# Chapter 3H. Air Quality

This chapter addresses the issue of dust storms at Mono Lake generated from lakebeds exposed by lowering of the water surface. The chapter begins with a comprehensive discussion of air pollution terminology, air quality standards for particulate matter, and air quality management by state and federal authorities for readers not familiar with these subjects. The chapter then describes prediversion conditions, point-of-reference conditions, impact assessment methodology, and impacts and mitigation measures in conformity with the other resource chapters. Appendix N provides more detail on background information summarized here.

## BACKGROUND INFORMATION

### Air Pollution Terminology

The discussion of air pollution issues affecting Mono Lake requires an understanding of terms that have a technical meaning. At a general level, it is important to understand the distinction between air pollutant emissions and ambient air quality. In addition, the technical terms used to describe suspended particulate matter are especially relevant to air pollution issues affecting Mono Basin.

#### Emissions and Ambient Air Quality

The term "pollutant emissions" refers to the amount (usually stated as a weight) of specific compounds or materials introduced into the atmosphere by a source or group of sources. In practice, most pollutant emissions data are presented as "emission rates": the amount of pollutants emitted during a specified increment of time or during a specified increment of emission source activity. Typical measurement units for emission rates on a time basis include pounds per hour, pounds per day, or tons per year. Typical measurement units for emission rates on a source activity basis include pounds per thousand gallons of fuel burned, pounds per ton of material processed, and grams per vehicle mile of travel.

The term "ambient air quality" refers to the atmospheric concentration of a specific compound or material (amount of pollutants in a specified volume of air) actually experienced at a particular geographic location that may be some distance from the source of the relevant pollutant emissions. The ambient air quality levels actually measured at a particular location are determined by the interactions among three groups of factors:

- emissions: the types, amounts, and locations of pollutants emitted into the atmosphere;

- meteorology: the physical processes affecting the distribution, dilution, and removal of these pollutants; and

- chemistry: any chemical reactions that transform pollutant emissions into other chemical substances.

Ambient air quality data are generally reported as a mass concentration (e.g., micrograms per cubic meter [Fg/m$^3$] of air) or as a volume fraction (e.g., parts per million by volume). Concentrations of gaseous pollutants can be described in either mass concentration or volume fraction units. Particulate matter concentrations are almost always reported in mass concentration units (Fg/m$^3$), although particle count measurements (million particles per cubic foot) are used on rare occasions.

## Aerosols and Particulate Matter

Most people would interpret the term "aerosol" as indicating some type of liquid droplet or mist sprayed into the air. Similarly, most people would interpret the term "particulate matter" as implying a solid particle (such as dust or fly ash). Air pollution specialists, however, use the terms "aerosol" and "particulate matter" interchangeably; both terms can refer to either liquid or solid material suspended in the air. In many industrial applications the term aerosol implies small particle sizes with low settling rates; a similar connotation is sometimes evident in air pollution discussions.

Suspended particulate matter is sometimes characterized as a "dispersion aerosol" or a "condensation aerosol" according to the mechanism of formation. Dispersion aerosols are formed by mechanical abrasion (for solid particles), atomization (for liquid particles), or mechanical dispersion (for powdery solids). Condensation aerosols are formed by a phase change of gaseous compounds (e.g., by condensation of saturated or supersaturated vapors) or by chemical reactions of gases to form nonvolatile compounds.

## 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. One million microns constitute a meter, and 25,400 microns constitute an inch. Most people cannot distinguish individual particles with a maximum physical dimension smaller than 50 microns.

Most solid particles have fairly complex and irregular shapes, thus complicating any description of physical size. Because many different techniques are used to collect and analyze suspended particulate matter, it is often important to distinguish between the various technical terms and descriptions that are commonly used to describe particle size. Appendix N provides additional information on particle size terminology.

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.

In this assessment, particle size is generally described in terms of the "aerodynamic equivalent diameter" (which is the diameter of a sphere with a density of 1 gram per cubic centimeter that has the same terminal settling velocity in still air as the particle under consideration) but results of studies employing sieve diameters or other particle size terminology are also reported.

## Air Quality Standards for Suspended Particulate Matter

Both the State of California and the federal government have established ambient air quality standards for several different pollutants (Table 3H-1). For some pollutants, separate standards have been set for different time periods. Most standards have been set to protect public health. For some pollutants, standards have been based on other values (such as protection of crops, protection of materials, or avoidance of nuisance conditions).

State ambient air quality standards were first established in 1959 and federal ambient air quality standards were first established in 1970. The numerical values of various state and federal air quality standards have been changed several times. In addition, the state and federal ambient air quality standards for suspended particulate matter have undergone a significant change in definition from total suspended particulate matter (TSP) to inhalable particulates (generally designated as $PM_{10}$), as discussed in Appendix N. Both TSP and $PM_{10}$ are defined primarily by the equipment used to monitor compliance with the standards.

### Definition of $PM_{10}$

$PM_{10}$ represents a sampling of suspended particulate matter that approximates the extent to which suspended particles with aerodynamic equivalent diameters smaller than 50 microns penetrate to the lower respiratory tract (tracheobronchial airways and alveoli in the lungs). Particle size enters into the definition of $PM_{10}$ as a probability distribution, not as a precise particle size limit (see Appendix N for additional discussion).

As a practical matter, $PM_{10}$ can be defined as any particles collected by a certified $PM_{10}$ sampler. In more technical terms, the numerical values of the federal and state $PM_{10}$ standards are applied to suspended particulate matter collected by a certified sampling device having a 50% mass collection efficiency for particles with aerodynamic equivalent diameters of 9.5-10.5 microns and a maximum aerodynamic diameter collection limit smaller than 50 microns. Collection efficiencies are greater than 50% for particles with aerodynamic diameters smaller than 10 microns and less than 50% for particles with aerodynamic diameters larger than 10 microns. The physical dimensions of particles meeting the definition of $PM_{10}$ can vary considerably, depending on the combination of particle shape and density.

### Current $PM_{10}$ Standards

State and federal standards for suspended particulate matter have been set for two time periods: a 24-hour average and an annual average of the 24-hour values. The state $PM_{10}$ standards are:

- # 50 Fg/m$^3$ as a 24-hour average and

- # 30 Fg/m$^3$ as an annual geometric mean (a "geometric mean" is the nth root of the product of n observations).

The federal $PM_{10}$ standards are:

- # 150 Fg/m$^3$ as a 24-hour average and
- # 50 Fg/m$^3$ as an annual arithmetic mean.

## Air Quality Management

Air quality management responsibilities exist at local, state, and federal levels of government. Local air pollution control programs generally preceded statewide programs, which in turn preceded federal air pollution control programs (Stern 1982). California counties were authorized to regulate air pollution in 1947. State air pollution control programs were first established in California in 1957. The first federal air pollution control programs were authorized in 1965.

Federal Clean Air Act legislation in the 1970s resulted in a gradual merger of local and federal air quality programs, particularly industrial source air quality permit programs. Air quality management planning programs developed during the past decade have generally been in response to requirements established by the federal Clean Air Act. The California Clean Air Act of 1988 is producing additional changes in the structure and administration of air quality management programs in California.

Both the federal and California acts use similar terminology for designating areas that violate or comply with ambient air quality standards. Areas that violate air quality standards are designated as "nonattainment" areas for the relevant pollutants. Areas that comply with air quality standards are designated as "attainment" areas for the relevant pollutants. Areas of questionable status are generally designated as "unclassified" areas.

## The Federal Clean Air Act

The federal Air Pollution Control Act of 1955 declared air pollution to be a state responsibility, with federal responsibilities limited to research, education, training, and financial assistance to state programs. The 1963 federal Clean Air Act established a federal role for mediating interstate disputes. The federal role was expanded in 1965 with Congressional authorization for uniform federal emission standards for motor vehicles.

The 1970 federal Clean Air Act amendments greatly expanded the federal role in air pollution control issues, establishing several regulatory programs:

- adoption of national ambient air quality standards,
- approval of state plans to achieve and maintain the national ambient air quality standards,
- adoption of emission standards for motor vehicles,
- adoption of emission standards for major new industrial facilities,
- adoption of emission standards for hazardous air pollutants, and
- approval of construction permits for major new industrial facilities.

The 1977 and 1990 amendments to the Clean Air Act revised and expanded some of the regulatory programs and added a new program involving operating permits for major industrial facilities.

The federal Clean Air Act requires each state to develop, adopt, and implement a plan (state implementation plan) to achieve, maintain, and enforce federal air quality standards throughout the state. These plans must be submitted to and approved by the U.S. Environmental Protection Agency (EPA). In California, local councils of governments and air quality management agencies have had the primary responsibility for developing and adopting elements of the state plan.

Deadlines for achieving the federal air quality standards have been changed several times since the original July 1, 1975 deadline set by the 1970 Clean Air Act.

All areas initially designated as nonattainment for $PM_{10}$ will be classified as moderate nonattainment areas with a December 31, 1994 attainment deadline. Areas subsequently classified as moderate $PM_{10}$ nonattainment areas will have up to 6 years to achieve the federal $PM_{10}$ standards. EPA has discretion to grant up to two 1-year extensions of the initial attainment deadline for moderate $PM_{10}$ nonattainment areas.

Area that cannot meet the initial or extended attainment deadline will be reclassified as serious $PM_{10}$ nonattainment areas. The attainment deadline for serious $PM_{10}$ nonattainment areas must be no later than 10 years from the date on which the area was identified as nonattainment for $PM_{10}$. EPA has discretion to grant one attainment deadline extension of up to 5 years for serious nonattainment areas.

Section 188(f) of the Clean Air Act also provides that EPA has the discretion to waive $PM_{10}$ attainment deadlines for areas where "nonanthropogenic" sources of $PM_{10}$ contribute significantly to the violations of the $PM_{10}$ standard. Nonanthropogenic emission sources are those natural sources of emissions that are not influenced directly or indirectly by human activity. Examples of nonanthropogenic sources include volcanic eruptions, salt spray in marine areas, smoke from natural forest fires, and windblown dust in undisturbed natural areas.

Anthropogenic emission sources, on the other hand, include any sources with emissions influenced directly or indirectly by human activity. Stensvaag (1991) notes that the U.S. House of Representatives committee report on the Clean Air Act amendments cites dust from the exposed lakebeds of Owens Lake and Mono Lake as examples of anthropogenic emissions because dust storms from these areas are ultimately caused by the human activity of diverting water from streams feeding these lakes.

Federal $PM_{10}$ nonattainment areas in California include:

- the San Joaquin Valley,
- the South Coast Air Basin,
- the Imperial Valley area,
- the Searles Valley area,
- the Coachella Valley area,
- the Mammoth Lakes area (Mono County), and
- the Owens Valley area (Inyo County).

In addition, EPA has identified Sacramento County and San Bernardino County as areas that should receive nonattainment status for $PM_{10}$; formal designation procedures have not yet been completed.

On January 8, 1993, EPA reclassified the San Joaquin Valley, South Coast Air Basin, Coachella Valley, and Owens Valley from moderate to serious $PM_{10}$ nonattainment areas. Mono Basin has not been formally designated as a federal $PM_{10}$ nonattainment area; however, available monitoring data suggest that a federal $PM_{10}$ nonattainment designation may be warranted. EPA action to designate Mono Basin as a federal $PM_{10}$ nonattainment area is expected during 1993.

**The California Clean Air Act of 1988**

Responsibility for air quality management programs in California is divided between the California Air Resources Board (ARB), as the primary state air quality management agency, and air pollution control districts (or air quality management districts) as the primary local air quality management agencies. The Great Basin Unified Air Pollution Control District (GBUAPCD) has jurisdiction in Mono and Inyo Counties.

The California Clean Air Act of 1988 establishes a state-level air quality planning process that generally parallels the federal process. The California Clean Air Act, however, focuses on attainment of the state ambient air quality standards, which often are more stringent than the comparable federal standards.

The act specifies that districts shall adopt and enforce rules and regulations to achieve and maintain the state and federal ambient air quality standards and may adopt and implement regulations to reduce or mitigate emissions from indirect and areawide sources of air pollution. The act requires that the state air quality standards be achieved as expeditiously as practicable, but does not set precise attainment deadlines.

Districts must prepare an air quality attainment plan if state air quality standards for carbon monoxide, sulfur dioxide, nitrogen dioxide, or ozone are notated with the district. No locally prepared attainment plans are required for areas that violate the state $PM_{10}$ standards.

The California Clean Air Act differs somewhat from the federal Clean Air Act by emphasizing the control of "indirect and areawide sources" of air pollutant emissions. The California act gives local air pollution control districts explicit authority to develop "area source and indirect source control programs" but it does not define indirect sources, areawide sources, or area sources.

Common practice in the air pollution field would define "area sources" as outdoor, unconfined sources of volatile or windblown emissions, and "areawide sources" as small stationary or mobile emission sources that occur throughout a large geographic area and that are not presently regulated or subject to permit requirements on an individual basis.

Most of the air quality planning provisions of the California Clean Air Act address attainment of the ozone, carbon monoxide, nitrogen dioxide, and sulfur dioxide standards. But the act also specifies that "[n]othing in this chapter restricts the authority of the state board or a district to adopt regulations to control suspended particulate matter, visibility reducing particles, lead . . . ." (California Health and Safety Code Section 40926).

Section 4213 of the California Health and Safety Code provides that the GBUAPCD "may require the City of Los Angeles to undertake reasonable measures, including studies, to mitigate the air quality impacts of its activities in the production, diversion, storage, or conveyance of water. . . . The mitigation measures shall not affect the right of the city to produce, divert, store, or convey water."

ARB has formally designated the Great Basin Valleys Air Basin (Mono and Inyo Counties) as being in violation of the state $PM_{10}$ standards. Two types of $PM_{10}$ problems are recognized in this air basin (California Air Resources Board 1991): extremely high 24-hour $PM_{10}$ concentrations in Inyo County due to windblown soil and salt, much of which originates in the Owens Valley, and high winter concentrations of $PM_{10}$ in the Mammoth Lakes area, due in part to residential wood combustion.

As described in a subsequent portion of this chapter, available monitoring data indicate that the Mono Lake area also experiences periodic violations of the state $PM_{10}$ standards.

## PREDIVERSION CONDITIONS

### Sources of Information

No ambient air quality monitoring was conducted in Mono Basin before 1979. Consequently, no quantitative data exist that describe air quality conditions in Mono Basin under prediversion conditions. The major existing air quality problem in Mono Basin is produced by windblown particulate matter. Because suspended particulate matter in Mono Basin is derived primarily from barren or sparsely vegetated lands, historical accounts of conditions in Mono Basin allow a qualitative assessment of prediversion air quality conditions.

The most useful historical account of conditions in Mono Basin comes from a reprint of an 1889 report of topographic and geologic investigations undertaken in summer 1883 (Russell 1984). Russell's account includes detailed descriptions of topographic features and visual conditions, as well as extensive geologic interpretations. Proper interpretation of Russell's observations is greatly improved by modern estimates of historical lake elevations. Although Russell estimated the 1883 elevation of Mono Lake as 6,380 feet, the lake was actually at an elevation of about 6,410 feet (Stine 1980, LADWP 1987).

Historical aerial photographs of Mono Lake from 1930 and 1940 provide additional perspective on interpretations drawn from the historical literature.

## Historical Information about Mono Basin Conditions

### Historical Written Accounts

As discussed in Appendix N, several early visitors referred to the presence of white crusty deposits at Mono Lake during the late 1800s and early 1900s (Russell 1984, Browne 1961, Mining and Scientific Press 1865, Chase 1911). Although many of the writers referred to the deposits as "alkali", a careful examination of these accounts indicates that almost all the references are to tufa and other calcium carbonate deposits.

I. C. Russell's report of geological studies conducted in the early 1880s contains extensive discussions of tufa deposits around Mono Lake (Russell 1984). The report also mentions the presence of active sand dunes and windblown foam produced by whitecaps on the lake. Russell's report is one of the few documents from the prediversion period that distinguishes between tufa deposits and salt deposits. Russell noted the presence of efflorescent salt deposits in only two situations: in the exposed cavities of partially submerged tufa crags and in cavelike recesses in cliffs at the water's edge, especially on Paoha Island. Russell noted that the efflorescent salts were primarily sodium carbonates and sodium sulfates, in contrast to the calcium carbonate of tufa deposits, and that they form on porous substrates exposed to the air as capillary action draws saline water to the surface.

### Aerial Photographs from 1930 and 1940

Historical aerial photographs of Mono Lake (Stine pers. comm.) provide additional evidence that efflorescent salt deposits were limited under prediversion conditions. The elevation of Mono Lake was about 6,420 feet in 1930 and about 6,417 feet in 1940. Photographs from 1929 and 1930 are somewhat difficult to interpret as there appears to be some snow on the ground. The photographs from 1940 are easier to evaluate.

Both the 1930 and 1940 photographs show limited amounts of efflorescent salt deposits in two situations: very narrow fringes of efflorescent salts along the edges of some ponds (lagoons) near the lakeshore; and scattered small patches of salt among partially vegetated sand dunes between Bridgeport Creek and Cottonwood Creek, mostly south of the present location of Highway 167. No efflorescent salt is visible in the 1930 or 1940 aerial photographs on the relatively narrow strip of barren sand bordering the north or east shores of the lake.

Ponds with a narrow fringe of efflorescent salt were present near DeChambeau Creek in 1930 but had drained without leaving salt deposits in 1940. Ponds east of the present location of Ten Mile Road were present with narrow fringes of efflorescent salt in both 1930 and 1940.

All other locations showing efflorescent salt deposits in the 1930 and 1940 aerial photographs represent low spots between partially vegetated sand dunes. Recent aerial photographs show only a few small salt deposits in the sand dune and former pond areas, with the largest patches occupying parts of the former ponds east of Ten Mile Road.

## Conclusions Regarding Prediversion Air Quality Conditions

Two conditions are notable by their absence in Russell's descriptions of conditions at Mono Lake in 1883: the absence of any accounts of windblown dust, sand, or salt and the absence of any description of significant shore zone efflorescent salt deposits.

Russell was obviously aware of wind erosion processes, as evidenced by his description of drifting sand dunes and windblown foam from the lake on windy days. The description of windblown foam also demonstrates that Russell was present during periods of strong winds. Thus, it is significant that Russell made no mention of blowing salt, sand, or dust.

It is also significant that Russell made little mention of efflorescent salt deposits around the lake, noting only small isolated deposits inside tufa towers and on portions of the shore of Paoha Island. Unlike other early observers, Russell clearly distinguished tufa formations from efflorescent salts, even noting the chemical differences between them. Russell's attention to chemical and mineralogical details makes it unlikely that he found but failed to discuss extensive salt deposits.

The apparent absence of shore zone efflorescent salt deposits would be puzzling if Russell's estimate of the 1883 elevation of Mono Lake (6,380 feet) had been accurate. Present day efflorescent salt deposits occur above the 6,380-foot elevation, with significant salt deposits up to the 6,390-foot elevation. Stine (1980) notes that the Negit Island benchmark left by Russell's party was relocated in 1950 and measured at an elevation of 6,410 feet, 30 feet higher than Russell's estimate of the lake's 1883 elevation.

Available evidence concerning historical lake elevations (see "Prediversion Conditions" in Chapter 3A, "Hydrology") makes it clear that Russell was viewing Mono Lake under conditions typical of the 1870-1890 period. Conditions in 1883 represented lake levels lower than any observed between 1895 and 1950.

Stine's analysis of historical lake levels provides convincing evidence that Mono Lake seldom dropped below 6,400 feet under prediversion conditions. Historical aerial photographs and the present distribution of exposed substrates and efflorescent salt deposits suggest that there were few exposed areas subject to severe wind erosion under prediversion conditions.

The limited salt deposits visible in 1930 and 1940 aerial photographs (when the lake elevation was 6,417-6,420 feet) may have been largely absent when Russell visited Mono Basin in 1883 with the lake at 6,410 feet. A drop of 3 feet in lake elevation between 1930 and 1940 eliminated the ponds and fringing salt deposits near DeChambeau Creek. Even if present during most of the prediversion period, the salt deposits between Bridgeport and Cottonwood Creeks would have been partially sheltered from wind erosion by the surrounding sand dunes. The small size and scattered distribution of these salt deposits would not have generated the type of large-scale dust episodes that have occurred in recent years.

While Russell's reference to active sand dunes suggests that localized episodes of blowing silt or sand must have occurred, the available evidence suggests that major dust storm events were rare under prediversion conditions. The few dust storm events that did occur under prediversion conditions would have been dominated by silt, clay, and sand particles with only small quantities of salt particles from interstitial salts and water spray off the lake.

## ENVIRONMENTAL SETTING

### Sources of Information

Temperature and precipitation data for Mono Lake are available in monthly and annual reports published by the National Climatic Data Center. Additional meteorological data are available from LADWP for the Cain Ranch and from the GBUAPCD for Lee Vining and Simis Ranch. The GBUAPCD data for Lee Vining and Simis Ranch provide most of the available information on wind patterns in Mono Basin. Figure 3H-1 shows the locations of the major meteorological and air quality monitoring sites in the Mono Lake area.

Early studies of air quality conditions in Mono Basin were conducted by researchers at the UC Davis (Kusko et al. 1981, Kusko and Cahill 1984, Cahill and Gill 1987). Useful summaries of more recent air quality data collected by the GBUAPCD are published in quarterly and annual data reports by ARB. Additional air quality data are available from GBUAPCD files.

Data from direct measurements of TSP and $PM_{10}$ concentrations are supplemented by photographic data provided by LADWP. LADWP staff have maintained a photographic record of visible dust events since 1980. These photographic data provide a very complete record of conditions at about 2 p.m. each day over an 11-year period.

No comprehensive studies of the physical, chemical, or mineralogical characteristics of erodible substrates, TSP samples, or $PM_{10}$ samples from Mono Basin have been performed. Some of the limited analyses that have been performed are discussed briefly in Appendix N.

No studies of the mineralogy or chemical reactions of salt deposits found in Mono Basin have been performed. Studies conducted in the Owens Valley (Alderman 1985, Smith and Friedman 1986, Smith et al. 1987, Saint-Amand et al. 1986) provide the basis for discussions presented in this document.

No comprehensive studies of wind erosion processes in Mono Basin have been performed. The physics of wind erosion processes have been widely studied, however (see Chepil 1958, Warren 1979, Gillette 1980, World Meteorological Organization 1983, and Zobeck 1991).

Efflorescent salt deposits subject to wind erosion in Mono Basin have been mapped by the staff of GBUAPCD; mapping was based on lakeshore foot transects. Efflorescence and its relation to groundwater in Mono Basin has been studied by Rogers and Dreiss (1991), Balance Hydrologics (1992), and, mostly recently, by SWRCB consultants (Chapter 3C, "Vegetation").

Inferences about the sources and susceptibility of sediments to wind erosion can be derived from the geological literature of Mono Basin (Lajoie 1968; Stine 1992, 1993; U.S. Soil Conservation Service n.d.; U.S. Forest Service n.d.). No soil survey of the relicted lands exists; some USFS and U.S. Soil Conservation Service (SCS) soil mapping for the near-lake environment exists, but it is in preliminary, unreconciled form and is not based on field sampling.

GBUAPCD has conducted portable wind tunnel studies of particulate emission rates in several locations on the northeastern relicted lands. These data are useful in modeling dust emissions from monitored wind speed data (see "Assessment Methodology" section of this chapter) although no measurements of emission rates of powdery efflorescent salts were made.

## Mono Basin Meteorology

Temperature, precipitation, and wind patterns affect the condition of substrate surfaces that may be susceptible to wind erosion, and wind is the driving energy of the dust storm phenomenon.

### Temperature Patterns

Temperature data from the Mono Lake monitoring station show a typical high desert annual pattern: cold winters and cool summers (Figure 3H-2). Data from the Cain Ranch indicate temperatures about 5° cooler than those recorded at Mono Lake (LADWP 1987). Annual mean temperatures are about 48°F at Mono Lake and 43°F at Cain Ranch. Most of the difference in temperature patterns between Cain Ranch and Mono Lake is attributable to the moderating influence of the lake (LADWP 1987).

## Precipitation Patterns

LADWP (1987) presented a precipitation contour map for Mono Basin, suggesting that precipitation averages about 10 inches per year at the western side of Mono Lake and about 6 inches per year at the eastern side of Mono Lake.

Long-term records of precipitation patterns are available from two monitoring sites: Mono Lake (at the northwest corner of the lake) and Cain Ranch (along Rush Creek just upstream from U.S. Highway 395 [U.S. 395]). Average monthly precipitation rates based on a 51-year data record for Cain Ranch show a typical Great Basin pattern of significant precipitation in every month, but with winter (November-March) storm precipitation 3.4 times as great as for summer thunderstorms (Figure 3H-3). Precipitation rates over that period averaged nearly 11 inches per year. The variation in annual precipitation at Cain Ranch is substantial, ranging from 3 to 20 inches (Figure 3H-4). For the 51-year period shown, the longest sequence of wet years (from 1977 to 1983) was followed by the longest sequence of dry years.

Precipitation data have been collected for short periods at a few other locations in Mono Basin. Measurements on the east side of the lake in the Warm Springs area indicate an average precipitation rate of 5.7 inches per year for a 10-year period compared to 12.7 inches per year at the Cain Ranch (1975-1985) (LADWP 1987). Data collected by the GBUAPCD at Lee Vining indicate 8.0 inches of precipitation in 1989 and 9.7 inches in 1990, compared to 5.1 and 6.2 inches in the same period at the Cain Ranch. The data available suggest that precipitation amounts along the west shore of Mono Lake are somewhat higher than precipitation amounts measured at Cain Ranch and that precipitation at the east side of the lake is much lower.

## Wind Patterns

The GBUAPCD collects wind pattern data at meteorological stations located in Lee Vining and at Simis Ranch (Figure 3H-1). Hourly average data from late 1985 through 1991 have been analyzed for this EIR. (Wind speed data are missing for the early part of 1986 at both stations, although wind direction data were recorded.) These studies have not attempted to validate the wind data records provided by GBUAPCD or to reconcile instances of extreme discrepancy in concurrent wind speed data for the Lee Vining and Simis Ranch monitoring sites.

**Wind Patterns at Lee Vining**. As shown in Figure 3H-5, nighttime and early morning winds at Lee Vining are predominantly from the south-southwest. Starting at about sunrise, the winds swing rapidly around through the west to the north. Northerly winds predominate into the early afternoon, when the wind direction begins a gradual swing back through the west to the south-southwest.

Wind speeds at Lee Vining typically drop through the night and early morning hours, reaching a minimum by 7 a.m. Wind speeds increase steadily through the early afternoon hours with the highest wind speeds persisting through the evening hours. Maximum wind speeds typically occur between 4 and 5 p.m. Wind speeds begin to drop after about 7 p.m.

Modest seasonal differences in wind speed are evident at Lee Vining (Table N-1 in Appendix N). Average wind speeds are highest during spring (night and morning hours) and summer (afternoon and evening hours). Very strong winds can occur during any season, although the highest wind speeds generally occur during fall or winter months. The data also suggest some minor seasonality in wind direction patterns.

**Wind Patterns at Simis Ranch**. As shown in Figure 3H-6, nighttime and early morning winds at Simis Ranch are predominantly from the north. Starting at about sunrise, the winds swing rapidly around through the east to the south. Onshore, southerly winds predominate from midmorning until midafternoon, when the wind direction begins a gradual swing through the west and back to the north.

Wind speeds at Simis Ranch typically drop through the night and early morning hours, reaching a minimum by 7-8 a.m. Wind speeds increase steadily through the afternoon hours. Maximum wind speeds typically occur in the 3-5 p.m. period. Wind speeds begin to drop after about 6 p.m.

Modest seasonal differences in wind speed are evident at Simis Ranch (Table N-2 in Appendix N). Average wind speeds are highest during spring. Very strong winds can occur during any season, although the highest wind speeds generally occur during spring or fall months. The data also suggest some minor seasonality in wind direction patterns.

**Comparison of Lee Vining and Simis Ranch Wind Patterns**. Lee Vining and Simis Ranch experience very different wind direction patterns. Wind directions are seldom in phase at Lee Vining and Simis Ranch. The differences in wind direction appear to be related to topographic features, with lake effects and upslope/downslope winds exerting strong influences. Lee Vining experiences higher peak wind speeds than does Simis Ranch, although average wind speeds at Lee Vining and Simis Ranch are similar.

## Mono Basin Air Quality Conditions

### Monitoring Studies by UC Davis

Early studies of air quality conditions in the Owens Valley and Mono Basin were conducted by researchers at the UC Davis. The instrumentation used for those studies and the duration of sample collection episodes preclude direct comparison of the UC Davis data with state or federal ambient air quality standards (see Appendix N).

The UC Davis data suggest that $PM_{10}$ concentrations above the current state 24-hour standard probably occurred in Lee Vining several times during 1980. The 7-day average $PM_{15}$ concentration of

73.7 $\mu g/m^3$ during the week of June 2-9, 1980 must have included episodes with 24-hour $PM_{10}$ concentrations above the current state standard of 50 $\mu g/m^3$.

## GBUAPCD Monitoring Data

**Summary of Monitoring Data**. TSP and $PM_{10}$ monitoring data for 1979-1991 in the Mono Lake vicinity are summarized in Table 3H-2. No violations of state or federal annual TSP standards have been recorded in Mono Basin. The state 24-hour TSP standard was exceeded at one or more locations in 1979, 1980, and 1982. The federal 24-hour TSP standard was exceeded at one or more locations in 1979, 1980, 1982, and 1985. As noted previously, state TSP standards were replaced by $PM_{10}$ standards in 1983 and federal TSP standards were replaced by $PM_{10}$ standards in 1987.

$PM_{10}$ monitoring did not begin in Mono Basin until 1986. $PM_{10}$ monitoring at Simis Ranch started in October 1986; $PM_{10}$ monitoring at Lee Vining started in March 1988. No violations of state or federal annual $PM_{10}$ standards have been recorded in Mono Basin. The state 24-hour $PM_{10}$ standard was exceeded at the Simis Ranch monitoring site in 1987, 1988, 1989, 1990, and 1991. The state 24-hour $PM_{10}$ standard was exceeded at the Lee Vining monitoring site in 1991. The federal 24-hour $PM_{10}$ standard was exceeded at the Simis Ranch monitoring site in 1989.

Table 3H-2 does not include data from 1992 because monitoring data for the last half of 1992 have not yet been published. Data for the first 6 months of 1992 reveal two exceedances of the state 24-hour $PM_{10}$ standard and one exceedance of the federal 24-hour $PM_{10}$ standard at Simis Ranch.

Table 3H-2 does not provide a complete summary of all TSP or $PM_{10}$ data collected by the GBUAPCD. A limited amount of additional TSP data was collected by the GBUAPCD at the Binderup site (near Simis Ranch) in 1979 and 1980; some of these additional data represent sampling periods longer than 24 hours. Limited $PM_{10}$ sampling was conducted at the base of Cedar Hill in the eastern end of Mono Basin during 1989-1991. In addition, $PM_{10}$ data collected with portable samplers at Warm Springs when dust storms were anticipated are not included in Table 3H-2.

Table 3H-2 includes much of the TSP data collected at the Binderup site. The additional TSP data from the Binderup site do not indicate any TSP concentrations higher than those reported in Table 3H-2. The Cedar Hill site $PM_{10}$ data did not indicate any exceedances of the state or federal 24-hour $PM_{10}$ standards.

Monitoring data from the Warm Springs sampling program are summarized in Table 3H-3. Some of the data collected at Warm Springs involved sampling periods of less than 24 hours. Additionally, some of the 24-hour sampling at Warm Springs was not done on a midnight-to-midnight cycle. Nevertheless, the data suggest that the state 24-hour $PM_{10}$ standard was exceeded at the Warm Springs monitoring site at least once during 1988, at least twice during 1990, at least three times during 1991, and at least three times during the first 6 months of 1992. The Warms Springs monitoring data also indicate that the federal

24-hour $PM_{10}$ standard was exceeded at least once in 1988, at least one in 1990, at least twice in 1991, and at least once during the first 6 months of 1992. These data show that particulate concentrations are usually higher at Warm Springs than at Simis Ranch.

**Correlations between TSP and $PM_{10}$ Values**. TSP and $PM_{10}$ concentrations have been monitored concurrently at the Simis Ranch site since 1990. Figure 3H-7 illustrates the relationship between paired TSP and $PM_{10}$ samples. On average, $PM_{10}$ concentrations are about 47% of the concurrent TSP concentration. The observed relationships between these two parameters are discussed further in Appendix N.

**Seasonality of High $PM_{10}$ Concentrations**. $PM_{10}$ monitoring data from Simis Ranch indicate a dual seasonality of high $PM_{10}$ concentrations. Figure 3H-8 shows the maximum $PM_{10}$ concentrations recorded at the Simis Ranch monitoring station according to month. Figure 3H-9 shows the monthly frequency of Simis Ranch $PM_{10}$ samples exceeding the state 24-hour standard.

$PM_{10}$ concentrations above the state 24-hour standard of 50 Fg/m$^3$ have been recorded primarily during spring (March, April, or May) or fall (September, October, or November) at Simis Ranch. No exceedances of the state 24-hour $PM_{10}$ standard have been reported during summer (June, July, or August).

$PM_{10}$ data from Lee Vining show a seasonality pattern that differs significantly from the Simis Ranch pattern. All recorded exceedances of the state $PM_{10}$ standard occurred during January 1991. Other relatively high $PM_{10}$ concentrations have occurred primarily during winter (December, January, or February).

**Frequency of High $PM_{10}$ Concentrations**. Modern instrumentation allows automated continuous monitoring of many air pollutants. Monitoring of suspended particulate matter concentrations, however, still requires significant manual efforts for filter preparation, instrumentation calibration and setup, filter collection, and filter analysis. Consequently, it is usually impractical to monitor suspended particulate matter concentrations every day of the year.

**Monitoring Conventions**. The normal monitoring convention for suspended particulate matter involves collection of a 24-hour sample once every 6 days. On a sampling schedule of 1 day in 6, 83% of the days are not sampled. Since 1989, $PM_{10}$ sampling at the Simis Ranch site has been more intensive than the normal schedule of 1 day in 6. But even in the most intensively sampled year (1990), 68% of the days were not sampled.

Because samples are not collected every day, it is misleading to refer to the number of samples above specific numerical values as if those were the only days exceeding the specified concentration. It is more accurate to discuss the percentage of collected samples that exceed various numerical values. If all months or seasons are represented by an adequate number of samples, it is possible to make reasonable extrapolations to estimate the annual frequency of high $PM_{10}$ concentrations.

$PM_{10}$ monitoring at Warm Springs has been concentrated in spring and fall months, with an effort made to sample on days expected to have strong winds. Because particulate matter sampling at Warm Springs is not intended to provide statistical representativeness, it is difficult to extrapolate the Warm Springs data to days that were not sampled. The following discussion emphasizes data from Simis Ranch and Lee Vining because these monitoring stations are operated throughout the year.

**Exceedance Event Patterns**. Most $PM_{10}$ samples collected at Lee Vining and Simis Ranch show concentrations well below the state 24-hour $PM_{10}$ standard of 50 Fg/m$^3$ (Figure 3H-10). Nearly 39% of the Lee Vining $PM_{10}$ measurements are 10 Fg/m$^3$ or less. Over 55% of the Simis Ranch $PM_{10}$ measurements are 10 Fg/m$^3$ or less.

Only a few $PM_{10}$ samples from either location have exceeded the state or federal 24-hour $PM_{10}$ standards. Data from Simis Ranch for October 1986 through June 1992 indicate that:

- # 3.9% of the $PM_{10}$ samples exceeded the state 24-hour $PM_{10}$ standard of 50 Fg/m$^3$ and

- # 0.5% exceeded the federal 24-hour $PM_{10}$ standard of 150 Fg/m$^3$.

Data from Lee Vining for 1988-1991 indicate that:

- # 0.8% of the $PM_{10}$ samples exceeded the state 24-hour $PM_{10}$ standard and
- # no Lee Vining samples exceeded the federal 24-hour $PM_{10}$ standard.

Table 3H-4 summarizes the monthly distribution of $PM_{10}$ samples from Lee Vining and Simis Ranch that exceed the state 24-hour $PM_{10}$ standard. As shown, the Lee Vining station has operated on a more uniform sampling schedule than has the Simis Ranch station. In recent years, the uniform sampling schedule at Simis Ranch has been supplemented by additional sampling during spring and fall. The last column in Table 3H-4 extrapolates available data on a monthly basis to estimate the average monthly exceedances of the state 24-hour $PM_{10}$ standard. The aggregated monthly data suggest three exceedances per year in Lee Vining and 13-14 exceedances per year at Simis Ranch.

Annual trends in $PM_{10}$ exceedances at Simis Ranch (Figure 3H-11) suggest that the frequency of $PM_{10}$ exceedances more than doubled from 1987 (an extrapolated eight exceedances) to 1991 (an extrapolated 21 exceedances). The apparent trend should be viewed with caution because the indicated frequencies reflect limited numbers of $PM_{10}$ samples, particularly for 1987 and 1988. The chance inclusion or omission of a single exceedance event in any year could measurably change the trend pattern.

The estimated monthly pattern of $PM_{10}$ exceedances at Simis Ranch is shown on Figure 3H-12 and is based on the data summarized in Table 3H-4. Although most observers report dust events as being most common in spring, the Simis Ranch station has recorded a slightly higher frequency of events during fall.

As with Figure 3H-11, the frequency pattern in Figure 3H-12 is prone to significant changes with the inclusion or omission of a few single events.

**Frequency and Seasonality of Low $PM_{10}$ Concentrations**. Although attention normally focuses on high $PM_{10}$ concentrations, the occurrence of very low $PM_{10}$ concentrations is informative. Lee Vining and Simis Ranch experience similar frequencies of $PM_{10}$ concentrations between 6 and 10 Fg/m$^3$ (Figure 3H-13). However, Simis Ranch exhibits a much higher frequency of very low $PM_{10}$ concentrations (between 1 and 5 Fg/m$^3$).

Simis Ranch and Lee Vining also exhibit different seasonality patterns for very low $PM_{10}$ conditions (Figures N-4 and N-5 in Appendix N). The monthly distribution of very low $PM_{10}$ concentrations at Simis Ranch parallels the monthly distribution of annual precipitation and the probability of frozen ground conditions, but no such meteorological correlation is evident at Lee Vining.

As discussed in a subsequent section, these differences between the Simis Ranch and Lee Vining low $PM_{10}$ data suggest differences in the sources contributing to observed $PM_{10}$ concentrations.

## LADWP Photographic Observations of Blowing Dust

In 1980, LADWP began a program to photographically document episodes of windblown dust. At approximately 2:00 p.m. each day, a panoramic sequence of three photographs is taken from the service road along the Lee Vining conduit above U.S. 395 (Figure 3H-1). The photographs are evaluated by LADWP staff and rated on a four-point scale according to the extent of windblown dust: no visible dust, faint windblown dust (mostly dust devils), recognizable windblown dust, and extensive windblown dust. In recent years, the apparent source areas for visible dust also have been recorded (land bridge, north shore, east shore, south shore, west shore, Paoha Island, or Negit Island), as discussed below.

Between March 1980 and February 1991, 3,872 sets of photographs were evaluated and classified, with 118 sets (3%) showing recognizable or extensive dust events. Figure 3H-14 illustrates the annual frequency of significant dust events (recognizable or extensive events in the LADWP classification system). In contrast to the apparent trend shown by the Simis Ranch $PM_{10}$ monitoring data (Figure 3H-11), the LADWP photographic record suggests little change in dust event frequency during recent years. The LADWP photographic record also suggests a noticeable decline in dust event frequency since 1985.

The monthly frequency of significant dust events detected in the LADWP photographic record (Figure 3H-15) is consistent with the qualitative seasonality pattern that most observers describe; that is, dust events are most frequent in spring. The year-to-year variability in seasonal dust event frequencies detected by the LADWP photographic record (Figure 3H-16) suggests that the seasonal pattern of blowing dust events can change significantly from year to year.

## Conclusions Regarding the Frequency and Seasonality of Blowing Dust Events

The Simis Ranch $PM_{10}$ monitoring data and the LADWP photographic record data provide different indicators of the frequency and seasonality of significant windblown dust events. These two data sets have different strengths and weaknesses.

The Simis Ranch $PM_{10}$ data provide a quantitative 24-hour integrated measure that can be directly compared to state and federal 24-hour standards. However, the Simis Ranch data represent only one geographic area and do not provide continuous data. The LADWP photographic data provide an extensive long-term record with broad geographic coverage. However, the data available from the photographs is qualitative with respect to the federal and state $PM_{10}$ standards and is representative of only a limited time interval.

Given the different temporal and geographic coverages of the two data sets, it is not surprising that the LADWP photographic data do not correlate strongly with the Simis Ranch $PM_{10}$ data. Figure 3H-17 illustrates that it is futile to attempt to correlate the LADWP photographic ratings with any specific range of $PM_{10}$ concentrations measured at Simis Ranch. The simplest explanation for the lack of correlation between the photographic ratings and measured $PM_{10}$ concentrations at Simis Ranch is that many dust events recorded in the LADWP photographs do not reach the $PM_{10}$ monitors at Simis Ranch. Additionally, dust events leading to violation of the state 24-hour $PM_{10}$ standard at Simis Ranch can occur before or after the LADWP photographs are taken.

The LADWP photographic data probably provide a more reliable indication of seasonal patterns in windblown dust events than do the Simis Ranch $PM_{10}$ data. Neither the Simis Ranch $PM_{10}$ data nor the LADWP photographic data provide a particularly reliable indicator of annual trends in the frequency of dust events. It is possible that dust events have increased in frequency near the Simis Ranch while the frequency of dust events basinwide has remained fairly stable.

# Sources of Particulate Matter in Mono Basin

## Introduction

Although there have been no comprehensive technical analyses of the relative source contributions to suspended particulate matter in Mono Basin, the major contributing sources can be easily identified. Most suspended particulate matter is produced by wind erosion of exposed soils, sediments, and salt deposits. Declining lake level not only significantly increased the extent of barren substrates around the shore of the lake, it resulted in the appearance of significant efflorescent salt deposits along the northern and eastern shores of the lake. Most observers consider the salt deposits to be the major source of suspended particulate matter during significant dust storm events.

Although most suspended particles will be derived from efflorescent, barren, and sparsely vegetated substrates, some suspended particulate matter will be salt crystals and entrained sediment formed by evaporation of spray droplets produced by wave action on Mono Lake. Biological sources (e.g., vegetation, molds, and fungi) will contribute small quantities of pollen and spores. Combustion processes (e.g., residential and commercial fuel use and motor vehicle exhaust) will also contribute to suspended particulate matter, especially on the west side of the lake. Dust generated by vehicle travel on paved and unpaved surfaces is probably a minor contributor to suspended particulate matter in Mono Basin and is probably more important at the Lee Vining monitoring site than at Simis Ranch. Differences in the seasonality of both high $PM_{10}$ and very low $PM_{10}$ concentrations suggest that Lee Vining is much less influenced by dust storms and more strongly influenced by fuel combustion and vehicle traffic sources than is Simis Ranch.

The high frequency of very low $PM_{10}$ concentrations measured at Simis Ranch indicates that long-distance transport of aerosols from outside Mono Basin is an infrequent contributor to Mono Basin particulate matter concentrations.

Unfortunately, the available data on the physical and chemical characteristics of suspended particulate matter is insufficient to quantify the contributions from different emission sources. The available chemical analyses confirm, however, that suspended particulate matter is predominantly a mix of soil, sediment, and salt particles. Some of the samples show very small amounts of selenium and arsenic, but the mineralogical carriers of these elements cannot be determined from the available data.

**Distribution of Major Sources of Observed Dust Storms**

GBUAPCD staff have observed numerous major dust events at Mono Lake and have estimated the geographic distribution of source areas of various frequencies (Figure 3H-18). Frequent source areas include a band around the northeastern shore setback from the lake edge, sediments that emerged as the Negit Island land bridge, and the emerged western portion of Paoha Island having very sparse greasewood cover. Less frequent source areas include the eastern lakeshore between Warm Springs and Simon's Spring and lower areas of the land bridge. Least frequent source areas include wet areas near the lake from Black Points to Warm Springs. Most of the source areas exhibit salt efflorescence, but some are especially fine sands and silts.

The locations recorded for "recognizable" and "extensive" dust storms in the LADWP photographic record also characterize source area distribution. Over 70% of the photographed events have been classified by source area. The most frequent source areas observed are along the eastern shore (Figure 3H-19), but the north shore, the land bridge, and Paoha Island are other major sources of "extensive" events. As the percentages in the figure indicate, on the average two source areas contribute to recognizable events and three to four areas contribute to extensive events.

A comparison of Figures 3H-18 and 3H-19 shows that LADWP's "eastshore" includes a substantial portion of GBUAPCD's northeast frequent source area. Together, then, the surveys reveal that the major sources of dust storms are relicted lands around the northern and eastern shorelines, the land bridge, and the west shore of Paoha Island.

**Efflorescent Salt Deposits**

Chemists define "efflorescence" as the dehydration of a hydrated salt when exposed to air. Some geologists retain this chemical perspective by defining "efflorescent salts" as powdery salts formed by dehydration of hydrated salts. Other geologists, many soil scientists, and this EIR use a less restrictive definition of "efflorescent salts" as any salts produced by evaporation of water at a sediment or soil surface exposed to the air.

Efflorescent salt deposits at Mono Lake are found primarily along the northern and eastern shores of the lake, generally below the 6,390 foot contour (Figure 3H-20). Small scattered deposits are found in other locations. The mineralogy of the Mono Lake deposits has not been studied, but probably has strong similarities to some of the efflorescent salt deposits at Owens Lake. The Mono Lake deposits are probably dominated by sodium carbonates and sodium sulfates, with smaller quantities of sodium chloride. Appendix N presents a discussion of the probable mineralogy of efflorescent salts such as those found at Mono Lake.

Efflorescent salts, virtually nonexistent in the prediversion period, covered an area of 4,975 acres of the relicted lands (65%) at the point of reference. They are light, weak materials typically forming a surface layer up to a few inches thick on underlying lakebed sediments, principally silts and fine sands. The salts are sometimes noncrystalline powdery deposits highly susceptible to wind erosion, or are more often crusted but subject to disturbance by saltating sand. The extreme salinity generally prohibits the colonization of efflorescent areas by plants (Chapter 3C, "Vegetation"), preventing the development of a cover affording protection from wind.

**Source of Efflorescence**. Efflorescent salts form as saline groundwater rises to the surface of permeable sediments through capillary action and evaporates. The salts, highly susceptible to removal by wind or rain, begin reforming once removed. Sources of evaporating saline water in these sediments may be intruding lake water or saline groundwater draining the adjacent lake basin sediments. Efflorescent salt deposits are seldom found where the groundwater table is more than 10 feet below the ground surface (Saint-Amand et al. 1986).

Test hole data indicate that relatively shallow groundwater flows toward the lake at locations all around the lake. In general, the west end of the lake is characterized by fresh groundwater with steeper slopes and higher flow rates, and the east end has saline water inflowing more slowly along a gentle gradient. Because the eastern end of the lake also has low topographic gradient, a wide zone of sediments with shallow saline groundwater is present in these areas (see Figure U-1 in Appendix U). By and large, these sediments exhibit salt efflorescence.

Because a similar zone of efflorescence was not present in the prediversion period, the phenomena is certainly the result of the reduced lake level. Groundwater draining the extensive basin of former lake sediments, extending up to 8 miles from the lake, may eventually reach a new equilibrium level with the lake surface, reducing or eliminating the efflorescent phenomena. The time interval for such a change to occur is unknown, but based on size and elevation of lakebed deposits in the basin and typical lakebed transmissivities and porosities, it is estimated to be at least hundreds of years (Appendix U).

Other areas of efflorescence, such as the immediate shoreline and portions of the land bridge, may result from simple intrusion of low-lying lakebeds with saline lake water.

In either case, the saline groundwater rises through capillary action to the surface, where it is evaporated, depositing its mineral content, or cooled, precipitating some of the dissolved minerals. The silty lakebeds produce a relatively large zone of capillary rise.

**Factors Affecting Wind Erodibility of Salt Deposits**. The erodibility of efflorescent salt deposits is determined primarily by their mineralogy and moisture content. As described in Appendix N, the mineralogy of efflorescent salt deposits can change on daily and seasonal cycles controlled by temperature, moisture conditions, and surface evaporation rates.

Table 3H-5 presents a simplified summary of salt deposit erosion susceptibility as influenced by surface temperatures and moisture content. Wet conditions prevent wind erosion regardless of salt deposit mineralogy. Cool salt deposit temperatures and low surface moisture levels favor the development of powdery noncrystalline salts that are highly susceptible to wind erosion. Warm, dry conditions favor the formation of a strongly cemented crust that is highly resistant to wind erosion.

Seasonal patterns of temperature and moisture at Mono Lake are most likely to result in powdery salt deposits during spring or after fall rains. Cemented salt deposits resistant to wind erosion are most prevalent during summer, but summer thunderstorms or unseasonable temperature changes at any time of the year can alter the prevailing condition of the salt deposits. Once eroded by wind or dissolved by rain, salt deposits will reform but may do so in a condition quite different from their previous state. The general seasonal pattern is combined with a diurnal pattern controlled by temperature, humidity, and evaporation. Particularly in spring and fall, the daily temperature cycle can lead to repeated transitions between strongly hydrated salts formed at night and powdery anhydrous salts during the day.

Moisture has geographic effects also. Efflorescent areas closest to the lake may only be infrequent dust emitters (Figure 3H-18) because groundwater is so shallow near the lakeshore that it only infrequently dries sufficiently to deflate. At the Ten-Mile Road area, for example, the lakeshore zone of infrequent emissions (Figure 3H-18) includes a 1,000-foot-wide band of frequently wet efflorescent lands, which extends upslope 8 vertical feet above the lake surface.

Reflecting these factors, a range of salt deposit conditions was observed over a transect from Ten-Mile Road to the lake on April 24, 1992 (Figures 3H-21 and 3H-22). The upper part of the salt deposit was characterized by a thin but hard salt crust, and a thin, weak, buckled crust was present toward the upper middle part of the deposit (Figure 3H-21). The lower middle part of the salt deposit was a relatively thick powder that was drying at the surface (Figure 3H-22); the lower part was wet.

**Other Exposed Sediments**

Several other unvegetated or sparely vegetated substrate types are widespread around Mono Lake, constituting 6,900 acres. This is an area about 39% greater than the area of efflorescent salts. The areas probably also contribute substantially to emissions during high wind episodes, based on wind-tunnel emission rates measured from some of them by GBUAPCD. The reasons for the lack of vegetation are complex (see Chapter 3C, "Vegetation").

Silty lakebeds with occasional clayey layers deposited by the prehistoric Lake Russell are exposed in streamcuts and presumably underlie many of the surface sands in Mono Basin. Little information is available on the particle sizes and surface distribution of these sediments.

Lakebed silts, clays, and diatomaceous sediments occur on Paoha Island (Chesterman and Gray 1966). Particles in diatomaceous sediments (microscopic silica shells secreted by some types of aquatic algae) have a complex physical structure that incorporates many void spaces. Consequently, diatomaceous particles have a very low density and can be transported long distances once eroded by the wind. As noted previously, the relicted flat on the west side of Paoha Island is a frequent dust storm source area.

Pumice sands are readily apparent along much of the east shore of Mono Lake. Even when ground into sand-sized particles, pumice contains many void spaces (McCrone and Delley 1973), resulting in a very low particle density. Pumice sands will be more subject to wind erosion than might be expected from the physical size of individual particles.

The geology of the volcanic rocks in most of Mono Basin suggests variable density and a low quartz content for sands derived from these sources. Volcanic rocks south of Mono Lake are predominantly rhyolitic ash and include obsidian domes and pumice fields (Scholl et al. 1966, Chesterman and Gray 1966, Stine 1992). Volcanic rocks of Negit Island are andesitic lavas (Chesterman and Gray 1966), and Black Point is a basalt cinder cone (Scholl et al. 1966, Stine 1992). Rhyolite is somewhat less dense than quartz, basalt is more dense, and andesite is essentially the same (Olhoeft and Johnson 1989).

### Surface of Mono Lake

Under windy conditions, the surface of Mono Lake is an additional source of suspended particulate matter. Spray droplets released into the air from waves on the surface of Mono Lake include dissolved salts and some fine suspended solids. Evaporation of the water in the spray droplet leaves salt, silt, and clay particles suspended in the air. No measurements of this phenomena have been made at Mono Lake, but the amount is relatively small compared to emissions from efflorescent and sediment sources.

As described by Stine (1992), longshore currents at Mono Lake entrain sediment delivered from the tributary streams. Driven by the prevailing southwest wind, these currents sweep stream-derived sediments eastward along the south shore and north shore (Figure 3H-23). Where these currents meet, an extensive sandy area and dune field extend northeastward from the lakeshore. During windy episodes, local transfer of lake-entrained sediment to terrestrial environments as particulate matter occurs here, but probably through saltation near the ground and not lofting into air. Such saltation may help dislodge adjacent efflorescent salt particles, however.

## IMPACT ASSESSMENT METHODOLOGY

### Impact Prediction Methodology

### Analytical Approach

The major air quality issue to be addressed in this EIR is the extent to which different lake level and streamflow standards might affect the location and extent of erodible substrates, with resulting effects on the magnitude, geographic extent, and general frequency of high concentrations of suspended particulate matter.

Predicting ambient air quality impacts requires consideration of the transport, dispersion, chemical transformation, and removal processes that affect pollutant emissions after their release into the atmosphere. Computer models provide the most practical method for developing quantitative air quality assessments of future conditions. Because air pollution problems at Mono Lake are dominated by physical processes rather than by chemical transformations, Gaussian dispersion models are a logical choice for the analyses in this EIR.

Although Gaussian dispersion models estimate the net effect of atmospheric dispersion processes on emissions, they do not mathematically simulate the physical process of turbulent dispersion. These models employ mathematical extrapolation techniques to estimate pollutant concentrations.

Gaussian dispersion models are generally structured as a series of mathematical terms multiplied together. The initial term in the equation represents the plume centerline concentration at the emission source. This term is multiplied by a series of fractions that reduce the initial concentration value to account for distance of a receptor downwind from the emission source, lateral offset from the plume centerline, and vertical offset from the plume centerline.

Dispersion models calculate pollutant concentrations at particular locations ("receptors" in modeling jargon) by applying appropriate horizontal and vertical dispersion factor equations to the initial pollutant concentration. The proper dispersion factor equations are determined from the position of the receptor relative to both the emission source and the centerline of the pollution plume extending downwind from the emission source.

Only a few Gaussian dispersion models have been structured to address wind-blown particulate matter as the pollutant of concern, although many different models have been developed over the last 15 years. The Fugitive Dust Model (FDM) (Winges 1990) provides a flexible model formulation that is easily applied to conditions at Mono Lake.

The initial FDM computer code was released in 1990 but is based on two other dispersion models that have been used extensively for over a decade: CALINE3 (Benson 1979) and ISCST (Bowers et al. 1979, Wagner 1987). FDM is most useful as an area source model, although it also contains subroutines that evaluate point sources and line sources. The line source and area source subroutines in FDM are based on the CALINE3 line source dispersion model.

The area source subroutines in FDM calculate both ambient concentrations ($\mu g/m^3$) and mass deposition rates (micrograms per square meter per second). Model computations are typically performed for sequences of 1-hour periods, with model results presented as 1-hour, 3-hour, 8-hour, or 24-hour averages. Results can also be averaged over the entire model sequence.

Additional details concerning Gaussian dispersion models in general and the FDM model in particular are presented in Mono Basin EIR Auxiliary Report No. 26 (Jones & Stokes Associates 1993).

## Delineation of Areas Contributing to Windblown Particulate Matter

The baseline vegetation and substrate map prepared from 1991 color aerial photographs (see Chapter 3C, "Vegetation") provided the basis for identifying areas near Mono Lake that are probable sources of windblown particulate matter. The vegetation/ substrate categories used for the vegetation mapping were reclassified into particulate matter source area categories. All well-vegetated, tufa, and barren rock areas were treated as being nonerosive. Remaining areas were categorized into background low-emission-rate source areas and high-emission-rate source areas. High-emission-rate source areas were identified by correlation with GBUAPCD's map of major emission source areas.

Background low-emission-rate source areas included:

- the surface of Mono Lake,
- barren basalt sands (Black Point sands),
- small isolated patches of efflorescent salt, and
- other sparsely vegetated or barren substrates (sands and silts).

High-emission-rate source areas were categorized as high, medium, and low frequency. These frequency characterizations generally reflect the relative duration of low moisture conditions in substrates; wet substrates are not subject to wind erosion.

The major low frequency source areas were separated into two categories:

- efflorescent salt deposits and
- other barren substrates.

The major medium frequency source areas were also separated into two categories:

- efflorescent salt deposits and
- other barren substrates.

The major high frequency source areas were separated into three categories:

- efflorescent salt deposits,
- diatomaceous sediments on Paoha Island, and
- other barren substrates.

The emission source categories listed above were assigned various combinations of values representing emission rates, particle size distributions, and particle densities.

All source area delineations were performed at a scale of 1:24,000 (the scale of 7.5-minute topographic quadrangles). The aerial photo base for the vegetation mapping reflects a lake elevation of 6,375.1 feet.

### Lake Levels Selected for Modeling

Lake contour overlays were prepared for the nominal lake elevation associated with each alternative. Additional lake contour overlays were prepared for the point-of-reference and prediversion elevations. Most major emission source areas would be under water at a lake elevation of 6,400 feet; only a portion of the Paoha Island major source area and a small section of the Negit Island land bridge would remain exposed at that lake elevation. Consequently, modeling analyses focused on lake elevations below 6,400 feet.

Comparison of lake elevation contours indicated that the extent of major source areas differed only slightly between the aerial photograph base elevation (6,375.1 feet) and the point-of-reference condition (6,376.3 feet). Therefore, the aerial photograph base condition was used as representative of the point-of-reference condition.

### Emission Rate Parameters

The FDM model applies particle settling and deposition adjustments to the basic Gaussian dispersion model equations. Thus, source area emissions are characterized by a basic emission rate equation, a particle size distribution, and a particle density.

**Wind Erosion Rate Equations**. As discussed in Auxiliary Report No. 26, the FDM model was modified to allow selection from five different emission rate equation formats on a source-by-source basis. Equations for the high-emission-rate source areas were derived from analysis of data collected by the GBUAPCD using a portable wind tunnel. Several different equation types provided an adequate fit to the available data. A sigmoidal equation format with a threshold wind speed of 15 mph was used for the high-emission-rate source areas.

The small salt deposits classified as background low-emission-rate source areas also were modeled with a sigmoidal equation. A revised equation was derived by reducing the upper asymptote of the original sigmoidal equation by 50% and increasing the threshold wind speed to 20 mph.

Other terrestrial background low-emission-rate source areas were modeled using third-order polynomial equations derived in a series of steps starting with data from the portable wind tunnel study. Emission rate values from a power function fit of the wind tunnel data were reduced by 70%. The modified equation results were then adjusted to reflect different threshold wind speeds (28 mph for basalt sands and 22 mph for other low emission rate sands). The tentative emission rate values produced in this manner were then used to derive third-order polymonial equations for use in the FDM model.

Salt spray from the surface of Mono Lake was modeled using a third-order polynomial equation derived from analysis of data presented in Blanchard and Woodcock (1980) and Monahan et al. (1983). A multiplier was added to the polynomial equation to reflect the higher salinity of Mono Lake. Blanchard and Woodcock (1980) give 8 mph as a threshold wind speed for salt spray off the open ocean; a threshold wind speed of 10 mph was used for Mono Lake.

**Particle Size Distributions for Wind-Eroded Sediments**. The FDM model can analyze transport, settling, and deposition of up to 20 particle size classes from each emission source area. As explained in Auxiliary Report No. 26, eight particle size classes were used in the modeling analyses conducted for this EIR. Particle size distributions for salt spray aerosols were derived from data in Blanchard and Woodcock (1980). Particle size distributions for sandy background source areas were derived from data in Pye (1987). Particle size distributions for other substrate types (salt deposits, diatomaceous sediments, and high-emission-rate sands and silts) were estimated by the SWRCB contractors.

**Particle Densities for Mono Basin Sediment Types**. Particle densities vary significantly among the different substrates found at Mono Lake (see Auxiliary Report No. 26 for additional details). The FDM modeling analyses performed for this EIR assumed the following particle densities for identifiable substrate categories:

- 2.1 grams per cubic centimeter ($g/cm^3$) for dry salt aerosols generated by spray from Mono Lake,
- 3.0 $g/cm^3$ for basalt-derived sands,
- 2.5 $g/cm^3$ for other sands,
- 0.7 $g/cm^3$ for diatomaceous substrates on Paoha Island, and
- 2.1 $g/cm^3$ for efflorescent salts deposits.

## Meteorological Data

Meteorological input to the FDM model was derived from Simis Ranch data for 1986-1991 from GBUAPCD files. Hourly meteorological data from the Simis monitoring station were sorted into calendar days, then screened for days with one or more hours of average windspeed of at least 15 mph. Days with missing data were dropped from the analysis. The remaining data set of several hundred days was then evaluated to identify days with different durations of high wind conditions and different wind direction patterns. Fifty days of historical meteorological data were selected for use in the modeling analyses.

Wind speed, wind direction, and air temperature data were taken directly from the monitoring data record. Stability class conditions and mixing height limits were estimated based on wind speed, horizontal wind direction fluctuation, statistics, and time of day.

## Assessment of Annual Dust Event Occurrence Frequencies

FMD modeling results provide an indication of the potential magnitude and geographic extent of high $PM_{10}$ concentrations for different meteorological conditions and different lake elevations. For the point-of-reference condition, modeling results presented in the impact assessment section indicate that days having 4 or more hours with wind speeds above 15 mph have the potential for generating $PM_{10}$ concentrations above the state 24-hour standard in an area of at least 5 square miles. However, estimates of the expected frequency of high $PM_{10}$ concentrations must recognize that dust storm occurrence is controlled more by substrate moisture conditions and temperature-related salt crust cementing than by wind speed conditions. Only when substrate conditions are susceptible to wind erosion will wind speed be a good indicator of probable dust generation.

Correlations between wind speed data and $PM_{10}$ monitoring data at Simis Ranch provide one approach for estimating the proportion of windy days when little actual dust is generated. Correlations between the LADWP photographic data and Simis Ranch wind speed data provide a second approach for estimating the proportion of windy days when little actual dust is generated. Both types of correlation analyses are complicated by significant amounts of missing meteorological data and by instances of unexplained major discrepancies in concurrent wind speed data for the Simis Ranch and Lee Vining monitoring stations. Further complications are the limited frequency of $PM_{10}$ monitoring and the limited temporal coverage of the LADWP photographic data.

The Simis Ranch monitoring station collected 376 $PM_{10}$ samples during 1986-1991. Complete wind speed data containing episodes of strong winds (4 or more hours with wind speeds of 15 mph or more) are available for 72 of the days for which $PM_{10}$ data are available. $PM_{10}$ concentrations above 50 Fg/cm$^3$ were recorded on only 13 of these days. Thus, the Simis Ranch monitoring data suggest that episodes of strong winds will result in high $PM_{10}$ concentrations about 18.1% of the time.

LADWP photographic data for 1986-1991 include 1,491 days when wind speed data are available from the Simis Ranch monitoring station. Average wind speeds for the 1-3 p.m. period exceeded 15 mph on 204 of the days with rated photographs. Only 21 of these windy days had photographs classified as showing recognizable or extensive dust events; the remaining 183 days had photographs rated as showing no visible dust or only faint dust. Thus, the LADWP photographic data suggest that episodes of strong winds will result in significant dust generation only 10.3% of the time.

## Criteria for Determining Impact Significance

Air quality impact assessments address a mix of issues regarding physical impacts, regulatory requirements, and policy or program consistency. Because no specific air quality management plan has yet been adopted to address $PM_{10}$ problems in Mono Basin, impact significance criteria used in this EIR focus on physical air quality impacts.

Physical air quality impacts are typically judged to be significant if a project would directly or indirectly:

- cause or contribute to a violation of state or federal ambient air quality standards;
- cause or contribute to noncriteria pollutant concentrations that pose an unacceptable health risk;

- cause or contribute to pollutant concentrations that produce undesirable biological, ecological, material damage, or economic effects;

- bring people into a situation where they will be exposed to air pollutants in concentrations that violate state or federal ambient air quality standards;

- bring people into a situation where they will be exposed to noncriteria air pollutants in concentrations that pose an unacceptable health risk; or

- violate federal, state, or local air quality agency emission limitations for specific pollutants or emission sources.

## SUMMARY COMPARISON OF IMPACTS AND BENEFITS OF THE ALTERNATIVES

Water diversions from Mono Basin have significantly lowered the level of Mono Lake, increasing the geographic extent of barren sediments subject to wind erosion. More importantly, however, the lowering of Mono Lake has produced conditions resulting in extensive deposits of efflorescent salt along the northern and eastern shores of the lake. The postdiversion increase in acreage subject to wind erosion and the development of extensive efflorescent salt deposits have significantly increased the magnitude and frequency of dust storm events in Mono Basin. In addition, the presence of erodible efflorescent salt deposits has significantly changed the physical and chemical nature of dust storm events. As discussed in Appendix N, little quantitative data exist to characterize particulate matter associated with dust storm events in Mono Basin.

Air quality effects of the alternatives have been investigated through dispersion modeling analyses as discussed in the assessment methodologies section. The modeling analyses provide comparative indicators of:

- the maximum expected 24-hour average $PM_{10}$ concentration,

- the geographic extent of high $PM_{10}$ concentrations under various meteorological conditions, and

- the duration of strong wind episodes necessary to create the potential for 24-hour average $PM_{10}$ concentrations above state or federal standards.

The potential frequency with which state or federal standards might be exceeded can be assessed qualitatively by considering the three categories of information noted above.

Table 3H-6 provides a summary comparison of the alternatives, the point-of-reference condition, and prediversion conditions using a mixture of quantitative and qualitative measures. Three key variables are addressed in Table 3H-6 for each alternative:

- the maximum expected 24-hour $PM_{10}$ concentration at major public use areas or at existing air quality monitoring locations,

- the maximum geographic area (anywhere in the basin) expected to be affected by $PM_{10}$ concentrations above the state 24-hour standard of 50 Fg/m$^3$, and

- the estimated annual frequency of 24-hour average $PM_{10}$ concentrations above 50 Fg/m$^3$ anywhere in the basin.

Several considerations must be noted when examining Table 3H-6:

- Table 3H-6 is based on the median lake elevation at dynamic equilibrium; the transition period to dynamic equilibrium is not considered in the table.

- The alternative names are more indicative of minimum lake elevations than average lake elevations at dynamic equilibrium.

- The maximum $PM_{10}$ concentrations listed in Table 3H-6 are based on public use locations and monitoring station locations, not the absolute maximum concentration generated by a model run.

- The estimated annual frequencies of $PM_{10}$ violations represent the judgment of the SWRCB's consultants (assuming 13-14 violations per year for the point of reference), not a direct model output.

As can be seen in Table 3H-6, the No-Restriction Alternative has more severe air quality noncompliance than the point of reference, the 6,372-Ft Alternative is comparable to the point of reference, and the other alternatives represent conditions that have less air quality degradation than the point of reference. The No-Restriction, 6,372-Ft, 6,377-Ft, and 6,383.5-Ft Alternatives all have significant adverse cumulative air quality impacts. The 6,390-Ft Alternative has the potential for minor air quality noncompliance. The 6,410-Ft and No-Diversion Alternatives do not pose any air quality problems.

Modeling output used to develop Table 3H-6 is summarized in Table 3H-7 and presented in greater detail in Mono Basin EIR Auxiliary Report 26, Air Quality Modeling Procedures and Results. The public use and monitoring station areas used in Table 3H-7 are shown in Figure 3H-24. As is shown in Figure 3H-24, clusters of modeled receptor points have been used to characterize most of the locations referenced in Table 3H-7. These clusters of receptor points have been used to represent zones of significant public use and to minimize an inherent limitation of the FDM model.

The FDM model, like all Gaussian dispersion models, assumes a geographically uniform pattern of wind speed and direction conditions. Wind speed and direction conditions measured at Simis Ranch were applied to the entire Mono Basin. In reality, however, wind speeds and directions will vary at different locations around Mono Lake. Consequently, the FDM model will tend to misrepresent the precise location of dust plumes, with the potential for displacement being greatest for plumes originating a significant distance from Simis Ranch.

Additional discussion of how modeling analyses were applied to each alternative are presented in the following sections of this chapter.

## MODELING RESULTS FOR THE POINT-OF-REFERENCE CONDITION

The point-of-reference condition was modeled using data derived from 1990 aerial photographs taken when the lake elevation was 6,375.1 feet. At the mapping scale used for the modeling analyses (1:24000), there are no meaningful differences between the 6,375.1-foot and 6,376.3-foot contours.

Fifty different days of meteorological data were modeled. No single day produced the peak concentration for all 12 of the receptor areas listed in Table 3H-7. Data from June 4, 1988, produced the most extensive dust plume event, the highest $PM_{10}$ concentration for any single receptor point, and the highest $PM_{10}$ concentration for the Simis Ranch area. Other modeled days produced higher $PM_{10}$ concentrations at other locations. Figure 3H-25 shows the modeling results produced using meteorological data from June 4, 1988. Mono Basin EIR Auxiliary Report No. 26 contains additional data generated by modeling the 6,375.1-foot lake elevation.

## IMPACTS AND MITIGATION MEASURES FOR THE NO-RESTRICTION ALTERNATIVE

### Changes in Resource Condition

The No-Restriction Alternative would allow lake levels to decline significantly from the point of reference, greatly increasing the amount of unvegetated, exposed substrate subject to wind erosion. Lake surface elevations would generally fluctuate between 6,345 feet and 6,365 feet under equilibrium conditions. Fluctuations at higher elevations would occur during the transition to equilibrium conditions.

No FDM modeling analyses were performed at lake elevations below 6,372 feet. It is clear from the modeling analyses for other lake elevations that the No-Restriction Alternative would generate more extensive and more frequent dust storm episodes than would the 6,372-Ft Alternative. The magnitude, frequency, and geographic extent of dust storm events would be greater under the No-Restriction Alternative than under point-of-reference conditions.

### Summary of Benefits and Significant Impacts and Identification of Mitigation Measures (No-Restriction Alternative)

- Significantly increases the magnitude, frequency, and geographic extent of dust storm episodes.

**Mitigation Measures**. No feasible mitigation measures have been identified for stabilizing efflorescent salt and lakebed sediments that constitute the major sources of windblown particulate matter in Mono Basin.

## IMPACTS AND MITIGATION MEASURES FOR THE 6,372-FT ALTERNATIVE

### Changes in Resource Condition

The 6,372-Ft Alternative would have a relatively narrow range of lake surface elevations under equilibrium conditions. The lake would fluctuate between 6,372 feet and 6,379 feet with a median elevation of about 6,375 feet.

Figure 3H-25 (presented in the discussion of point-of-reference conditions) is applicable to the median lake level for the 6,372-Ft Alternative. Figure 3H-26 shows the modeled dust storm conditions for a 6,372-foot lake level under June 4, 1988 wind conditions. Figure 3H-27 shows modeled dust storm conditions for a 6,377-foot lake level under June 4, 1988 wind conditions.

The magnitude, frequency, and geographic extent of dust storm events would be greater under the 6,372-Ft Alternative than under point-of-reference conditions. As presented previously in Table 3H-7, $PM_{10}$ concentrations above the state 24-hour standard would be possible in many locations, including the South Tufa, Navy Beach, Simis Ranch, Ten Mile Road, Warm Springs, Simon's Spring, and Cedar Hill areas.

### Summary of Benefits and Significant Impacts and Identification of Mitigation Measures (6,372-Ft Alternative)

- # Increases the magnitude, frequency, and geographic extent of dust storm episodes.

- # Increases maximum $PM_{10}$ concentrations by 20-25% in the South Tufa area and 25-30% in the Simis Ranch/Ten Mile Road area.

**Mitigation Measures**. No feasible mitigation measures have been identified.

## IMPACTS AND MITIGATION MEASURES FOR THE 6,377-FT ALTERNATIVE

### Changes in Resource Condition

The 6,377-Ft Alternative would have a relatively narrow range of lake surface elevations under equilibrium conditions. The lake would fluctuate between 6,376 feet and 6,383 feet with a median elevation of about 6,379 feet.

Figure 3H-25 (presented in the discussion of point-of-reference conditions) is applicable to the low lake level for the 6,377-Ft Alternative. Figure 3H-27 (presented in the discussion of the 6,372-Ft Alternative) shows the modeled dust storm conditions for a 6,377-foot lake level under June 4, 1988 wind conditions. Figure 3H-28 shows the modeled dust storm conditions for a 6,381.3-foot lake level under June 4, 1988 wind conditions.

The magnitude, frequency, and geographic extent of dust storm events under the 6,377-Ft Alternative would be similar to conditions under the point-of-reference. As presented previously in Table 3H-7, $PM_{10}$ concentrations above the state 24-hour standard would be possible in many locations, including the South Tufa, Navy Beach, Simis Ranch, Ten Mile Road, Warm Springs, Simon's Spring, and Cedar Hill areas.

### Summary of Benefits and Significant Impacts and Identification of Mitigation Measures (6,377-Ft Alternative)

- # Causes little change in the magnitude, frequency, and geographic extent of dust storm episodes.

## IMPACTS AND MITIGATION MEASURES FOR THE 6,383.5-FT ALTERNATIVE

### Changes in Resource Condition

The 6,383.5-Ft Alternative would have a relatively narrow range of lake surface elevations under equilibrium conditions. The lake would fluctuate between 6,383 feet and 6,389 feet with a median elevation of about 6,386 feet.

Figure 3H-29 shows the modeled dust storm conditions for a 6,383.5-foot lake level under June 4, 1988 wind conditions. Figure 3H-30 shows the modeled dust storm conditions for a 6,387-foot lake level under June 4, 1988 wind conditions.

The magnitude, frequency, and geographic extent of dust storm events under the 6,383.5-Ft Alternative would be less than conditions under the point-of-reference. As presented previously in Table 3H-7, $PM_{10}$ concentrations above the state 24-hour standard would be possible in the South Tufa, Navy Beach, Simis Ranch, Ten Mile Road, and Warm Springs areas.

### Summary of Benefits and Significant Impacts and Identification of Mitigation Measures (6,383.5-Ft Alternative)

# Significantly decreases the magnitude and geographic extent of dust storm episodes.

# Decreases maximum $PM_{10}$ concentrations by 30% in the South Tufa area, by 40-80% in the Simis Ranch/Ten Mile Road area, and by 20-40% in the Warm Springs area.

# Causes modest decreases in the frequency of dust storm events for Mono Basin as a whole.

## IMPACTS AND MITIGATION MEASURES FOR THE 6,390-FT ALTERNATIVE

### Changes in Resource Condition

The 6,390-Ft Alternative would have a relatively narrow range of lake surface elevations under equilibrium conditions. The lake would fluctuate between 6,389 feet and 6,395 feet with a median elevation of about 6,392 feet. The transition to equilibrium conditions, however, may take 30 years.

Figure 3H-31 shows the modeled dust storm conditions for a 6,390-foot lake level under June 4, 1988 wind conditions. The dust plume contours in Figure 3H-31 look identical to those in Figure 3H-30. This similarity in contours is due to the spacing of modeled receptor points and the procedures used by the computer program that produced the figures. As indicated as Table 3H-7, a lake level of 6,390 feet would in fact adversely affect a smaller area than would a lake level of 6,387 feet.

After reaching equilibrium conditions, the magnitude, frequency, and geographic extent of dust storm events under the 6,390-Ft Alternative would be significantly less than conditions under the point of reference. As presented previously in Table 3H-7, only a few $PM_{10}$ episodes above the state 24-hour standard would be expected in major public use areas or at existing monitoring stations. Modeling results indicate the potential for limited areas of high $PM_{10}$ concentrations along the east side of the lake and on Paoha Island.

### Summary of Benefits and Significant Impacts and Identification of Mitigation Measures (6,390-Ft Alternative)

# Gradually reduces the magnitude, frequency, and geographic extent of dust storm episodes during the 30-year transition to equilibrium lake level conditions.

# After transition to dynamic equilibrium, significantly decreases the magnitude, frequency, and geographic extent of dust storm episodes; few violations of state $PM_{10}$ standards expected at major public use areas or at existing monitoring stations.

## IMPACTS AND MITIGATION MEASURES FOR THE 6,410-FT ALTERNATIVE

### Changes in Resource Condition

The 6,410-Ft Alternative would have a relatively narrow range of lake surface elevations under equilibrium conditions. The lake would fluctuate between 6,408 feet and 6,415 feet with a median elevation of about 6,411 feet. The transition to equilibrium conditions, however, may take 80 years.

Figure 3H-32 shows the modeled dust storm conditions for a 6,400-foot lake level under June 4, 1988 wind conditions. No FDM modeling of higher lake levels was performed.

After reaching equilibrium conditions, the magnitude, frequency, and geographic extent of dust storm events under the 6,410-Ft Alternative would be significantly less than conditions under the point of reference. As presented previously in Table 3H-7, no $PM_{10}$ concentrations above the state 24-hour standard would be expected in major public use areas or at existing monitoring stations. Modeling results indicate the potential for very limited areas of high $PM_{10}$ concentrations on Paoha Island.

### Summary of Benefits and Significant Impacts and Identification of Mitigation Measures (6,410-Ft Alternative)

# Gradually reduces the magnitude, frequency, and geographic extent of dust storm episodes during the 80-year transition to equilibrium lake level conditions.

# After transition to dynamic equilibrium, significantly decreases the magnitude, frequency, and geographic extent of dust storm episodes; no violations of state $PM_{10}$ standards expected at major public use areas or at existing monitoring stations.

## IMPACTS AND MITIGATION MEASURES FOR THE NO-DIVERSION ALTERNATIVE

### Changes in Resource Condition

The No-Diversion Alternative would have a modest range of lake surface elevations under equilibrium conditions. The lake would fluctuate between 6,424 feet and 6,436 feet with a median elevation of about 6,427 feet. The transition to equilibrium conditions, however, may take more than 100 years.

No FDM modeling was performed for lake levels above 6,400 feet. No significant source areas for fugitive dust emissions would remain exposed at lake levels above 6,410 feet.

After reaching equilibrium conditions, all fugitive dust-related violations of state and federal $PM_{10}$ standards would be eliminated.

### Summary of Benefits and Significant Impacts and Identification of Mitigation Measures (No-Diversion Alternative)

- Gradually reduces the magnitude, frequency, and geographic extent of dust storm episodes during the 100-year transition to equilibrium lake level conditions.

- After transition to dynamic equilibrium, eliminates all fugitive dust-related violations of state and federal $PM_{10}$ standards.

## CUMULATIVE IMPACTS OF THE ALTERNATIVES

Cumulative impacts reflect the overall impact of LADWP's Mono Basin water diversions. No other projects or activities are known to have contributed to the dust storm phenomena at Mono Lake. Cumulative air quality impacts have been assessed by comparing conditions under the alternatives with prediversion conditions as summarized in Table 3H-7.

## Significant Cumulative Impacts

### No-Restriction Alternative

The No-Restriction Alternative would allow the lake to decline to levels below 6,365 feet, greatly increasing the amount of unvegetated, exposed substrate subject to wind erosion. No FDM modeling analyses were performed for lake elevations below 6,372 feet. However, it is clear from the modeling analyses for other lake elevations that the No-Restriction Alternative would generate more extensive and more frequent dust storm episodes than would the other alternatives. Modeling results for the other alternatives indicate that the No-Restriction Alternative would produce significant violations of the state and federal 24-hour $PM_{10}$ standards at several locations in Mono Basin, including the South Tufa, Simis Ranch, Ten Mile Road, Warm Springs, Simon's Spring, and the Cedar Hill areas.

### 6,372-Ft Alternative

As is indicated by the summary of FDM modeling results presented in Table 3H-7, the 6,372-Ft Alternative would generate extensive dust storm episodes. Modeling results for the 6,372-Ft Alternative indicate that violations of the state and federal 24-hour $PM_{10}$ standards would be likely in several portions of Mono Basin, including the South Tufa, Simis Ranch, Ten Mile Road, Warm Springs, Simon's Spring, and the Cedar Hill areas. The 6,372-Ft Alternative would have significant and unavoidable cumulative air quality impacts.

### 6,377-Ft Alternative

As is indicated by the summary of FDM modeling results presented in Table 3H-7, the 6,377-Ft Alternative would generate extensive dust storm episodes. Modeling results for the 6,377-Ft Alternative indicate that violations of the state and federal 24-hour $PM_{10}$ standards would be likely in several portions of Mono Basin, including the Simis Ranch, Ten Mile Road, Warm Springs, Simon's Spring, and the Cedar Hill areas. Modeling results also suggest the possibility of occasional violations of the state $PM_{10}$ standard in the South Tufa area. The 6,377-Ft Alternative would have significant and unavoidable cumulative air quality impacts.

### 6,383.5-Ft Alternative

As is indicated by the summary of FDM modeling results presented in Table 3H-7, the 6,383.5-Ft Alternative would generate significant dust storm episodes. Dust storm episodes would be less frequent and less severe than conditions for lower lake levels, but would still occur several times a year. Modeling results for the 6,383.5-Ft Alternative indicate that violations of the state 24-hour $PM_{10}$ standards would be likely in several portions of Mono Basin, including the South Tufa, Navy Beach, Simis Ranch, Ten Mile Road, Warm Springs, and Simon's Spring areas. Violations of the federal 24-hour $PM_{10}$ standard would be most likely in the Warm Springs, Simis Ranch, and Ten Mile Road areas. The 6,383.5-Ft Alternative would have significant and unavoidable cumulative air quality impacts.

**6,390-Ft Alternative**

As is indicated by the summary of FDM modeling results presented in Table 3H-7, the 6,390-Ft Alternative would have a limited potential to generate dust storm episodes once the lake reached equilibrium conditions. The 30-year transition period to equilibrium lake levels would, however, have dust storm episodes of variable intensity. After reaching equilibrium conditions, few $PM_{10}$ concentrations above the state 24-hour standard would be expected in major public use areas or at existing monitoring stations. Modeling results indicate the potential for limited areas of high $PM_{10}$ concentrations along the east side of the lake and on Paoha Island.

The 6,390-Ft Alternative would have significant and unavoidable cumulative air quality impacts during the transition to equilibrium lake levels, but would bring Mono Basin very close to (and possibly into) attainment of the state and federal $PM_{10}$ standards.

**6,410-Ft Alternative**

As is indicated by the summary of FDM modeling results presented in Table 3H-7, the 6,410-Ft Alternative would have little or no potential to generate dust storm episodes once the lake reached equilibrium conditions. At least the first half of the 80-year transition period to equilibrium lake levels would, however, have dust storm episodes of variable intensity. After reaching equilibrium conditions, no $PM_{10}$ concentrations above the state or federal 24-hour standard would be expected in major public use areas or at existing monitoring stations. The mapped distribution of major fugitive dust source areas indicates that equilibrium lake levels would cover essentially all major dust sources.

The 6,410-Ft Alternative would have significant and unavoidable cumulative air quality impacts during part of the transition to equilibrium lake levels, but would eventually bring Mono Basin into attainment of the state and federal $PM_{10}$ standards.

**No-Diversion Alternative**

The No-Diversion Alternative would have little or no potential to generate dust storm episodes once the lake reached equilibrium conditions. At least the first half of the 100-year transition period to equilibrium lake levels would, however, have dust storm episodes of variable intensity. After reaching equilibrium conditions, no fugitive dust-related $PM_{10}$ concentrations above the state or federal 24-hour standard would be expected in Mono Basin.

The No-Diversion Alternative would have significant and unavoidable cumulative air quality impacts during part of the transition to equilibrium lake levels, but would eventually bring Mono Basin into attainment of the state and federal $PM_{10}$ standards.

### Mitigation Measures for Significant Cumulative Impacts

No practical mitigation measures have been identified for stabilizing efflorescent salt and lakebed sediments that constitute the major sources of windblown particulate matter in Mono Basin.

## CITATIONS

### Printed References


Alderman, S. S., Jr. 1985. Geology of the Owens Lake evaporite deposit. Pages 75-83 in B. C. Schreiber and H. L. Harner (eds.), Sixth International Symposium on Salt. Volume I. The Salt Institute. Alexandria, VA.

Balance Hydrologics, Inc. 1992. Interactions between surface and groundwater in wetlands developed on lakebeds exposed since 1940 at Mono Lake. (Mono Basin EIR Auxiliary Report No. 19.) California State Water Resources Control Board. Sacramento, CA.

Benson, P. E. 1979. CALINE3 - a versatile dispersion model for predicting air pollutant levels near highway and arterial streets. Interim report. (FHWA/CA/TL-79/23). California Department of Transportation. Sacramento, CA.

Blanchard, D. C. and A. H. Woodcock. 1980. The production, concentration, and vertical distribution of the sea-salt aerosol. Pages 330-347 in T. J. Kneip and P. J. Lioy (eds.), Aerosols: anthropogenic and natural, sources and transport. (Annals of the New York Academy of Sciences, Volume 338.) New York Academy of Sciences. New York, NY.

Bowers, J. F., J. R. Bjorklund, and C. S. Cheney. 1979. Industrial source complex (ISC) dispersion model user's guide. (EPA 450/4-79-030; PB80-133044 and PB80-133051.) National Technical Information Service. Springfield, VA.

Browne, J. R. 1961. J. Ross Browne's illustrated mining adventures: California and Nevada, 1863-1865. Paisano Press. Balboa Island, CA.

Cahill, T. A., and T. E. Gill. 1987. Air quality at Mono Lake. Air Quality Group, Crocker Nuclear Laboratory, University of California. Davis, CA. Prepared for Community and Organization Research Institute (CORI), University of California, Santa Barbara, CA.

California Air Quality Data. 1979-1991. Volumes XI (1979) to XXIII (1991), annual summaries.

California Air Resources Board. 1991. Prospects for attaining the state ambient air quality standards for suspended particulate matter ($PM_{10}$), visibility reducing particles, sulfates, lead, and hydrogen sulfide. Technical Support Division. Sacramento, CA.

Chase, J. S. 1911. Yosemite trails. Camp and pack-train in the Yosemite region of the Sierra Nevada. Houghton Mifflin Company. Boston, MA.

Chepil, W. S. 1958. Soil conditions that influence wind erosion. (U.S. Department of Agriculture Technical Bulletin No. 1185.) Government Printing Office. Washington, DC.

Chesterman, C. W., and C. H. Gray. 1966. Geology and structure of the Mono Basin, Mono County, California. Pages 11-18 in J. R. Evans (ed.), Guidebook along the east-central front to the Sierra Nevada: annual field trip of the Geological Society of Sacramento, June 18-19, 1966. Sacramento, CA.

Climatological Data: California. 1987. Annual summary. Volume 91(13). National Climatic Data Center. Ashville, NC.

Gillette, D. 1980. Major contributions of natural primary continental aerosols: source mechanisms. Pages 348-358 in T. J. Kneip and P. J. Lioy (eds.), Aerosols: anthropogenic and natural, sources and transport. (Annals of the New York Academy of Sciences, Volume 338.) New York Academy of Sciences. New York, NY.

Jones & Stokes Associates. 1993. [Dust storm modeling impacts and results.] (JSA 89-171.) (Mono Basin EIR Auxiliary Report 16.) Sacramento, CA.

Kusko, B. H., J. B. Barone, and T. A. Cahill. 1981. The effect of Mono Lake on the air quality in the Mono Lake region. (Final report, Contract A9-147-31.) Air Quality Group, Crocker Nuclear Laboratory, University of California. Davis, CA. Prepared for the California Air Resources Board, Sacramento, CA.

Kusko, B. H., and T. A. Cahill. 1984. Study of particle episodes at Mono Lake. (Final report, Contract A1-144-32.) Air Quality Group, Crocker Nuclear Laboratory, University of California. Davis, CA. Prepared for the California Air Resources Board, Sacramento, CA.

Lajoie, K. R. 1968. Quaternary stratigraphy and geologic history of Mono Basin, Eastern California. M.S. thesis. University of California. Berkeley, CA.

Los Angeles Department of Water and Power. 1987. Mono Basin geology and hydrology. Aqueduct Division. Los Angeles, CA.

McCrone, W. C., and J. G. Delly. 1973. The particle atlas: an encyclopedia of techniques for small particle identification. Edition two. Volume III: the electron microscope atlas. Ann Arbor Science Publishers. Ann Arbor, MI.

Mining and Scientific Press (San Francisco). 1865. A visit to Mono Lake - the Dead Sea of the west. XI(14):210. October 7, 1865.

Monahan, E. C., C. W. Fairall, K. L. Davidson, and P. J. Boyle. 1983. Observed inter-relations between 10 m winds, ocean whitecaps and marine aerosols. Quarterly Journal of the Royal Meteorological Society 109:379-392.

Olhoeft, G. R., and G. R. Johnson. 1989. Densities of rocks and minerals. Pages 138-176 in R. S. Carmichael, (ed.), CRC practical handbook of physical properties of rocks and minerals. CRC Press. Boca Raton, FL.

Pye, K. 1987. Aeolian dust and dust deposits. Academic Press. Orlando, FL.

Rogers, D. B., and S. J. Dreiss. 1991. Variable density groundwater flow near a closed-basin saline lake: a case study at Mono Lake, California. (Final project report, U.S. Geological Services, Grant No. 14-08-0001-G1652.) Earth Sciences Board, University of California. Santa Cruz, CA.

Russell, I. C. 1984. Quaternary history of Mono Valley, California. Reprinted from pages 267-394 of the Eighth Annual Report of the United States Geological Survey, 1889. Artemsia Press. Lee Vining, CA.

Saint-Amand, P., L. A. Mathews, C. Gaines, and R. Reinking. 1986. Dust storms from Owens and Mono Valleys, California. (NWC TP 6731.) Naval Weapons Center. China Lake, CA.

Scholl, D. W., R. von Huene, and P. Saint-Amand. 1966. Geology of Mono Lake. Pages 22-41 in J. R. Evans (ed.), Guidebook along the east-central front to the Sierra Nevada: annual field trip of the Geological Society of Sacramento, June 18-19, 1966. Sacramento, CA.

Smith, G. I., and I. Friedman. 1986. Seasonal diagenic changes in salts of Owens Lake, California, 1970-1977. Pages 21-29 in F. A. Mumpton (ed.), Studies in diagenesis. (U.S. Geological Survey Bulletin 1578.) U.S. Geological Survey. Denver, CO.

Smith, G. I., I. Friedman, and R. J. McLaughlin. 1987. Studies of Quaternary saline lakes. Volume III. Mineral, chemical, and isotopic evidence of salt solution and crystallization processes in Owens Lake, California, 1969-1971. Geochimica et Cosmochimica Acta 51:811-827.

Stensvaag, J. 1991. Clean Air Act 1990 amendments: law and practice. John Wiley & Sons. New York, NY.

Stern, A. C. 1982. History of air pollution legislation in the United States. Journal of the Air Pollution Control Association 32(1):44-61.

Stine, S. 1980. A reinterpretation of the 1857 surface elevation of Mono Lake. (Report No. 52.) California Water Resources Center, University of California. Davis, CA.

___________. 1989. Late Holocene fluctuations of Mono Lake, eastern California. Elsevier Science Publications 78(1990):333-381.

___________. 1992. Distribution of substrate types at Mono Lake. (Mono Basin EIR Auxiliary Report No. 20.) California State Water Resources Control Board. Sacramento, CA.

___________. 1993. Historic and modern distribution of shore-fringing wetlands, Mono Lake, California. (Mono Basin EIR Auxiliary Report No. 21.) California State Water Resources Control Board. Sacramento, CA.

U.S. Forest Service. N.d. Soil survey data for Mono Basin. Mono Lake Ranger District. Lee Vining, CA.

U.S. Soil Conservation Service. N.d. Preliminary soil survey data for Mono and Owens Basins. Bishop, CA.

Wagner, C. P. 1987. Industrial source complex (ISC) dispersion model user's guide. Second edition (revised). (EPA-450/4-88-002a and EPA-450/4-88-002b.) U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC.

Warren, A. 1979. Aeolian processes. Pages 325-351 in C. Embleton and J. Thornes (eds.), Process in geomorphology. Halsted Press. New York, NY.

Winges, K. D. 1990. User's guide for the fugitive dust model (FDM) (revised). Volume I: user's instructions. (EPA-910/9-88-202R.) U.S. Environmental Protection Agency, Region 10. Seattle, WA.

World Meteorological Organization. 1983. Meteorological aspects of certain processes affecting soil degradation - especially erosion. (Technical Note No. 178; WMO No. 591.) Secretariat of the World Meteorological Organization. Geneva, Switzerland.

Zobeck, T. M. 1991. Soil properties affecting wind erosion. Journal of Soil and Water Conservation 46(2):112-118.

### Personal Communications

Cox, Bill. Director of technical services. Great Basin Unified Air Pollution Control District, Bishop, CA. April 24, 1992 - meeting at Mono Lake.

Stine, Scott. Consulting geologist. Berkeley, CA. December 29, 1992 - meeting at Jones & Stokes Associates' office to review 1929/1930 and 1940 aerial photographs of Mono Lake.