as geothermal features) add further complexity.

There also is evidence of disturbance from public access to many shoreline areas (foot traffic, dune buggies, and other off-road vehicles). The resulting ground disturbance enhances the potential for wind erosion.

Natural revegetation is very slow in desert areas, and salinity conditions in exposed lakebed sediments will further retard natural revegetation rates. Thus, natural revegetation is not expected to provide meaningful protection from wind erosion events on a time scale shorter than many decades. Relatively rapid natural revegetation can be expected only in riparian and wetland areas where relatively fresh water inflows can leach salts from the exposed sediments and provide moisture conditions favorable to plant growth.

Conditions at Owens Lake and Mono Lake provide important information concerning the mechanisms of dust storm generation and the importance of salt deposit mineralogy for situations where extensive efflorescent salt deposits are likely to form. Efflorescent salt deposit areas are important contributors to fugitive dust problems at Owens Lake and Mono Lake. But conditions at the Salton Sea are different from those at Owens Lake and Mono Lake. In particular, the primary mechanisms for salt deposit formation at Owens Lake (full desiccation of the lake) and Mono Lake (exposed shoreline zones of mineralized groundwater inflow) do not seem to exist at the Salton Sea. Consequently, the frequency, geographic scale, duration, and intensity of dust storms at Owens Lake and Mono Lake may not provide much guidance regarding the frequency and scale of dust storm events that might be expected at the Salton Sea.

The types of extensive salt deposits observed at Owens Lake and Mono Lake are not expected to form at the Salton Sea due to differences in water chemistry, air and water temperatures, and groundwater flow conditions. But localized areas of salt deposits, soil crusting, and cemented soil conditions would be expected. The formation of localized salt deposits can have varied effects on the potential for wind erosion, while soil crusting and the development of cemented soil conditions would tend to reduce the potential for wind erosion.

Localized salt deposits at the Salton Sea may be a seasonal phenomenon, and could vary in chemistry and mineralogy along different portions of the shoreline. Salt crusts dominated by sodium chloride would be resistant to wind erosion. But seasonal salt crusts dominated by sodium sulfate salts or sodium carbonate salts would have the potential for transforming into physical forms that are highly susceptible to wind erosion. Available information on surface and groundwater quality suggests that sodium carbonate salts would not be expected at the Salton Sea, but that sodium sulfate salts may be present. Some localized areas of powdery efflorescent salts (probably sodium sulfate salts) have been observed at various locations along the shore of the Salton Sea. One of those areas on the southeastern shore produced a local dust storm that has been photographed by staff from the Salton Sea Science Office. Those photographs are included in the Attachments section of this paper as Figure 4.

Soil crusting and soil cementing from precipitation of calcium carbonate or gypsum would tend to protect soils from wind erosion. Such crusting and cementing occurs in various areas around the Salton Sea, but has not been evaluated in any detail, and no maps have been developed to illustrate the extent of such conditions. Similar crusting and cementing would be expected in some of the sediments exposed by a lowering of Salton Sea water levels, but there is no data from which to extrapolate the future extent of such crusting. It also is important to recognize that weathering of crusts and disturbance by human access to shoreline areas could disrupt or eliminate these crusts.

The size of the area that might be exposed by lowering of Salton Sea water levels as discussed in the water transfer EIS/EIR is comparable to the size of the entire Owens Lake playa, and much larger than the size of the areas around Mono Lake that contribute to dust storm events. While there is no reason to expect development of geographically extensive salt deposits at the Salton Sea, the total size of the lakebed area that could be exposed raises concerns over the potential for fugitive dust problems. The potential size of the exposed area, combined with the variability of existing shoreline areas, precludes any simple prediction of the geographic scale, frequency, or intensity of windblown dust events that would be generated from exposed lakebed areas. But any area of barren soils can become a source of fugitive dust under the right conditions.

The overall consensus of the workshop panel is that episodes of windblown dust should be expected if there is a significant reduction in Salton Sea water levels. Presently available information does not allow for reasonable quantification of the frequency, geographic scale, duration, or intensity of potential dust storm events at the Salton Sea under conditions of lowered water levels. The consensus of the panel is that the geographic extent and severity of these dust storm events normally would be less than those at Owens Lake. But even localized dust storm events can be important if they impact residential, recreational, or agricultural areas.

Any visible dust storm event that persists for more than an hour is likely to result in air quality conditions at some locations that exceed the federal 24-hour average standard for PM_{10}. Visible dust plumes typically have particle mass concentrations of several thousand micrograms per cubic meter. Saint-Amand, et al. (1986) estimated that Owens Lake dust storm particle concentrations of 5,000 micrograms per cubic meter would reduce visibility to about 1.3 miles. Chepil and Woodruff (1957) suggested that dust storm visibilities of 1 kilometer (0.62 miles) were associated with total dust loadings of 56,000 micrograms per cubic meter. Although the visibility versus dust concentration relationships estimated by Saint-Amand et al. (1986) and by Chepil and Woodruff (1957) were not based on PM_{10} data, those estimates clearly indicate significant visibility reductions are associated with very high suspended particle concentrations. A 1-hour average PM_{10} concentration above 3,600 micrograms per cubic meter would by itself cause the federal 24-hour standard of 150 micrograms per cubic meter to be exceeded.

DATA GAP ISSUES AND RECOMMENDATIONS

The following future study suggestions attempt to address data gap issues identified by the panel. For convenience, they have been grouped into the following categories: portable wind tunnel studies; improved air quality and meteorological monitoring; additional soil and sediment data collection and mapping; Laguna Salada studies; and salt mineralogy studies. Portable wind tunnel studies were identified as the preferred method to quantify emission rates associated with wind erosion of different soil or sediment types at the Salton Sea. Reliable emission rate data are a high priority for any modeling studies that might be undertaken to better define the potential for future fugitive dust problems at the Salton Sea. Air quality and meteorological monitoring in the immediate vicinity of the Salton Sea would provide both baseline data and on-going monitoring for early detection of any fugitive dust problems that might develop. The Laguna Salada studies were identified during panel discussions of areas that might provide a surrogate for the types of conditions that could develop if water levels decline significantly at the Salton Sea.

PORTABLE WIND TUNNEL STUDIES AT THE SALTON SEA

The panel identified portable wind tunnel studies as a major way to determine wind erosion rates for different soil and sediment conditions around the Salton Sea. Existing upland areas around the shore of the Salton Sea could be used as surrogates for the adjacent submerged areas that might be exposed by a lowering of water levels. The panel also discussed the possibility of extracting large sediment cores from offshore areas, draining and drying the intact cores on shore, and then performing portable wind tunnel analyses on the material.

An additional option is to identify an existing area that is a reasonable surrogate for conditions that might develop on Salton Sea lakebed areas that might be exposed in the future, and to conduct additional portable wind tunnel studies at that location. The panel identified the Laguna Salada area of Mexico as a potential surrogate area (discussed further below).

The panel feels that fixed wind tunnel studies using sieved samples give only the maximum possible emission rate. While such evaluations have applicability to heavily disturbed area or to sediments lacking any cohesive structure, they are not the preferred approach where there is a cohesive structure to soils or sediments.

ADDITIONAL SOIL AND SEDIMENT DATA COLLECTION AND MAPPING

The panel felt there was a clear need for more data on texture conditions for both submerged areas and existing shoreline areas. Given the large size of the Salton Sea, available data is based on a rather limited number of samples. Panel member Pat Chavez suggested that detailed bottom sediment mapping could be obtained in a cost-effective manner by using side scan sonar, acoustic profiling, or related equipment. There also is a need to develop soil texture maps for the existing shoreline areas so that correlations can be made between currently exposed areas and areas that are presently submerged.

The panel also felt that information was lacking on the extent of organic matter in currently submerged sediments and the effects of that organic matter on the stability of those sediments once they are exposed.

IMPROVED AIR QUALITY AND METEOROLOGICAL MONITORING

Any future quantitative analysis of potential wind erosion conditions at the Salton Sea will require compilation and analysis of existing meteorological data for the Salton Sea vicinity. Historical wind speed data needs to be evaluated in terms of the frequency and persistence of strong winds and the directional patterns that occur during episodes of strong winds. CIMIS data sets require transformation of the measured wind speed values into equivalent 10-meter height values so that comparisons can be made with other standard meteorological data sets.

There also is a need for baseline air quality data from locations near the shore of the Salton Sea, including hazardous air pollutants and chemical analyses of particulate matter. Specific instrumentation requirements were not discussed in detail. The panel did not try to identify the specific locations at which monitoring sites should be established, but it was considered important to establish multiple sites in close proximity to the Salton Sea shoreline. The size of the Salton Sea and the variability of shoreline conditions suggests that at least three and perhaps as many as six monitoring sites would be desirable. Monitoring sites should include meteorological data collection using instrument heights appropriate for use in dispersion models. The panel noted that it is important to get a reasonable amount of baseline data before water levels decline significantly. On-going monitoring would then be able to identify changes in air quality conditions that might occur gradually if water levels at the Salton Sea decline over a period of many years.

The panel also felt that there is a need for improved identification of local dust storm events. At present, there does not appear to be any systematic identification of the frequency or extent of localized dust storm events. A mechanism for reporting and mapping locations that generate visible fugitive dust events would assist in evaluating the nature and extent of fugitive dust problems at the Salton Sea. Once areas most susceptible to wind erosion are identified, the frequency and severity of blowing dust could be monitored with automated digital cameras activated by wind speed sensors. Panel member Ted Schade noted that electronic devices called Sensits and/or passive sand catch devices known as Cox sand catchers can be used on exposed areas to monitor the amount of material that moves across an area. A grid of these devices coupled with automatic cameras and human observers allows accurate mapping of erosion-prone areas. Trained observers can use GPS devices to map the boundaries of areas that show evidence of wind erosion after dust storm events.

LAGUNA SALADA STUDIES

Panel discussions concerning wind tunnel studies at the Salton Sea recognized the potential that current upland areas might not fully reflect conditions that would occur on exposed lakebed areas. One option for addressing such concerns is to study other locations that could serve as better surrogate areas than exising upland areas at the Salton Sea. The panel identified the Laguna Salada area of Mexico as a location that might be a reasonable surrogate for conditions that could develop on areas that would be exposed at the Salton Sea by a lowering of water levels. An initial reconnaissance study could be conducted in a relatively short time frame to better characterize the Laguna Salada area and to determine if it is a reasonable surrogate for conditions that might develop if water levels drop significantly at the Salton Sea. If the Laguna Salada area proves to be a reasonable surrogate area, portable wind tunnel studies could be conducted to identify potential wind erosion rates for various sediment conditions.

SALT MINERALOGY STUDIES

Although the panel does not expect the Salton Sea to develop the types of extensive salt deposits observed at Owens Lake and Mono Lake, some panel members felt it would be useful to develop a salt mineralogy model for the Salton Sea similar to that developed by the Saint-Amand study at Owens Lake (Saint-Amand, et al., 1986).

OPTIONS FOR MITIGATING POTENTIAL FUGITIVE DUST PROBLEMS

While it is premature to recommend any specific mitigation strategies before the scale and magnitude of wind erosion problems are better defined, the panel did discuss some general options for mitigating fugitive dust problems. A common requirement for all mitigation programs should be an adequate air quality monitoring system to help assess baseline conditions, the magnitude of air quality problems, and the effectiveness of mitigation programs. In addition, it may be possible to develop test sites for some mitigation options so that their feasibility can be evaluated before there are major changes in Salton Sea water levels.

Mitigation programs at Owens Lake emphasize three measures:

- placing gravel cover over highly erosive areas;
- creating shallow flooding of erosive areas; and
- vegetation establishment programs.

The vegetation establishment programs at Owens Lake generally require an initial step of leaching of salts from soil, followed by an active program of vegetation planting. Current plantings focus on salt-tolerant grasses, since they have proven to be more tolerant of sand blasting than have shrubby species.

The panel also discussed various other options that might be useful at the Salton Sea. If wind erosion problems do develop on areas near the shoreline of the Sea, it may be possible to establish a cemented sediment crust (calcite, gypsum, or sodium chloride salts) by spraying water from the Sea on the exposed sediment area. This type of measure would require testing to determine its overall feasibility, effectiveness, and durability.

Controlling access to localized high emission rate “hot spots” should be considered if disturbance to these areas appears to be a contributing factor in the resulting wind erosion condition. Access control may also be necessary in any locations where artificial vegetation establishment programs are attempted.

Although sand fences were not effective at Owens Lake, they might be more effective in the conditions that occur at some locations around the Salton Sea. Sand fences are being used as one control element for the Coachella Valley PM_{10} SIP.

Maintaining existing water levels at the Salton Sea would avoid the potential for creating new wind erosion problem areas. Some of the Salton Sea restoration project alternatives involve the creation of salt evaporation ponds. Placing those ponds on areas exposed by the lowering of Salton Sea water levels should be considered as one option for minimizing the extent of areas susceptible to wind erosion.

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ATTACHMENTS TO THE WHITE PAPER

Figure 1. The Salton Basin Showing the Maximum Extent of Historical Lake Cahuilla. This figure provides an excellent overview of topographic features in the Salton Basin and indicates the size of the area that has been influenced by sediments deposited in historic Lake Cahuilla. The Lake Cahuilla area appears to have been filled and desiccated four times within the last 2,000 years due to shifting of the Colorado River channel. Numerous smaller inundations occurred up until the formation of the current Salton Sea. Inflows occurred from the south, creating the New and Alamo Rivers. This figure also shows the general bathymetry of the Salton Sea. Major highways and place names for various locations also are included on this figure. Although communities in the Imperial Valley south of Brawley are not labeled, they are easily identified: the small community of Imperial and the larger community of El Centro along Highway 86 south of Brawley; Calexico at the U.S.-Mexico border; and Mexicali south of the border. The crossed runways of the El Centro Naval Air Facility are readily visible to the west of the Imperial - El Centro area, near the New River. The community of Holtville is visible east of El Centro near Highway 115. A portion of the Laguna Salada area of Mexico is readily visible just south of Mexico Highway 2, separated from the Lake Cahuilla area by the Sierra Cucapa range. Although water is present in Laguna Salada in this satellite photo, that area normally is desiccated.

Figure 2. Sediment Grain Size Distribution on the Floor of the Salton Sea. This figure uses color coding to indicate expected lakebed sediment texture conditions. The figure was generated using data from 73 sediment samples collected by LFR Levine-Fricke during December 1998 and January 1999. Standard USDA soil texture categories define clay as particles with sieve diameters smaller than 2 microns, silt as particles with sieve diameters between 2 and 50 microns, and sand as particles with sieve diameters between 50 and 2,000 microns.

Figure 3. Air Quality and Meteorological Monitoring Stations in the Salton Sea Area. This figure shows the locations of air quality monitoring stations and California Irrigation Management Information System (CIMIS) meteorological monitoring stations in the Coachella and Imperial Valleys. Different symbols are used to identify stations operated by different agencies: air quality monitoring stations operated by the South Coast AQMD; air quality monitoring stations operated by the Imperial Valley APCD; air quality monitoring stations operated in Mexico; and current CIMIS meteorological stations. Most monitoring stations are identified by their name. Space limitations preclude full identification of the multiple air quality monitoring stations in the Calexico and Mexicali areas. Note that some CIMIS meteorological stations are named for nearby communities, but are physically located in agricultural areas outside those communities. Some of the air quality monitoring stations include meteorological towers.

Figure 4. Dust Storm Photos Provided by the Salton Sea Science Office. This set of three photos illustrates a dust storm event observed by Salton Sea Science Office staff on the south shore of the Salton Sea. The source of the dust storm event was a mudflat area west of Davis Road. Photo one appears to show a thin deposit of salt minerals on the mudflat surface. All three photos illustrate that while the dust plume had a relatively shallow depth, it was at times quite dense.

Figure 5. Example PM_{10} Sampler Collection Efficiency Curves. The collection efficiency curves presented in this figure reflect a range of collection efficiency curves that meet the PM_{10} sampler certification requirements presented in 40 CFR 53.43. The certification requirements allow for a range of collection efficiency curves without defining absolute lower and upper bounds. The curves presented in this figure illustrate the general envelope of collection efficiencies likely to be encountered among current sampling devices.

Table 1. Comparison of Salton Sea, Owens Lake, Mono Lake, and Laguna Salada. This table summarizes a variety of physical features and historical events that may be relevant to the comparison of fugitive dust issues associated with the Salton Sea, Owens Lake, Mono Lake, and Laguna Salada. The table covers various geographic, meteorological, and hydrologic features of the basins, the hydrologic prehistory and recent history of the basins, water quality aspects of the historical and current lakes, and conditions that are related to fugitive dust generation in these basins. The purpose of this table is to tabulate both similarities and differences between conditions at the Salton Sea and those at Owens Lake, Mono Lake, and Laguna Salada. The table notes when relevant information on a topic is not readily available.

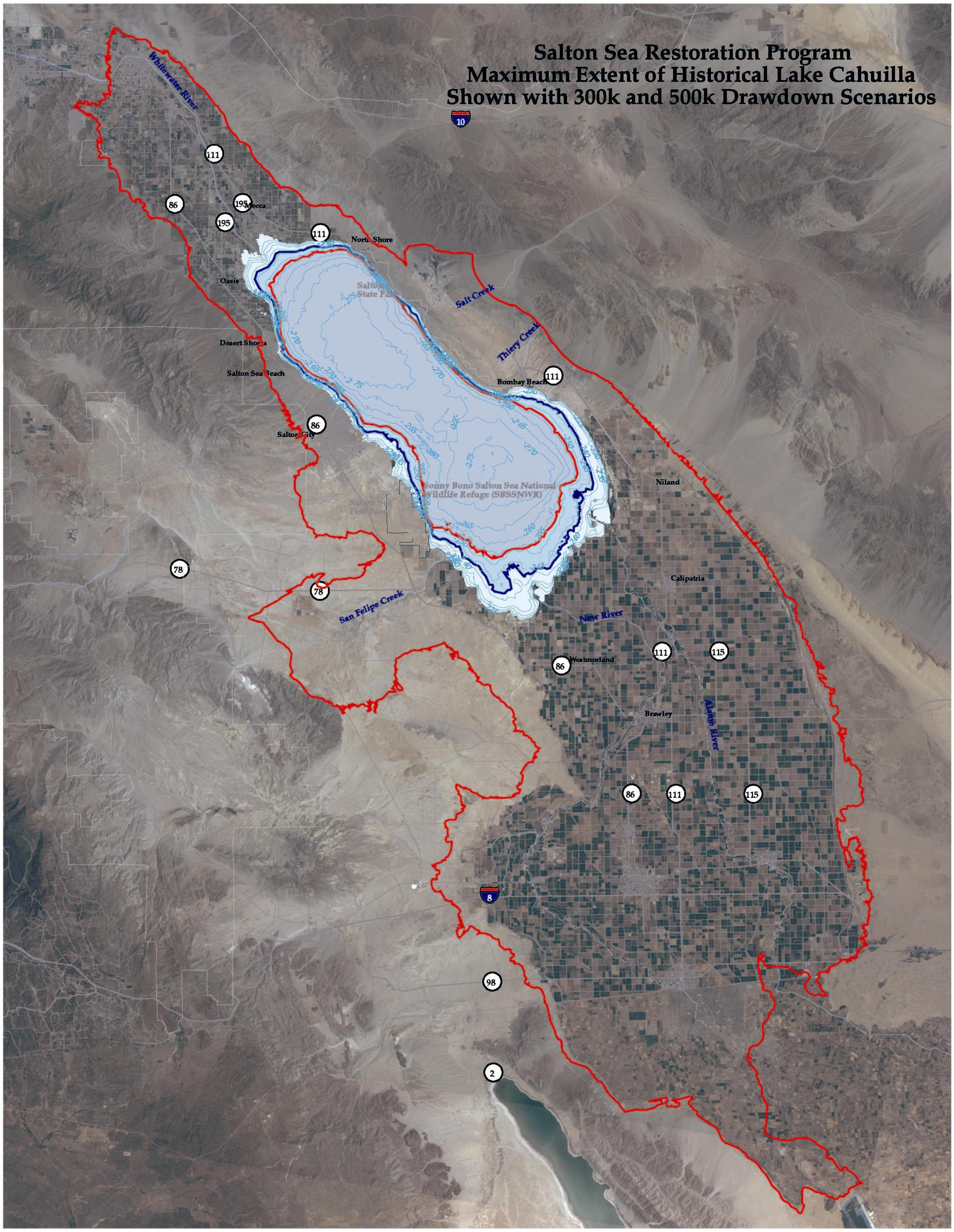
Salton Sea Restoration Program
Maximum Extent of Historical Lake Cahuilla
Shown with 300k and 500k Drawdown Scenarios
Whitewater River
10
111
86
195
Mecca
195
111
North Shore
Oasis
Salt Creek
Thiery Creek
Desert Shores
Salton Sea Beach
Bombay Beach
111
86
Salton City
Bonny Bono Salton Sea National
Wildlife Refuge (SBSSNWR)
Niland
78
78
San Felipe Creek
Calipatria
New River
111
115
86
Westmorland
Brawley
Alamo River
86
111
115
8
98
2

FIGURE 1

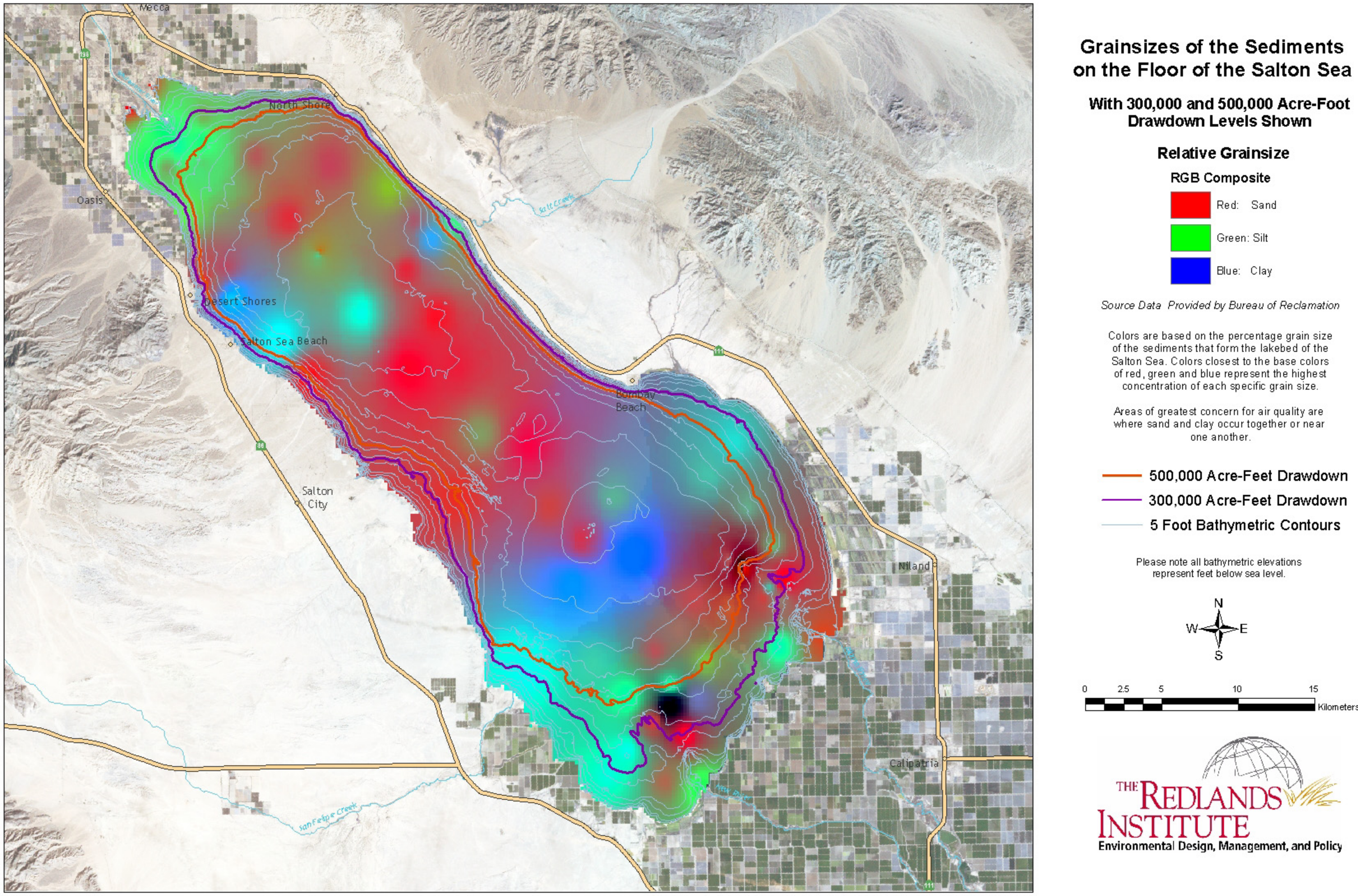
Grainsizes of the Sediments on the Floor of the Salton Sea
With 300,000 and 500,000 Acre-Foot Drawdown Levels Shown
Relative Grainsize
RGB Composite
Red: Sand
Green: Silt
Blue: Clay
Source Data Provided by Bureau of Reclamation
Colors are based on the percentage grain size of the sediments that form the lakebed of the Salton Sea. Colors closest to the base colors of red, green and blue represent the highest concentration of each specific grain size.
Areas of greatest concern for air quality are where sand and clay occur together or near one another.
500,000 Acre-Feet Drawdown
300,000 Acre-Feet Drawdown
5 Foot Bathymetric Contours
Please note all bathymetric elevations represent feet below sea level.
N
W
E
S
0
2.5
5
10
15
Kilometers
THE REDLANDS INSTITUTE
Environmental Design, Management, and Policy
Mecca
North Shore
Oasis
Desert Shores
Salton Sea Beach
Salton City
Bombay Beach
Niland
Calipatria
Salt Creek
San Felipe Creek

FIGURE 2.

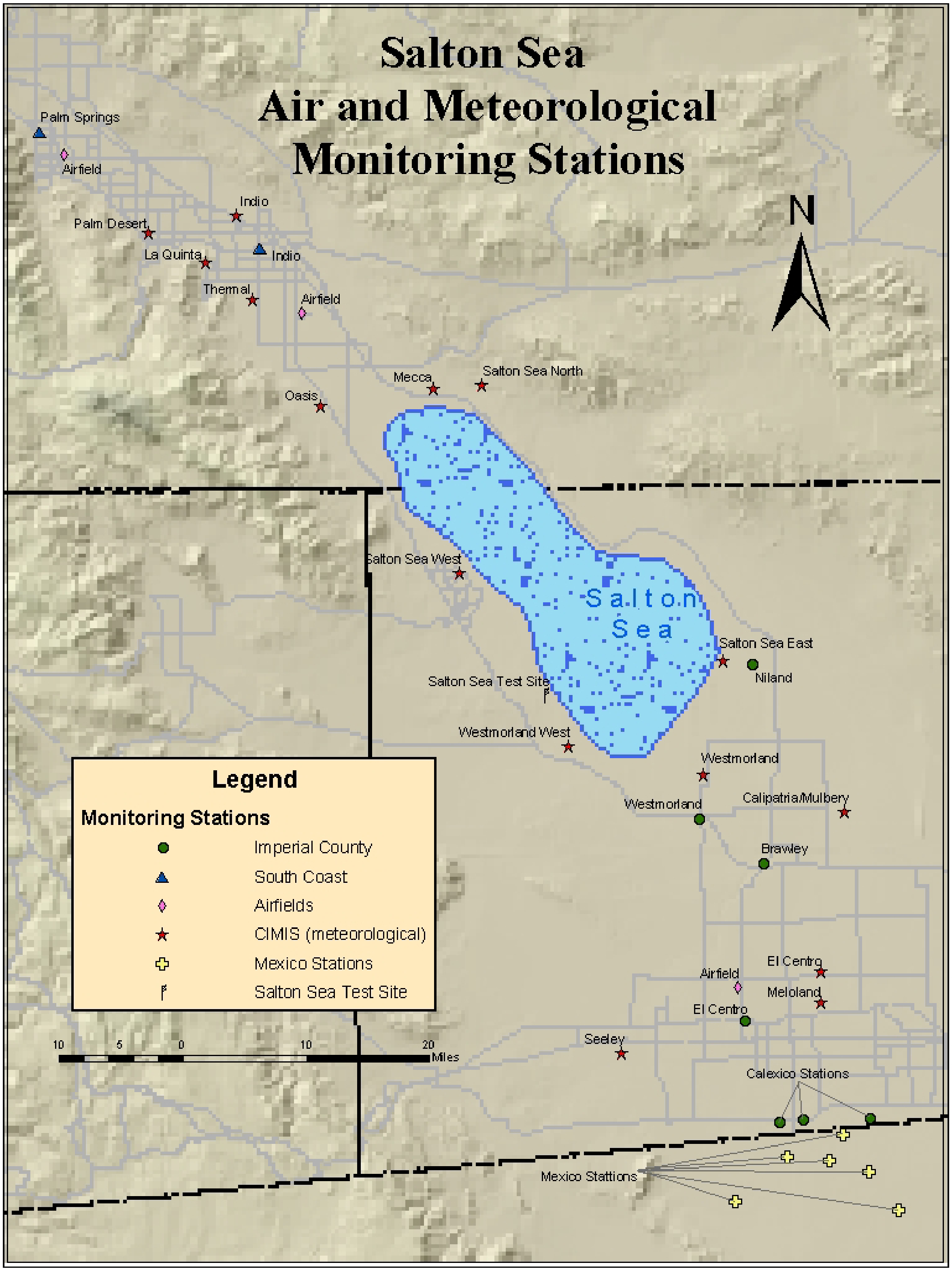
Salton Sea
Air and Meteorological
Monitoring Stations
N
Palm Springs
Airfield
Indio
Palm Desert
La Quinta
Indio
Thermal
Airfield
Mecca
Salton Sea North
Oasis
Salton Sea West
Salton Sea
Salton Sea East
Niland
Salton Sea Test Site
Westmorland West
Westmorland
Westmorland
Calipatria/Mulbery
Brawley
Airfield
El Centro
Meloland
El Centro
Seeley
Calexico Stations
Mexico Stattions
Legend
Monitoring Stations
Imperial County
South Coast
Airfields
CIMIS (meteorological)
Mexico Stations
Salton Sea Test Site
10
5
0
10
20
Miles

FIGURE 3.

FIGURE 4.

DUST STORM PHOTOS PROVIDED BY THE SALTON SEA SCIENCE OFFICE

(Note: brightness levels have been increased from those in the original image files, but no color or contrast changes have been made to the images.)

PHOTO 1: DUST STORM EVENT AT DAVIS ROAD (photo by Milt Friend)

PHOTO 2: DUST STORM EVENT AT DAVIS ROAD (photo by Milt Friend)

PHOTO 3: DUST STORM EVENT AT DAVIS ROAD (photo by Milt Friend)

FIGURE 5.

ALLOWABLE PM10 SAMPLER COLLECTION EFFICIENCIES: EXAMPLE LOWER AND UPPER BOUND CURVES

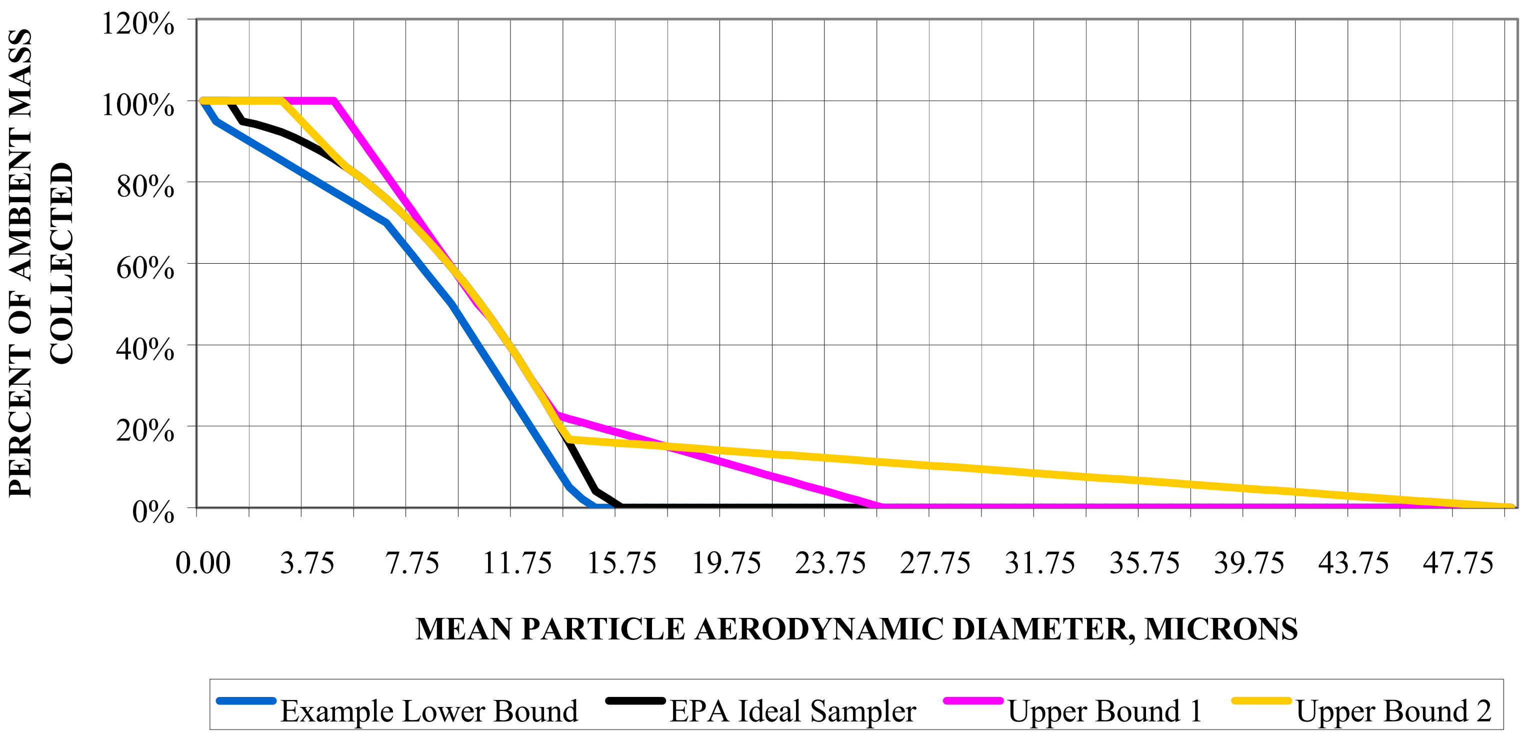

TABLE 1.

COMPARISON OF THE SALTON SEA TO OWENS LAKE, MONO LAKE, AND LAGUNA SALADA

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
General Weather Conditions for Basin	Annual rainfall about 3 inches per year in the lower Coachella Valley, 2.5 inches per year in the Imperial Valley. Desert pattern with important contributions from summer thunderstorms. Average evaporation rate about 69 inches per year. Average daily temperature range is 40 deg F to 71 deg F during winter, 72 deg F to 105 deg F during summer. Maximum hourly average wind speed (10-meter equivalent) was 36 mph in 1997 and 30 mph in 1998 at CIMIS station # 127 (Salton City).	Annual rainfall about 4 inches per year. Winter/fall pattern, some summer thunderstorms. Average pan evaporation rate data not readily available, but should be higher than at Mono Lake. Average daily temperature range is 23 deg F to 55 deg F during winter, 52 deg F to 92 deg F during summer. Maximum hourly average wind speed less than 40 mph in most years.	Strong rain shadow effect; annual rainfall about 12 inches per year on the western side of Mono Lake, about 6 inches per year on the eastern side. Winter/fall pattern, some summer thunderstorms. Average evaporation rate about 48 inches per year. Average daily temperature range is 21 deg F to 43 deg F during winter, 47 deg F to 81 deg F during summer. Maximum hourly average wind speed less than 35 mph for 1986 through 1991 data from Simis Ranch site.	Limited information. One source gives annual rainfall of less than 0.5 inch per year. Average annual temperature range given as 54 deg F to 120 deg F. Annual evaporation rate not readily available. No wind data readily available.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Lake Basin Prehistory	Prehistory of periodic lake formation and desiccation linked to shifting discharge point for the Colorado River. At least 4 lakes filled the Salton Basin to above sea level during the last 2,000 years. The last such lake (Lake Cahuilla) desiccated about 300 years ago. Numerous smaller lakes formed by Colorado River overflows after that. At least 8 smaller lakes reported between 1824 and 1904. Desiccation of temporary lakes sometimes left a salt pan in the low points of the basin. Present lake formed in 1905.	Ancient prehistory of lake formations and partial desiccations. Deep cores show no evidence of full desiccation. The largest Pleistocene period lake overflowed from Owens Valley into Indian Wells Valley (China Lake) and Searles Lake. Historic Owens Lake present from Pleistocene times until desiccation in 1926 (due to diversion of the Owens River).	Ancient prehistory without any evidence of full desiccation. The largest Pleistocene period lake overflowed from the Mono Basin southward into Adobe Valley and eventually into the Owens Valley.	Little readily available information, but probably a long history of periodic lake formation and desiccation due to overflows from the Colorado River. Also sometimes flooded by extreme high tides in the Gulf of California (before construction of Highway 5).

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Lake Basin Shape and Drainage Context	Elongated valley. Terminal basin for surface and groundwater flows. Current maximum depth about 51 feet. Current natural surface and groundwater flows insufficient to maintain a natural lake. Lake presently maintained by agricultural drainage flows.	Shallow depression. Terminal basin for surface and groundwater flows. Pre-diversion maximum depth about 50 feet (1872 and 1878 lake surface at 3,597 feet, visible strand line at 3,600 feet). Many references cite a depth of about 30 feet, based on lake surface at 3,579 feet in 1912.	Deep bowl. Terminal basin for surface and groundwater flows. Current maximum depth about 159 feet. Pre-diversion period maximum depth about 193 feet for lake at 6,417 feet.	Limited information. An elongated shallow basin within the delta of the Colorado River. In 1984, maximum depth of lake was 13 feet.
Current Lake Surface Elevation	-227 +/- Feet	3,553 +/- Feet	6,383 +/- Feet; overall trend of rising water levels.	Data not readily available, but appears to be below sea level.
Current Size of Lake	Current lake surface about 240,000 acres.	Lake surface of about 71,700 acres in 1878; this area is now the Owens Lake playa. Remnant brine pool normally varies in size from about 5,000 acres to 19,000 acres.	Lake presently covers about 45,000 acres (including islands). Pre-diversion lake covered about 54,700 acres.	In 1984, the lake covered 100,600 acres.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Natural Surface Inflows	Historically, periodic Colorado River inflows, mostly via the New River and Alamo River. Perennial inflow from Salt Creek. Seasonal local flows via the Whitewater River, New River, Alamo River, and numerous intermittent creeks.	Owens River and minor intermittent streams. Several Sierra Nevada streams flowed directly into Owens Lake prior to their diversion into the LA aqueduct.	Primary inflows from Sierra Nevada streams: Rush Creek, Lee Vining Creek, Mill Creek, and other smaller creeks. Various intermittent creeks around the northern, eastern, and southern shoreline.	Historically, periodic inflows from the Colorado River and extreme high tide flooding from the Gulf of California.
Artificial Surface Inflows	Significant agricultural drainage flows and some municipal wastewater flows via the New, Alamo, and Whitewater Rivers.	Minimal.	Minimal; some storm drainage inflows from the Lee Vining area.	Agricultural drains and a flood protection canal diverting Colorado River flows away from agricultural areas.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Groundwater Inflows	Presumably minimal under natural conditions, with greatest inflows from the Coachella Valley. Groundwater pumping has substantially reduced inflow from the Coachella Valley under current conditions. Canal seepage and agricultural irrigation may have augmented natural groundwater flows or created new groundwater flows in some areas, but total quantity appears to be small.	Several natural springs, some with artesian flow, some with geothermal influence. Groundwater inflow from the north along the Owens River channel. Other shallow groundwater inflows.	Several natural springs (mostly non-saline), some with artesian flow. Non-saline groundwater from the west and south. Saline groundwater from the north and east.	Data not readily available. Presumably minimal given climatic conditions.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Lake Water Chemistry	Saline and sulfurous, pH about 8.2 at present. Basically fresh water during initial formation of the present Salton Sea in 1905 – 1907, but relatively rapid conversion to saline conditions in subsequent decade (due partly to dissolving of sodium chloride salt deposits left from prior lake desiccations). Sulfate content has increased somewhat faster than chloride content since 1907, but chlorides still dominate in terms of molar equivalents. Other chemical influences mostly from agricultural chemicals. Selenium and some heavy metals in bottom sediments are a concern.	Saline, alkaline, and sulfurous. High phosphate levels. Prior to desiccation, dissolved sulfates and carbonates predominated over dissolved chlorides. Obvious influence from volcanic deposits in watershed (high arsenic, cadmium, boron, nickel, and lithium levels).	Saline, alkaline, and sulfurous, pH about 10. High phosphate levels. Obvious influence from volcanic deposits in watershed (high boron, fluoride, arsenic, strontium, and lithium levels).	Data not readily available. General descriptions imply saline and alkaline conditions, although temporary freshwater conditions possible at times of initial water body formation from Colorado River flood flows. Salt deposits left from prior desiccations probably cause rapid change to saline and alkaline conditions even when Colorado River flood flows are the initial water source.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Major Dissolved Salts	Sodium chloride, magnesium chloride, sodium sulfate. Very low dissolved carbonate and bicarbonate levels. Chloride salts dominate. On a molar equivalent basis, about 21% of dissolved salts are sulfate. Calcium carbonate deposition occurring. Calcium sulfate (gypsum) deposition suspected.	Sodium carbonate, sodium bicarbonate, sodium sulfate, sodium chloride. Prior to desiccation, dissolved carbonate, bicarbonate, and sulfate accounted for 54% of dissolved sodium salts on a molar equivalent basis. Calcium carbonate deposition under natural conditions in areas of calcium-rich water inflows.	Sodium carbonate, sodium bicarbonate, sodium sulfate, sodium chloride. Dissolved carbonate, bicarbonate, and sulfate account for 45% of dissolved sodium salts on a molar equivalent basis. Calcium carbonate deposition under natural conditions (including biologically mediated deposition of tufa formations).	Data not readily available. Given sources of water inflow, would expect both chloride and sulfate salts. Extent of sodium carbonate and sodium bicarbonate salts uncertain.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Lake Water Temperatures	Seasonal cycle of 15 to 30 deg C (59 to 86 deg F) in most years.	No data. Based on location and size, seasonal cycle probably had maximum temperatures below 25 deg C (77 deg F) prior to desiccation.	Seasonal cycle of 3 to 22 deg C (37 to 72 deg F) in the upper 2 meters. Lower temperatures at deeper levels. Ice formation rare because high salinity prevents density reversal as temperatures approach freezing, allowing coldest water to sink rather than rise to the surface.	Data not readily available. Undoubtedly warm water temperatures during periods when lake is present.
Pre-Interference Lake Salinity Levels	1907: 0.36% 1914: 1.14% 1929: about 3.3% 1960: about 3.6% 1970: about 3.9% currently: 4.4%	Fluctuations during 1866 to 1886: 6.5% - 10% Fluctuations during 1905 to 1912: 9.6% - 21.4% Owens River diverted in 1917.	1941: 4.8% Diversion of major creeks started in 1941.	No data.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Post-Interference Lake Salinity Levels	Draft EIS/EIR for the Salton Sea Restoration Project estimated the following salinities if inflow reductions reach 300,000 acre-feet per year between now and 2015: No Action: 7.5% in 2030 and 12.3% in 2060; Action Alternatives: 4.6% to 4.7% in 2030 and 3.5% to 4.0% in 2060. If inflows reduced by an additional 200,000 acre-feet per year after 2015: No Action: 17.8% in 2060; Action Alternatives: 3.8% to 4.5% in 2060.	Lake desiccated between 1917 and 1926. Saturated brine pool remains.	Salinity levels increased to about 9% in 1990. Salinity levels have declined somewhat since then due to reduced stream diversions and resulting increase in water inflows. Current salinity is about 8.1%.	Lakes at Laguna Salada appear to be temporary features under both natural conditions and with the limited human activities that have occurred so far (highway construction, flood flow diversion canal, etc.).

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Fate of Dissolved Salts with Water Diversion Interference	No indications that sodium salts would reach saturation within the next 50 years even if inflows reduced by up to 500,000 acre feet per year. Calcium carbonate and calcium sulfate (gypsum) deposition would continue. Dissolved sulfate levels would have to exceed 10% before sodium sulfate precipitation would be expected at a winter water temperature of 15 deg C, and chloride levels would have to exceed 25% for sodium chloride precipitation at that temperature. Saturation concentrations for sodium sulfate and sodium chloride are both above 25% at a summer water temperature of 25 deg C.	Salts reached saturation at various times starting in 1920. Sequential precipitation from lake waters produced horizontal and vertical zonation of salts as the lake desiccated. Sodium carbonate, sodium bicarbonate, and sodium sulfate salts precipitated on outer portions of playa and at bottom of salt beds before sodium chloride salts started to precipitate. Spatial patterns have been modified by partial dissolution and re-precipitation when playa is flooded by aqueduct breaks or runoff from major storms. Efflorescent salts continue to form from evaporation of mineralized groundwater.	No direct precipitation of sodium salts within Mono Lake as water levels declined after 1941. Salt deposits have formed on exposed shoreline in areas where mineralized groundwater previously entered the lake. Evaporative salt deposits also form in immediate shoreline areas where lake waters saturate the sediments. Physical characteristics of salt deposits imply a dominance by sodium carbonate, bicarbonate, and/or sulfate salts. No direct studies of chemical composition or mineralogy of salt deposits.	Desiccation of temporary lakes leaves salt deposits. No readily available data on extent, chemical composition, or mineralogy.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Extent of Current Salt Deposits	Limited information. No deposits that match the relative geographic scale of the salt deposits at Owens Lake or Mono Lake.	A substantial portion of the 70,000 acre playa is affected by permanent or seasonal salt deposits. Central salt deposits are not erosive.	About 5,000 acres of salt deposits above the lake shoreline in 1990; deposits covered about 35% of the area exposed by lowered lake levels.	Data not readily available.
Chemistry and Mineralogy of Current Salt Deposits	No good information. Distinctions between calcium carbonate, gypsum, and sodium salt deposits not always readily obvious when sodium salts are in a cemented, crystallized form. Expect most sodium salt deposits to be either sodium chloride or sodium sulfate salts, with sodium chloride salts expected to be dominant in most areas due to chemistry of lake waters. Deposits could vary seasonally.	Complex mixture of sodium carbonate, sodium bicarbonate, sodium sulfate, and sodium chloride salts. Complex double salts also present. Sodium carbonate, bicarbonate, and sulfate salts exhibit numerous mineralogical phases due to hydration and dehydration processes. Temperature and moisture dependent phase changes for sodium carbonate, bicarbonate, and sulfate salts, including transformation into anhydrous powdery forms.	Physical appearance of salt deposits, physical phase changes, and seasonality of dust storm events all suggest that the salt deposits include the same types of sodium carbonate, sodium bicarbonate, and sodium sulfate salts found at Owens Lake. Sodium chloride salts also likely to be present.	Data not readily available. Given sources of water inflow, would expect both chloride and sulfate salts. Extent of sodium carbonate and sodium bicarbonate salts uncertain.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Source of Current Salt Deposits	Limited information. Expect most deposits in immediate shoreline areas to be formed by surface evaporation of lake waters that saturate shoreline sediments. May be areas where lake waters pond from wave runup, then evaporate to leave salt deposits. Probably some areas where salt deposits form from evaporation of mineralized creek waters or from mineralized springs. Salt deposit formation from evaporation of mineralized groundwater possible, but not well documented. Geothermal resource facilities may be responsible for salt deposits in some areas.	Direct precipitation onto lakebed from desiccating lake accounts for most of the salt deposit in the remnant brine pool. Additional salts have formed and continue to form from evaporation of mineralized groundwater. Some salts dissolve and reform on a seasonal basis due to precipitation, surface runoff, or inflow from springs.	Most salt deposits formed by evaporation of mineralized groundwater after lake levels fell below the zone of groundwater inflow. Some deposits in immediate shoreline areas formed by surface evaporation of lake waters that saturate shoreline sediments.	Desiccation of temporary lakes.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Soil and Sediment Texture Conditions for Basin	Complete soil survey not available. Extensive lacustrine sediments as parent material result in deep deposits of clays and fine silts, especially in Imperial Valley portion of basin. Alluvial fan materials on east and west sides of basin contribute coarser grained sediments. Lacustrine deposits less extensive in Coachella Valley portion of basin.	Lacustrine basin origin for soils in much of the Owens Valley, with alluvial fan deposits along the sides of the valley contributing coarser grained sediments. Analysis of a deep core from the Owens Lake playa showed a dominance of interbedded fine silts and clays in the upper 640 feet, with the next 420 feet showing interbedded silts and fine sands. Occasional lenses of sands and gravels occurred in the upper 640 feet of the core, and were common in the next 420 feet of the core.	No complete soil survey available. Lacustrine basin origin for soils in much of basin, but complicated by extensive volcanic materials of relatively recent origin, including pumice sands, basalt sands, and volcanic tuff deposits. Sandy surface layers underlain by finer grained sediments in many areas. Some active sand dune areas.	Data not readily available. Origin as Colorado River delta deposits suggests silt and clay sediments intermixed with sandier sediments from larger flood inflow episodes. Probably typical sandy desert surface layers in areas around central playa area.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
General Assessment of Current Fugitive Dust Problems Attributable to Lake Vicinity	No good data on frequency, magnitude, duration, or geographic extent of fugitive dust events under current conditions.	Numerous dust storm events of variable magnitude and duration each year. Periodic massive dust storm events affecting locations outside the Owens Valley.	Several dust storm events of variable magnitude and duration each year, primarily affecting areas east and northeast of the lake within the Mono Basin.	Data not readily available.
Source Areas Contributing to Fugitive Dust	No good information on specific areas responsible for fugitive dust events. Whitewater River delta area may be responsible for some events. Various areas along the southern shoreline may be responsible for other events.	Approximately 35% of the playa (outer portions of the playa extending from the north end, around the eastern side, and down to the south end of the playa) categorized as the primary active dust source areas. Some limited areas beyond the playa where materials deposited by dust storm events can be re-suspended during subsequent events. Includes permanent and seasonal salt deposit areas plus other barren lakebed sediments.	Primary dust sources include areas showing permanent or seasonal salt deposits, diatomaceous sediments on the western side of Paoha Island, and perhaps some volcanic tuff deposits on Paoha Island.	Data not readily available.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Characterization of Major Fugitive Dust Components	No good data. Mixed sand and silt deposits in the Whitewater Delta area seem to be subject to wind erosion. One observed dust storm attributable to salt deposits that formed on the bed of an evaporation pond on the southern shoreline (sodium sulfate salts suspected). The evaporation pond has been used for disposal of geothermal brines, so the source of the salt might be geothermal brines rather than lake water or local groundwater.	No routine analysis of PM_{10} samples for chemical content. No routine sulfate, nitrate, chloride, or ammonium analysis of PM_{10} samples from stations near Owens Lake (analysis of samples from Lone Pine stopped in 1996). Some special analyses of PM_{10} filters. High PM_{10} events typically show high salt content (sodium, calcium, magnesium, potassium, bromine, carbonate, bicarbonate, sulfate, and chloride) and high soil mineral content (aluminum, sulfur, iron, titanium, molybdenum, manganese). Also arsenic, strontium, barium, lanthanum.	No routine analysis of PM_{10} samples for chemical content. No routine sulfate, nitrate, chloride, or ammonium analysis of PM_{10} samples from the Mono Basin. Salt, clay, and silt particles undoubtedly dominant, with diatomaceous sediments expected from events originating on the west side of Paoha Island. Fine pumice sands may also be a component.	Data not readily available.

FEATURE	SALTON SEA	OWENS LAKE	MONO LAKE	LAGUNA SALADA
Seasonality of Fugitive Dust Events	No good data on seasonality of existing fugitive dust events. Observed dust storm event along the south shore was during the spring.	Most events during winter, spring, or fall.	Most events during spring or fall. Some events during winter warm spells.	Data not readily available.
Geographic Scale of Dust Storm Events	No good data on geographic extent of existing fugitive dust events.	Dust storm events vary in scale from localized events to massive regional events affecting areas more than 100 miles downwind. Dust storms from Owens Lake have caused violations of federal PM_{10} standards 50 miles downwind.	Dust storm events vary in scale, but generally are confined within the Mono Basin. Most events affect the northern and eastern portions of the basin. Unusual for dust storm events to reach the southwestern portion of the basin near Lee Vining.	Data not readily available.