CHAPTER 4

PM_{10} Emissions Inventory

FIGURES

TABLES

4

PM_{10} Emissions Inventory

4.1 INTRODUCTION

Criteria pollutant emissions in the Owens Valley PM_{10} nonattainment area are dominated by PM_{10} emissions from wind erosion on the exposed Owens Lake playa. Other wind erosion sources in the Owens Valley Planning Area include off-lake sources of lake bed dust, small mining facilities and open areas near Lone Pine and Independence that have been disturbed by human activity, including Inyo County's Lone Pine landfill. There is a lack of large industrial sources in the Owens Valley and the only other sources of criteria pollutant emissions are wood stoves, fireplaces, unpaved and paved road dust and vehicle tailpipe emissions. Prescribed burning for wildland management on federal and private lands also generates PM_{10} in and around the nonattainment area. However, prescribed burning is not normally conducted on windy days when Owens Lake dust storms occur. Predicted high wind days are avoided when doing prescribed burns for fire safety reasons.

The emissions inventory includes PM_{10} sources within the expected control area for the plan. This covers the southern half of the designated nonattainment area, which includes the community of Lone Pine on the control area's northern boundary. The future emissions inventory is not expected to grow significantly for population-based sources. Changes to future population and traffic-related emissions are expected to be insignificant in comparison to the wind-blown PM_{10} from Owens Lake. The Inyo County population actually declined 1.6 percent between 1990 and 2006 (from 18,281 to 17,988) (US Census Bureau, 2007).

The annual PM_{10} emissions for the Owens Valley PM_{10} Planning Area are shown in Figure 4.1 for the 2006 emissions inventory base-year. This base-year emissions inventory replaces the 2000 base year inventory that was used for the 2003 SIP. A special effort was made to estimate PM_{10} emissions due to wind erosion from the Owens Lake bed. Except for the off-lake dunes, PM_{10} emissions for other wind erosion areas are not included in the inventory. These dust source areas are usually sporadic and are very small in comparison to dust from the Owens Lake bed. However, along with other area and point sources these emissions are included as a contributor to the background concentration (20 $\mu g/m^3$) in the air quality model.

4.2 NON-OWENS LAKE PM_{10} EMISSIONS

4.2.1 Entrained Paved Road Dust and Vehicle Exhaust Emissions for Mobile Sources

PM_{10} emissions from paved road dust are based on estimates from the California Air Resources Board (CARB) for the 2005 emissions inventory. CARB estimates annual PM_{10} emissions of 336 tons of PM_{10} per year (0.92 tons per day) in Inyo County. PM_{10} emissions from vehicle exhaust were estimated at 0.04 tons per day (T/d) in Inyo County for 2005 (CARB, 2007a).

Assuming that vehicle traffic in the emissions inventory planning area is primarily on Highway US 395, a simple proportion of the mileage in the control area to the length of US 395 in Inyo County yields a good estimate of the PM_{10} 24-hour and annual emissions from mobile sources.

Entrained Road Dust:
(30 miles/115 miles) x 0.92 T/d = 0.24 tons of PM_{10} per day
0.24 T/d x 365 days = 87.6 tons of PM_{10} per year

Vehicle Exhaust:
(30 miles/115 miles) x 0.04 T/d = 0.010 Tons of PM_{10} per day
0.010 T/d x 365 days =3.65 tons of PM_{10} per year

Future emissions can be estimated based on the forecasted change in vehicle miles traveled for Inyo County. The California Department of Transportation forecasts a 15 percent increase in total vehicle miles traveled in Inyo County from 2005 through 2020 (Caltrans, 2005). Assuming that future projections for entrained road dust and vehicle tailpipe emissions will be proportional to the change in vehicle miles traveled, future emissions for these categories are shown below.

Year	Vehicle Mile Traveled Per Year (millions)	Entrained Road Dust (Tons PM_{10}/ year)	Vehicle Exhaust (Tons PM_{10}/Year)
2005	512	87.6	3.65
2010	536	91.7	3.82
2015	568	97.2	4.05
2020	589	100.8	4.20

4.2.2 Entrained Unpaved Road Dust

An estimate of PM_{10} emissions for reentrained road dust from unpaved roads is based on emission factors found in the USEPA's *Compilation of Air Pollutant Emission Factors, AP-42.* Note that this emission factor equation has been revised since the 2003 SIP (USEPA, 2006a).

Equation 4.1

$$E = \frac{k\left(s/12\right)^{a}\left(S/30\right)^{d}}{\left(M/0.5\right)^{c}} - C$$

Where: E = PM_{10} emissions in pound per vehicle mile traveled
s = silt content of road surface material (5 percent)
S = mean vehicle speed (30 miles per hour)
M = surface material moisture content (assume 0.3% from lake bed sand)
C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear (0.00047 for PM_{10}).

For PM_{10} from public unpaved road: $k = 1.8$, $a = 1$, $d = 0.5$ and $c = 0.2$

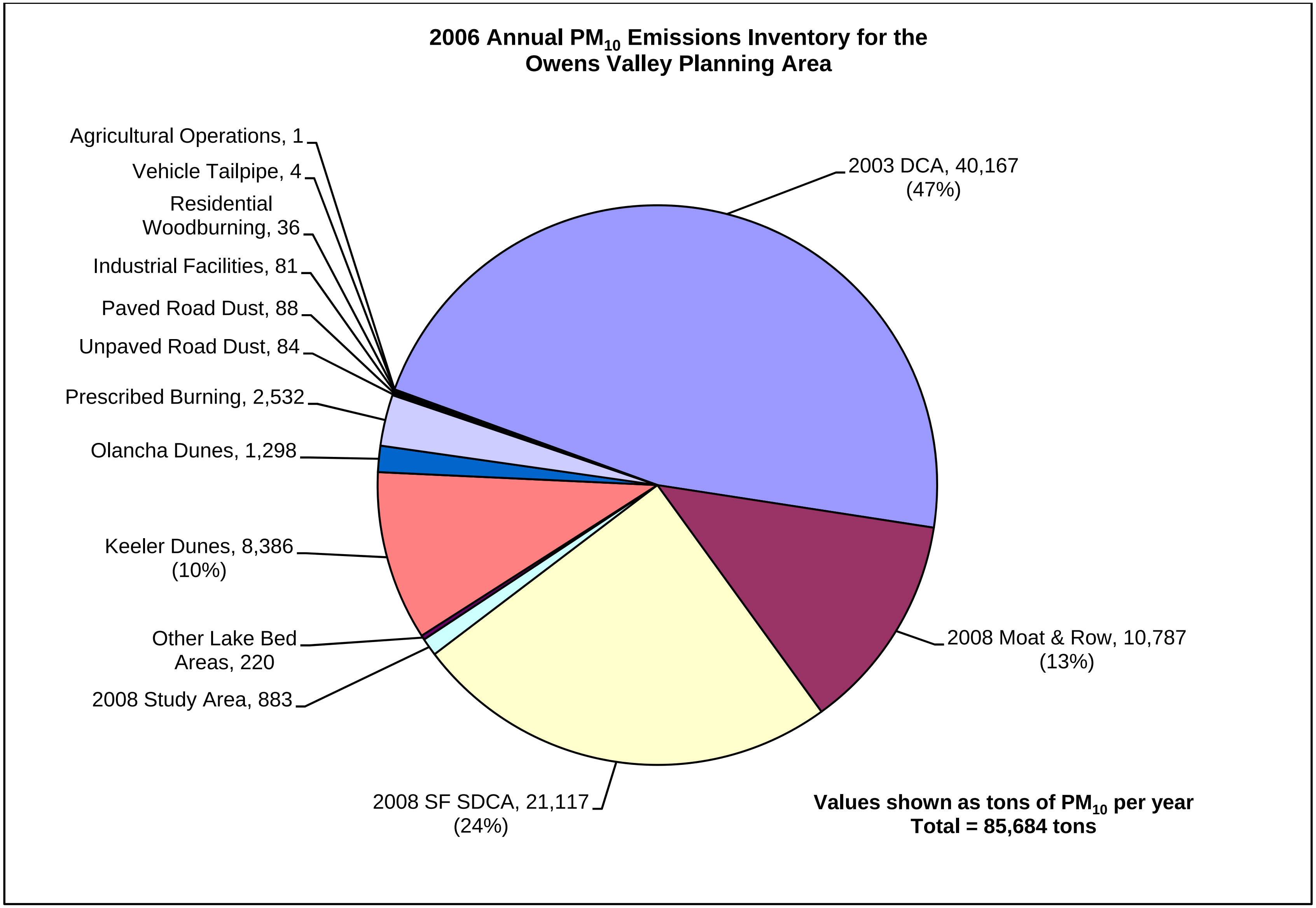


Figure 4.1 – 2006 annual PM$_{10}$ emissions inventory for the Owens Valley Planning Area

BLANK PAGE

The appropriate values for each variable in the emission estimate are shown above. The 5 percent silt content value is based on samples taken in the Owens Lake area from the Cerro Gordo Road and Keeler, which showed the silt content ranged from 1 to 6 percent (Murphy, 1997).

One emission estimate was made for local residents who travel on unpaved roads near Lone Pine and Owens Lake, and another was done for vehicle traffic associated with Owens Lake bed operations conducted by the Los Angeles Department of Water and Power (City). For local residents, emission estimates are based on the assumption that there may be as many as 50 vehicles per day, with an average trip length of 10 miles. Since the population has been relatively stable in Inyo County, there is no forecasted growth or decline for travel on unpaved roads for future years due to local residents. The estimated population growth in Inyo County from 2000 through 2006 is 0.2 percent as compared to 7.6 percent for California for the same period. (US Census Bureau, 2007) This yields 0.21 tons of PM_{10} per day, or 76 tons of PM_{10} per year.

For operations conducted by the City, there has been a substantial increase in traffic around Owens Lake for the construction and operation of dust control measures on the lake bed and for the Lower Owens River Project. It is assumed that for ongoing maintenance operations that the current level of traffic will decrease and that there may be about 20 vehicles per day with an average trip length of 10 miles on lake bed roads. As part of the Owens Lake dust control program, the City is required to control dust from the roads on a regular basis. The main lake bed roads are graveled and water trucks are used to reduce dust from the unpaved roads. Assuming that watering the unpaved roads raises the average surface moisture content from 0.3 percent to 2 percent, this will reduce estimated emissions by about 75 percent according to estimates based on the methodology in USEPA's AP-42 (USEPA, 2006b). This yields 0.02 tons of PM_{10} per day, or 8 tons of PM_{10} per year from traffic associated with ongoing maintenance of dust control measures at Owens Lake. Combined with travel for local residents the overall PM_{10} emission estimate for unpaved roads is 0.23 tons per day and 84 tons per year.

4.2.3 Residential Wood Combustion

The AP-42 emission factor for wood stoves is 15 grams of PM_{10} per kilogram of wood burned. An estimate of residential wood combustion emissions for the planning area can be made by using the wood usage estimate of 2 cords of pine per year (density = 800 kg/cord) for Bishop, which is 60 miles north of the control area. The heating season is about 150 days per year. The population estimate for the area is 2,745. A high-end estimate for the number of wood stoves is one for every two people (1,372.5 stoves). This yields an estimate of 0.24 tons of PM_{10} per day and 36.3 tons of PM_{10} per year for residential wood combustion in the control area.

Since the population has been relatively stable in Inyo County between 2000 and 2006 (less than 0.2%), there is no forecasted growth or decline for these emission estimates for future years. (US Census Bureau, 2007)

4.2.4 Prescribed Burning Emissions and Regulations

Prescribed burning activities will take place on federal lands for forest management and private lands for rangeland improvement and wildland management purposes. The U.S. Forest Service provided air pollution emission estimates for historic pre-settlement smoke emissions in the Owens Valley PM_{10} nonattainment area (McKee, 1996). The Forest Service plans to increase prescribed burning activities in the national forest to a level that is comparable to historic natural forest fire cycles in the Eastern Sierra. Based on the Forest Service's fuel models and the historic fire return rate to forest land in the Owens Valley PM_{10} nonattainment area, an annual average estimate of 2,532 tons per year of PM_{10} is determined. As the burn season for prescribed burning is expected to last about 60 days per year, daily average emissions will be about 42.2 tons per day.

The inclusion of these emission estimates for prescribed burning is for SIP conformity purposes to ensure that prescribed burning activities in the nonattainment area have been considered in the Owens Valley PM_{10} SIP attainment demonstration. General conformity requirements contained in District Regulation XIII, require that federal actions and federally funded projects conform to SIP rules and that they do not interfere with efforts to attain federal air quality standards.

Prescribed burning activities are not expected to take place on windy days when Owens Lake dust storms might occur. Predicted high wind days are avoided when performing prescription burns for fire safety reasons. In addition, prescribed burning is regulated through District Rules 410 and 411 for wildland and forest management burning. These rules require that a burn plan be submitted to the Air Pollution Control Officer prior to conducting the burn, and that burning will not cause or contribute to violations of the air quality standards. In addition, in 2005 the District entered into an agreement with the Inyo National Forest and the Bureau of Land Management to implement wildland fire smoke management actions that specifically limit the smoke impacts in Eastern Sierra communities (GBUAPCD, 2005). If prescribed burning is done in a manner that complies with District rules, burning activities are not expected to interfere with attainment of the PM_{10} NAAQS in the Owens Valley.

4.2.5 Industrial Facilities

Emissions from industrial facilities are based on permitted emissions under each facility's daily permit limit for throughput or operating hours. Annual emissions are extrapolated from peak daily emissions over a 351-day work year. There are 3 industrial facilities in the planning area near Owens Lake: Big Pine Distributors (21 tons/yr), Pacific Lightweight Product (32 tons/yr) and Federal White Aggregate (28 tons/yr). Total PM_{10} emissions from industrial facilities are 0.23 tons of PM_{10} per day and 81 tons per year.

4.2.6 Agricultural Operations

There are very few agricultural operations near Owens Lake. In the area south of Lone Pine and north of Haiwee reservoir, there are about 200 acres of pastureland and 20 acres of alfalfa. Emissions for agricultural operations are less than 1 ton of PM_{10} per year using estimates provided by the California Air Resources Board. (CARB, 1997 and Keisler, 1997). There is no significant change foreseen for agricultural operations in the planning area.

4.3 LOCATING AND ESTIMATING WIND-BLOWN DUST PM_{10} EMISSSIONS

4.3.1 Dust ID Program Overview

Because wind erosion is the dominant source of PM_{10} in the planning area, a significant effort was made to improve the methods used to estimate emissions and to locate the sources of dust on the lake bed. Traditional methods of estimating emissions such as the use of wind tunnel generated emission estimates and methods described in USEPA's AP-42 were investigated prior to developing the Dust ID method that is discussed in this section. The 1998 Owens Valley SIP used emission algorithms based on wind tunnel tests performed at Owens Lake. PM_{10} emissions were estimated for different seasons as a function of wind speed (Ono, 1997). With the wind tunnel method, the size of the dust producing area was fixed at 35 square miles, and it was assumed that dust would be produced whenever winds were greater than 17 miles per hour. Although these assumptions were adequate for modeling the largest dust events, smaller events were overestimated due to smaller erosion areas, and variable threshold wind speeds. The U.S. EPA suggests another approach to estimate PM_{10} due to wind erosion using methods contained in AP-42 (USEPA, 2006b). The AP-42 approach also has the same shortfalls as the wind tunnel method since it assumes a fixed threshold wind speed for a fixed area size. Ono, *et al*. (2003b) compared the daily emission estimates using AP-42 to those generated using the Dust ID method and found that the AP-42 method often predicted significant emissions when no erosion activity was detected at Owens Lake, and significantly underestimated emissions for the largest dust events. A new method was needed that could account for the changing threshold wind speeds and could also locate the source of the emissions. Ideally, such a method would provide hourly PM_{10} emissions from each area of the lake bed and could be used in an air quality model to determine which areas of the lake bed were causing or contributing to violations of the PM_{10} NAAQS.

The District initiated a field monitoring program at Owens Lake in 1999 to identify dust source areas and to estimate their PM_{10} emissions and air quality impacts. This monitoring program is known as the Owens Lake Dust Source Identification Program (Dust ID Program). The Dust ID Program follows the data collection and analysis procedures described in the Owens Lake Dust ID Field Manual (GBUAPCD, 2007). Data collected from the Dust ID Program from January 2000 through June 2002 were used to identify the 29.8 square miles of dust source areas that were controlled through the 2003 SIP. Data and observations for the period from July 2002 through June 2006 were used to estimate PM_{10} emissions and air quality impacts that were used to identify the 13.2 square miles of dust control areas proposed for this 2008 SIP control strategy.

The Dust ID Program design was based on previous observations and field studies that suggested that PM_{10} emissions are related to the flux of saltating sand-sized particles. As shown conceptually in Figure 4.2, wind erosion involves particles that creep along the surface, and sand-sized particles or agglomerates that bounce or saltate across the surface. These creeping and saltating particles loosen other particles and abrade the surface, causing finer particles, including PM_{10} to go into suspension. Near the surface, creeping and saltating sand-sized particles are blown horizontally and finer dust particles are ejected and mix vertically in the turbulent air stream to form visible dust plumes. Previous research at Owens Lake and in other areas showed that the vertical flux of PM_{10} dust emissions is generally proportional to the horizontal flux of sand or saltation particles. Using this assumption, PM_{10} emissions were estimated from sand flux measurements that were taken with instruments placed in the saltation zone, which may range from the ground to about one meter above the surface. As discussed later in this section, the proportion of PM_{10} associated with the sand flux was later inferred by comparing monitored PM_{10} concentrations with the predicted concentrations from an air quality model.

Hourly sand flux rates are measured using electronic sensors and passive sand catchers that are placed on the lake bed. In 2001, there were 135 sand flux monitoring sites on the lake bed. They were initially spaced 1 kilometer apart in areas that were likely to produce dust. The monitoring network was increased every year and the monitoring density was increased in some areas to improve emission estimates for those areas. The maps in Figures 4.3 and 4.4 show the configuration of the Dust ID monitoring network in 2002 and 2006.

The proportion of PM_{10} to sand flux was found to increase during winter and spring, and was found to vary spatially on the lake bed with different soil textures. The proportionality factor, known as the K-factor (K_f), was used to estimate PM_{10} emissions at Owens Lake using Equation 4.2.

Equation 4.2

$$PM_{10} = K_f \times q$$

Where,

q = Sand flux measured at 15 cm above the surface [g/cm^2/hr]

K_f = K-factor, empirical ratio of the vertical PM_{10} emission flux to the horizontal sand flux at 15 cm.

Sand flux was measured using Cox Sand Catchers (CSCs), which are passive sand collectors, and Sensits, which are electronic erosion measurement devices. The Sensits were used to time-resolve the CSC mass to provide hourly sand flux. Sand flux was measured at 15 cm above the surface to represent a measurement of the total horizontal sand flux at the site. An analysis of the total horizontal sand flux measured from the surface to one meter showed that the sand flux at 15 cm was proportional to the total sand flux with very little deviation (Ono, *et al*., 2003a, and Gillette, *et al*., 2004).

The Dust ID network currently provides hourly PM_{10} emissions and source area information for dust source areas that are modeled as a series of grid cells that are 250 m by 250 m. In comparison, most air quality models used for PM_{10} SIPs lack good spatial information, and use 24-hour temporal resolution for their PM_{10} emission inventories. The fine-scale spatial and temporal resolution for the Owens Lake inventory was very useful for modeling wind-blown dust using the CALPUFF air quality model (Scire, *et al.*, 2000). The methods and results of the Dust ID Program are discussed in Chapters 6 and 7. Additional details can be found in Chapter 8 (Attachment C), Appendix B, Ono, *et al*., 2003a, Richmond *et al*., 2003 and the Owens Lake Dust ID Field Manual (GBUAPCD, 2007).

4.3.2 Sand Flux Measurements

Co-located Sensits and CSCs were used to determine hourly sand flux rates for each dust source area. Sensits are electronic sensors that measure the kinetic energy and the particle counts of sand-sized particles as they bounce across the surface. Due to differences in the electronic response of individual Sensits, each was co-located with a CSC to compare each Sensit output against the CSC-collected mass. An example of the linear relationship between the CSC mass and the output from a co-located Sensit is shown in Figure 4.5. By using collocated instruments, the CSC mass could be time-resolved to provide an hourly sand flux rate.

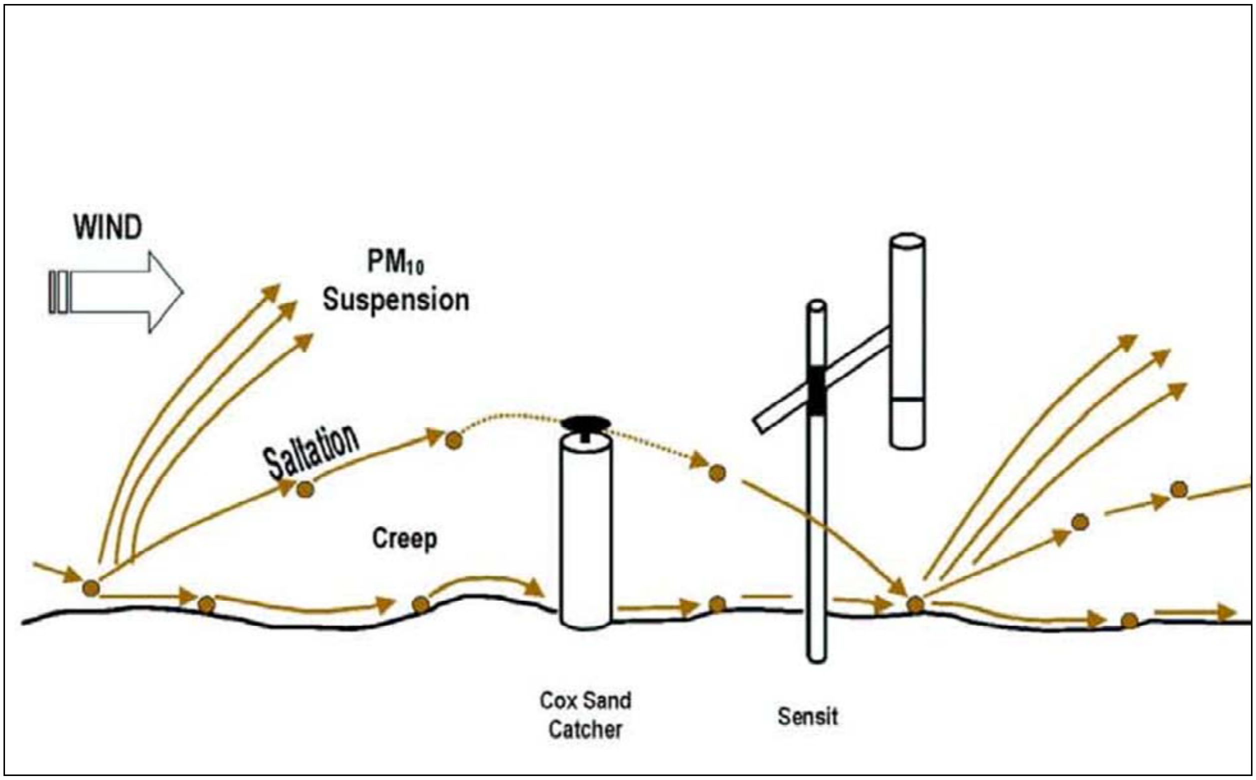


Figure 4.2 - Conceptual depiction of the wind erosion process with a Cox Sand Catcher and Sensit positioned in the saltation zone to measure sand flux

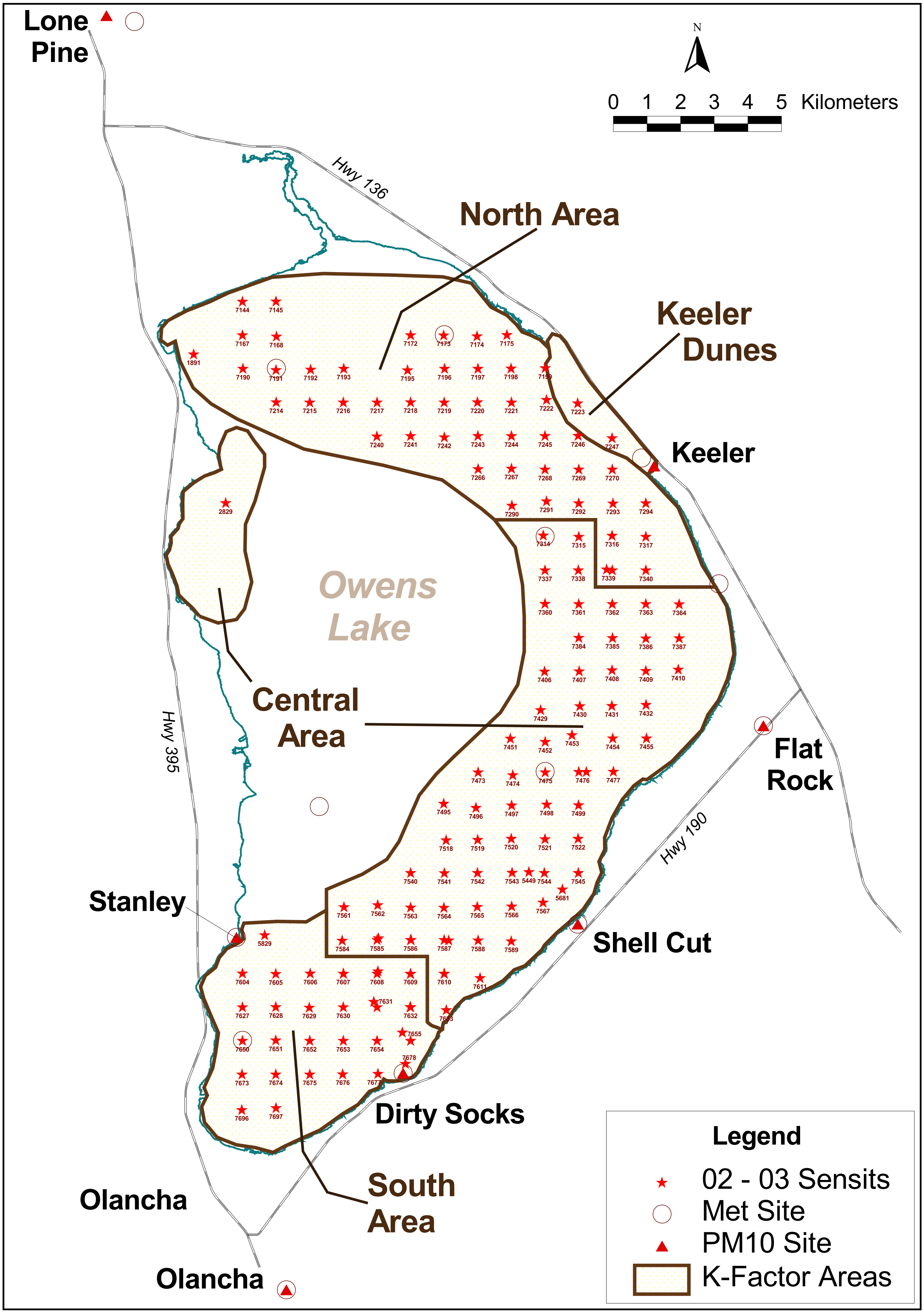


Figure 4.3 - Owens Lake Dust ID monitoring network 2002-2003

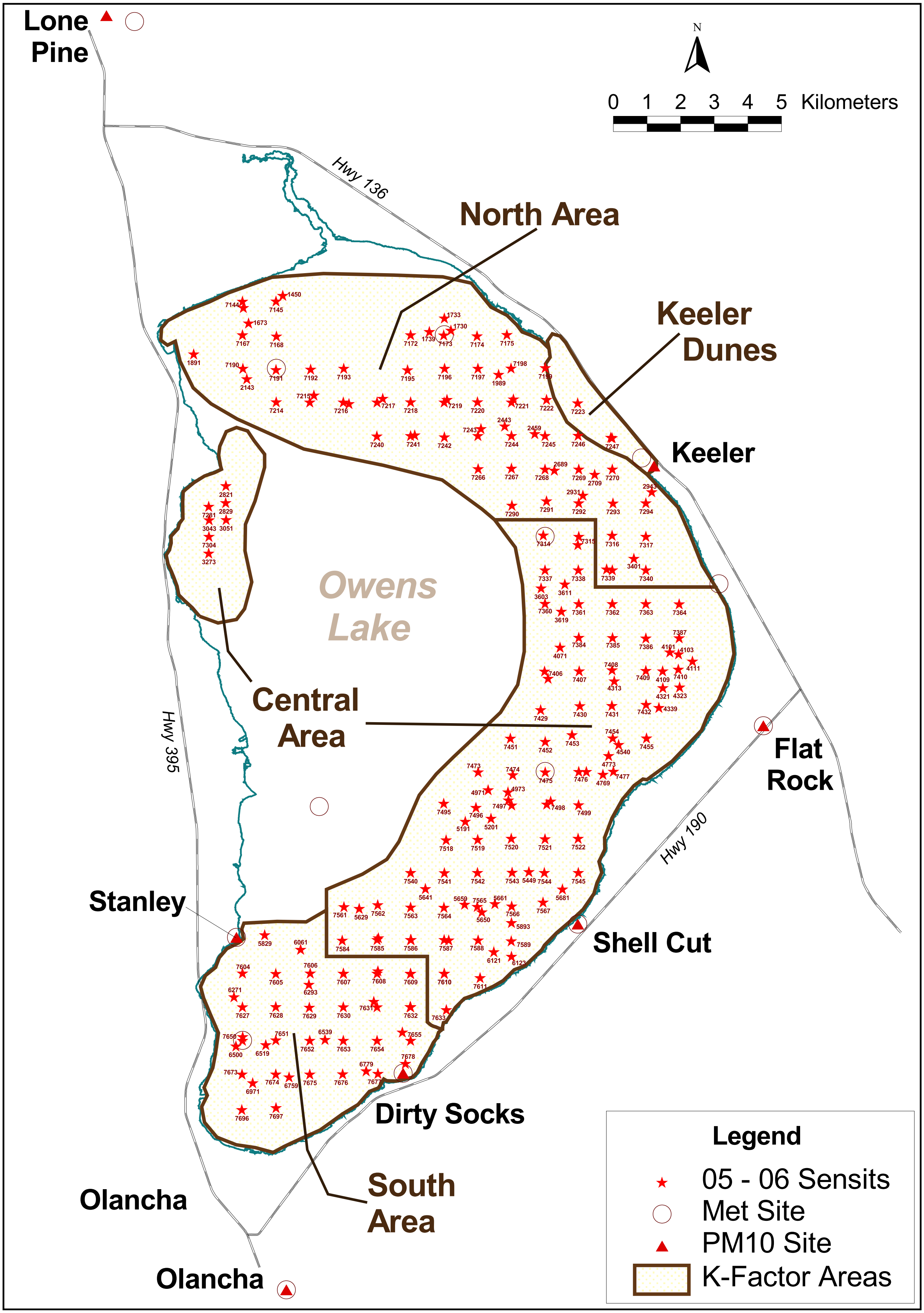


Figure 4.4 - Owens Lake Dust ID monitoring network 2005-2006

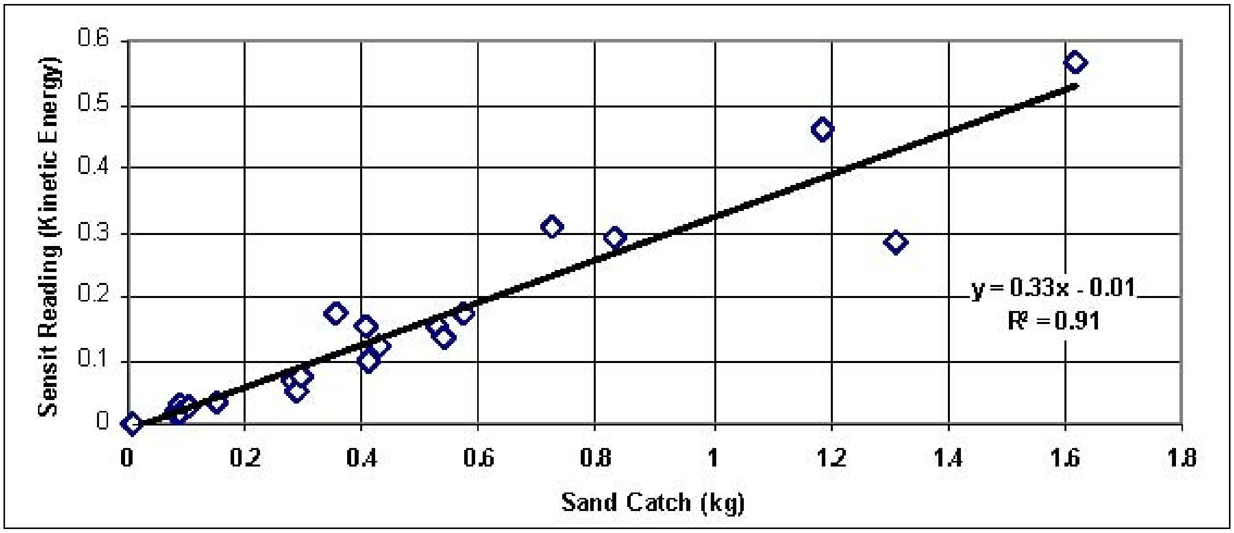


Figure 4.5 – An example of the linearity between CSC mass and Sensit readings (Sensit No. 7291 using total kinetic energy)

Figure 4.6 shows a Sensit suspended above the ground and a CSC in the ground to the left. Sensits are battery-powered with solar charging systems. A datalogger records 5-minute average data during active erosion periods. Data from the dataloggers are sent daily by radio transmission to the District's Keeler Office.

CSCs are passive instruments that capture sand-sized particles that are blown across the surface during a dust event. These instruments were designed and built by the District as reliable instruments that can withstand the harsh conditions at Owens Lake. CSCs have no moving parts and can usually collect sand for a month or more at Owens Lake without overloading the collectors. Field personnel must visit each CSC site to collect and weigh the sand catch. A diagram of the CSC is shown in Figure 4.7. The internal sampling tube and a height adjustment sleeve can be seen in the photo in Figure 4.8. The internal sampling tube is removed from the PVC casing to measure the sand catch sample. The lengths of the sampling tubes and casings are adjusted during construction to accommodate the amount of sand flux in each area and to avoid overloading the CSCs. The CSC length ranges from about 2 to 4 feet. Because the PVC casing is buried in the ground, an adjustment sleeve is used to keep the inlet height at 15 cm to compensate for surface erosion and deposition.

4.3.3 Source Area Mapping

The Dust ID Program includes four methods to locate dust source areas and to delineate the source area boundaries. The methods are: 1) visual mapping by trained observers, 2) time-lapse cameras, 3) surface inspections with GPS mapping, and 4) sand flux activity (as measured with Sensits and CSCs).

- Mapping Dust Source Areas from Off-Lake Observation Sites

During dust events, trained observers are stationed at viewpoints to create hourly maps of the visible boundaries of any dust source areas, their plume direction and note if the visible plume crosses the shoreline. To the extent practicable, all lake bed and off-lake dust sources are included in the observations. Figure 4.9 shows an example of sand flux measurements and the cumulative information that can be collected by observers mapping the dust plumes from different locations.

- Time-lapse Video

Remote time-lapse video cameras record dust events during daylight hours. This information is reviewed to help identify source areas that may have been missed by observers, or to help confirm source area activity detected by PM_{10} monitors or the sand flux network. Remote time-lapse video is also used to help verify modeled impacts that were not monitored by the PM_{10} network, to check compliance of dust control areas, and to identify off-lake sources not measured by any of the other methods.

- Mapping Using GPS

Dust observations, Sensit activity, elevated PM_{10} concentrations and video are used to initiate the deployment of field technicians to map the boundaries of dust source areas on the lake bed. The boundaries of the emissive area(s) are mapped using a Global Positioning System (GPS). Surveyors conducting the mapping ride an ATV or walk around the outer boundary of the wind-damaged surface surveying a line with the GPS. A wind-damaged surface is defined as a soil surface with wind erosion evidence and/or aeolian deposition that has not been modified to an unrecognizable point by precipitation since the last dust storm. Sometimes the boundaries of the erosion area are indistinct and it is not possible to visually map the source area. In that case, sand flux data may be the primary source of information to delineate the source area. The detailed procedures used to map dust source areas are described in the Owens Lake Dust ID Field Manual (GBUAPCD, 2007).

- Mapping Using Sand Flux Monitors

Dust source area boundaries can be delineated or refined using default cell boundaries represented by active sand flux monitors. The area represented by the active sand flux monitor site may be shaped to exclude known non-emissive areas, such as: existing DCM areas, wetlands, or areas with different soil texture where there is evidence that it is non-emissive.

The District compiles the cumulative mapping information from the visual observers and field inspections using the GPS into a Geographic Information System (GIS) database. Overlays of the maps generated from sand flux monitors, video cameras, visual observers and GPS'd source areas are compared qualitatively, considering the information may have been collected at different times. District staff analyzes all the available information and determines for each dust source area, the boundaries of that area and which sand flux monitor site best represents the erosion activity that took place in the dust source area. For modeling purposes, each source area is further broken into a series of 250 m by 250 m cells that fit the shape of the dust source area.

4.3.4 Temporal and Spatial K-factors

To estimate PM_{10} emissions using Equation 4.2, the proportion of PM_{10} to sand flux, or K-factors, must be determined for different areas and periods. A three step process was used to develop these spatial and temporal K-factors. The first step was to calculate K-factors for each hour of a dust event, the second step was to screen the hourly K-factors for weak plume impacts, and the final step was to group the hourly K-factors into spatial and temporal groups for the emissions inventory.

Hourly K-factors were inferred from the CALPUFF model by using hourly sand flux as a surrogate for PM_{10} emissions. Predicted PM_{10} concentrations were then compared to monitored concentrations at PM_{10} monitor sites to determine the K-factor that would correctly predict the monitored concentration for each hour. A K-factor of 5×10^{-5} was initially used to run the CALPUFF model and to generate concentration values that were close to the monitored concentrations. Hourly K-factor values were then adjusted in a post-processing step to determine the K-factor value that would make the modeled concentration match the monitored concentration at the PM_{10} monitor site. The initial K-factor was then adjusted using Equation 4.3.

Equation 4.3

$$K_f = K_i \left(\frac{C_{obs.} - C_{bac.}}{C_{mod.}} \right)$$

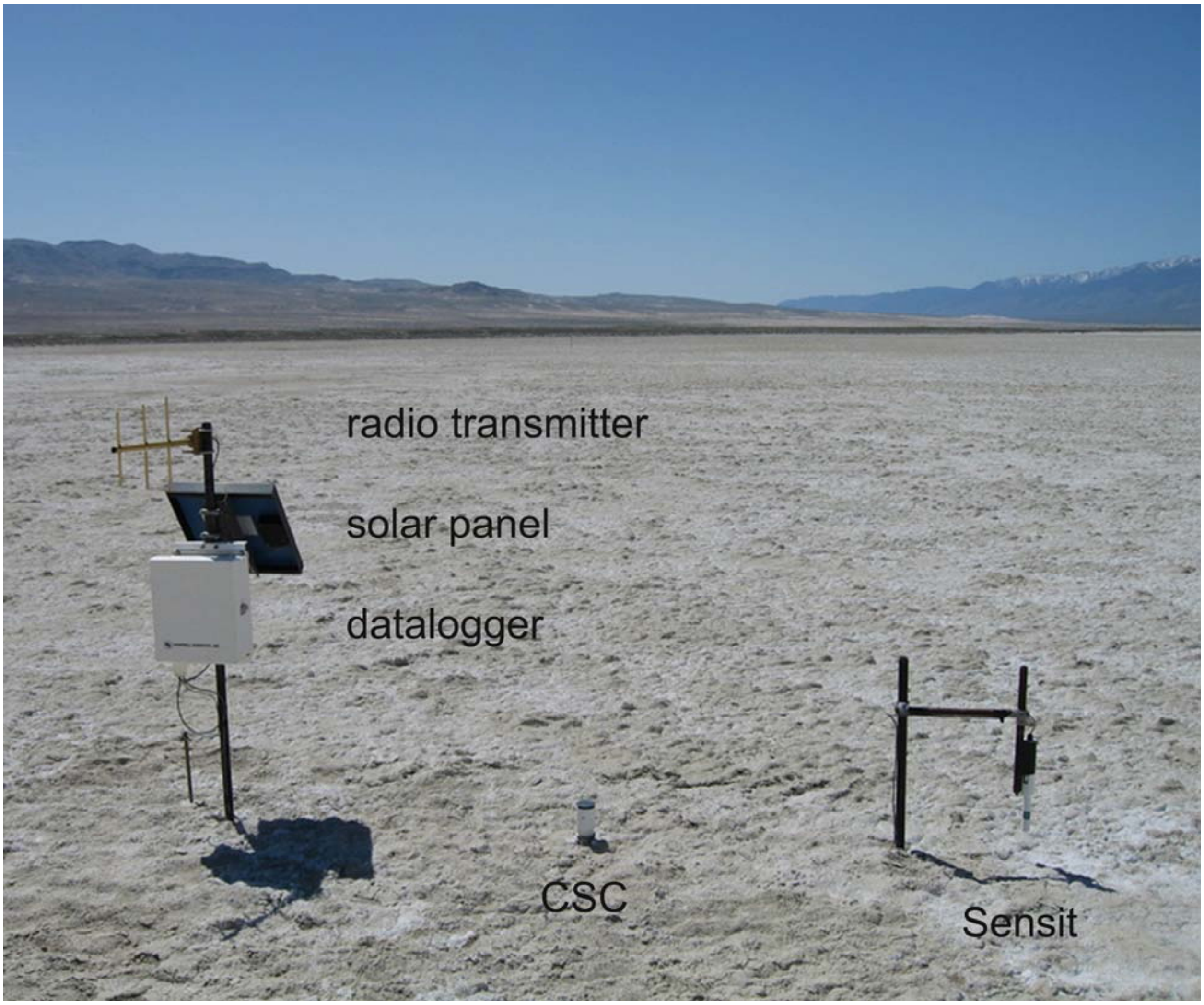


Figure 4.6 – Example of Dust ID sand flux monitor site on the Owens Lake bed

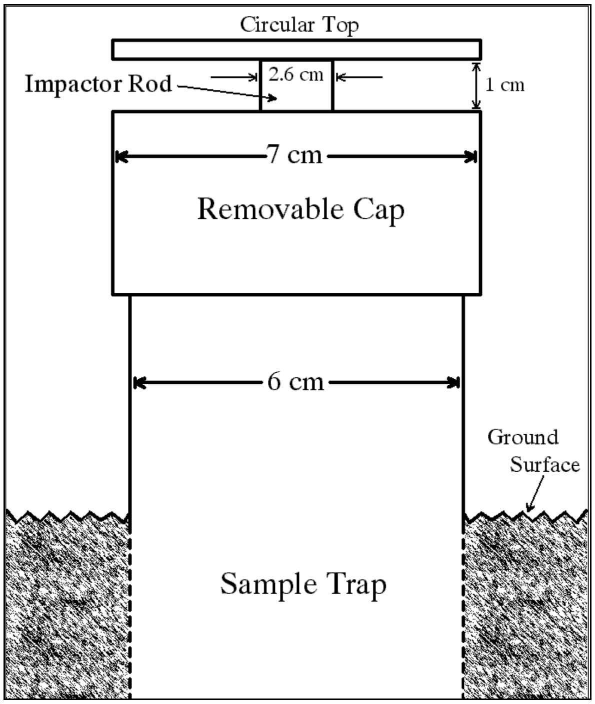
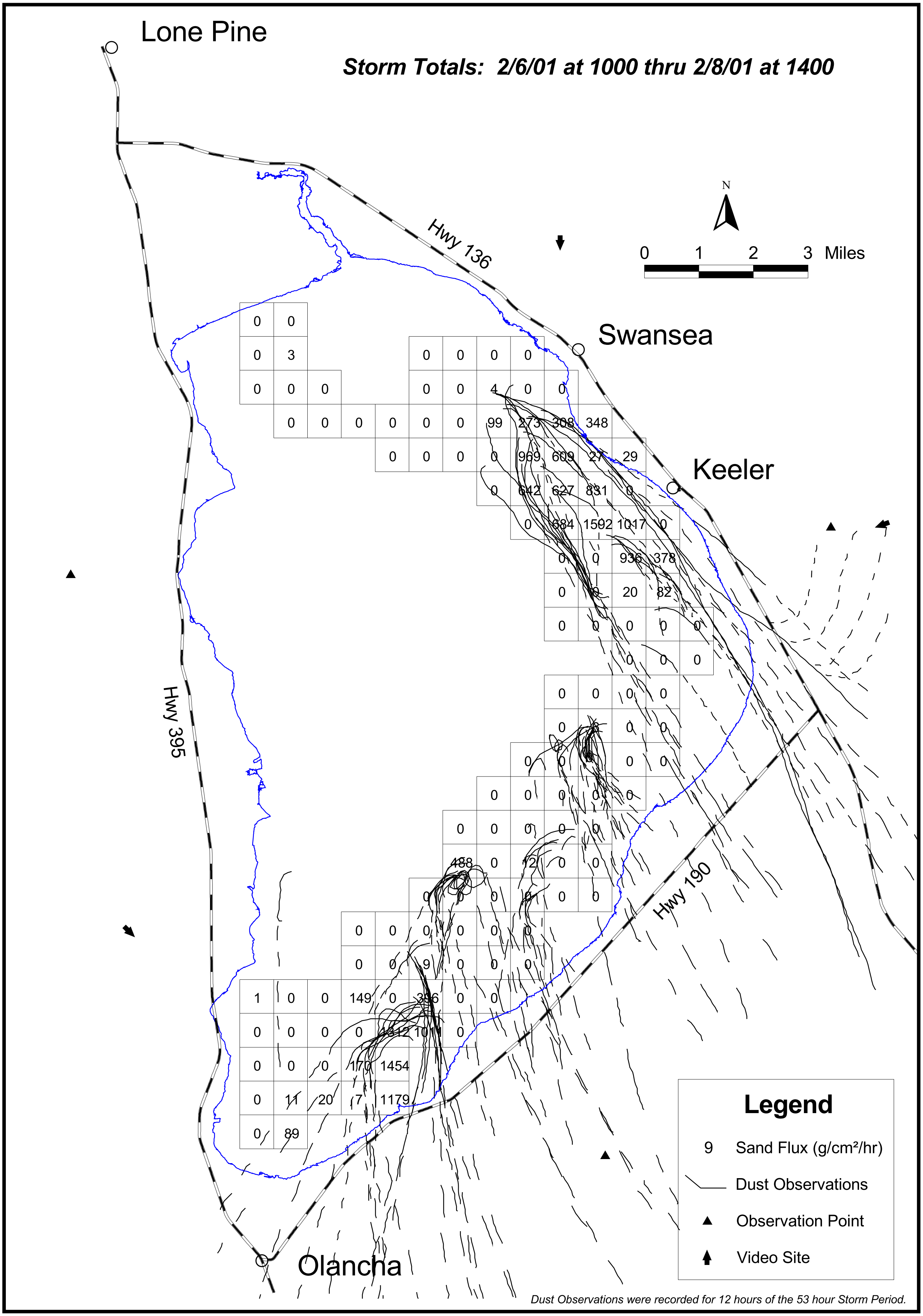


Figure 4.7 – Diagram of the Cox Sand Catcher CSC) used to measure sand flux at Owens Lake

Figure 4.8 – Example of a Cox Sand Catcher (CSC) with the inner sampling tube removed



Storm Totals: 2/6/01 at 1000 thru 2/8/01 at 1400

Dust Observations were recorded for 12 hours of the 53 hour Storm Period.

Figure 4.9 - Example of network sand flux measurements and visual observations during a dust event

BLANK PAGE

Where:

K_i = Initial K-factor (5×10^{-5})
C_{obs} = Observed hourly PM_{10} concentration. (µg/m^3)
$C_{bac.}$ = Background PM_{10} concentration (assumed 20 µg/m^3)
$C_{mod.}$ = Model-predicted hourly PM_{10} concentration. (µg/m^3)

Hourly K-factors were screened to remove hours that did not have strong source-receptor relationships between the active source area (target area) and the downwind PM_{10} monitor. For example, the screening criteria excluded hours when a PM_{10} monitor site was located on the edge of a dust plume. Because the edge of a dust plume has a very high concentration gradient a few degrees error in the plume direction could greatly affect the calculated K-factor.

The hourly K-factor was excluded if it did not meet any of the following criteria:

1) Wind speed is greater than 5 m/s at 10-m height.
2) Hourly modeled and monitored PM_{10} concentrations were both greater than 150 µg/m^3 at the same monitor-receptor site.
3) Hourly wind direction is from the lake bed to the monitor site.
4) The mean sand flux for all sites with non-zero sand flux is greater than 0.5 g/cm^2/hr.
5) At least one sand flux grid center located within the target area and within a 30-degree upwind cone has sand flux greater than 2 g/cm^2/hr.
6) All sources are within a distance of 15 km of the receptor.
7) More than 65 percent of the PM_{10} contribution at a monitor site came from the target source area (North area, South area, Central area or Keeler dunes).
8) Eliminate hours when sand flux data are missing from one or more cells that are located within a 30-degree upwind cone and within 10-km of the shoreline monitor. For Olancha and Lone Pine, which are both located 5 to 10 km from the lake bed, the distance limitation is changed to 10 km upwind of the shoreline.

Figure 4.10 shows the hourly K-factors for the South area of the lake bed. The results show scatter in the hourly values, but the 75th percentile K-factor values (blue line) are relatively consistent during certain periods of the year. While the K-factors may change by a factor of two or three, their consistency is in contrast to the large shifts in the hourly sand flux rates, which often change by three orders of magnitude and drive the emissions using Equation 4.2. Hourly K-factors and storm averages for the South area, as well as other areas usually increase during the winter and early spring. This period corresponds to the formation of an efflorescent salt on the surface that forms a very powdery and loose surface. Efflorescent salts form annually at Owens Lake due to precipitation and cold temperatures.

In addition to the South area, three other areas of the lake bed were identified for the spatial K-factor sets: the Keeler dunes, the Central area and the North area. The boundaries of the four areas, which are shown on the map in Figure 4.3, were delineated by a survey of the surface soil textures. All four areas showed temporal K-factor trends, as well as some differences that may be attributed to different soil textures. Figure 4.11, Figure 4.12 and Figure 4.13 show the hourly and storm average K-factors for the Keeler dunes, Central area and North area from January 2000 through June 2006. Temporal cut-points for each area were subjectively selected based on shifts in the 75-percentile storm-average values, which also appeared to correspond to seasonal shifts in the observed surface conditions, such as efflorescent salt formation or surface crusting. The blue line in these figures represents the K-factor values that were used to estimate emissions using Equation 4.2.

Table 4.1 shows a summary of the temporal and spatial 75-percentile K-factors that were generated from the screened K-factors. For the 2003 SIP, it was determined through a model performance analysis of the 50-percentile, 75-percentile and 95-percentile storm-average, that the75-percentile storm-average values provided the best model performance for the high PM_{10} days and the attainment demonstration.

4.3.5 Daily and Annual PM_{10} Emissions for Lake Bed Areas

Using the Dust ID method, hourly, daily, and annual PM_{10} emissions can be calculated using Equation 4.2. In 2000, wind blown dust emissions from the lake bed were estimated at 76,191 tons of PM_{10} per year. The highest daily emission estimate from the lake bed was 6,956 tons on May 2, 2001. Annual PM_{10} emissions were not calculated for the years from 2002 through 2005. During this period, many of the key sand flux monitor sites were removed for the construction of control measures, so a complete data set that would be representative of lake bed emissions was not available. From July 2005 through June 2006 most of the active erosion sites were monitored for wind blown dust emissions. In 2006, wind blown dust emissions from the lake bed were estimated at 73,174 tons, with the highest daily emissions at 10,834 tons on February 15, 2006. The 2006 emissions inventory included many wind blown dust source areas that were not active during the 2000 emissions inventory period. Because of the addition of these new dust source areas, the 2006 emissions inventory for the lake bed is almost as high as the 2000 inventory, even though dust control measures were implemented on 16.5 square miles of the lake bed in 2003.

In future years, PM_{10} emissions from dust control areas will be generated from construction-related activities and from residual PM_{10} emissions from the lake bed. Construction-related emissions may be generated by fugitive dust from unpaved roads, installing drainage systems, pipes, or berms, and preparing the soil to plant saltgrass. PM_{10} emissions from construction activities are estimated at 59.5 pounds per day, and 10.4 tons per year (GBUAPCD, 2007b). These emissions are not included in the emissions inventory, since construction is a transient activity that will be completed in less than a year on each control area, and because including them may double count the uncontrolled wind-blown dust emissions that would be generated from the same area. The District requires that the City take reasonable measures to control and minimize fugitive dust emissions caused during dust control measure construction activities.

4.3.6 Daily and Annual PM_{10} Emissions for Off-Lake Dune Areas

In addition to the PM_{10} source areas on the Owens Lake playa, PM_{10} emissions are also generated from off-lake source areas adjacent to the lake bed. The two main sources consist of the Keeler dunes and the Olancha dunes (Figure 4.14). The Keeler dunes are included in the Dust ID network and emissions can be calculated for them in the same manner as for emissions from lake bed areas. The Keeler dunes PM_{10} emissions estimate for 2006 is 8,386 tons, with maximum day emissions of 680 tons on May 27, 2006. This is higher than the emission estimate in 2000 of 2,909 tons per year. The maximum day emission estimate was 252 tons on May 2, 2001.

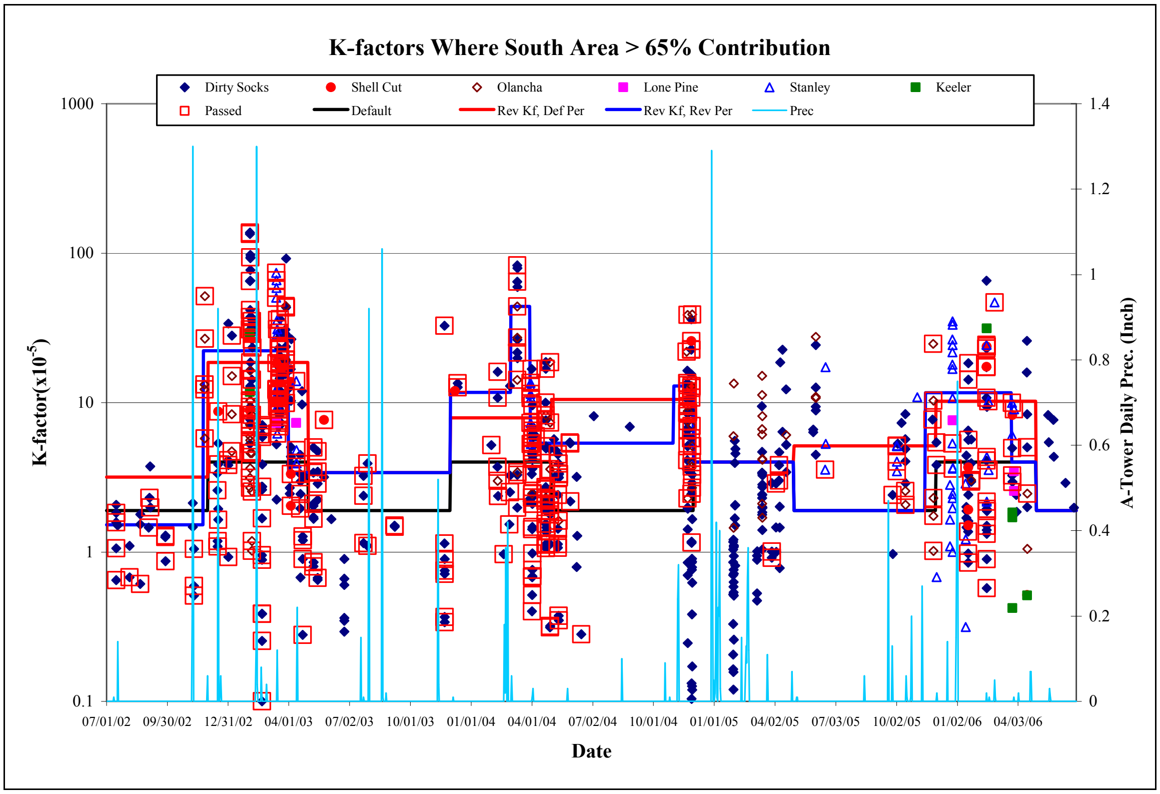


Figure 4.10 – Hourly and period K-factors for the South area.

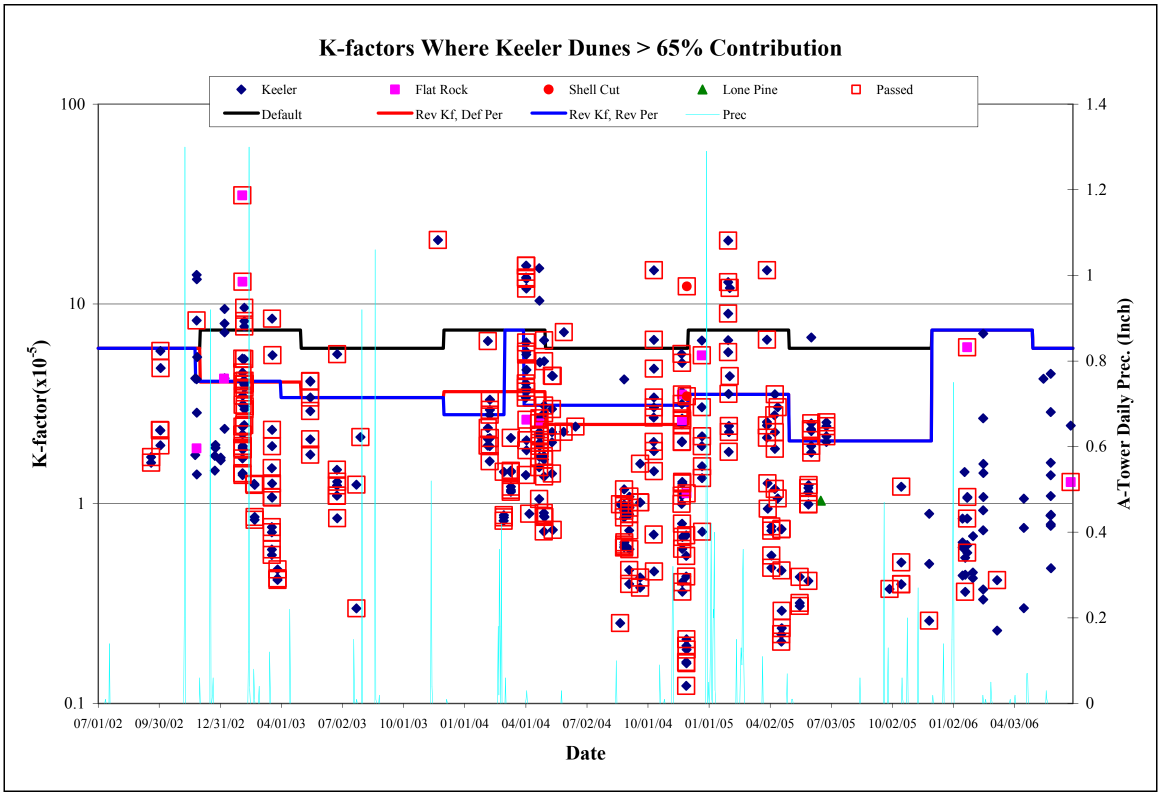


Figure 4.11 – Hourly and period K-factors for the Keeler dunes.

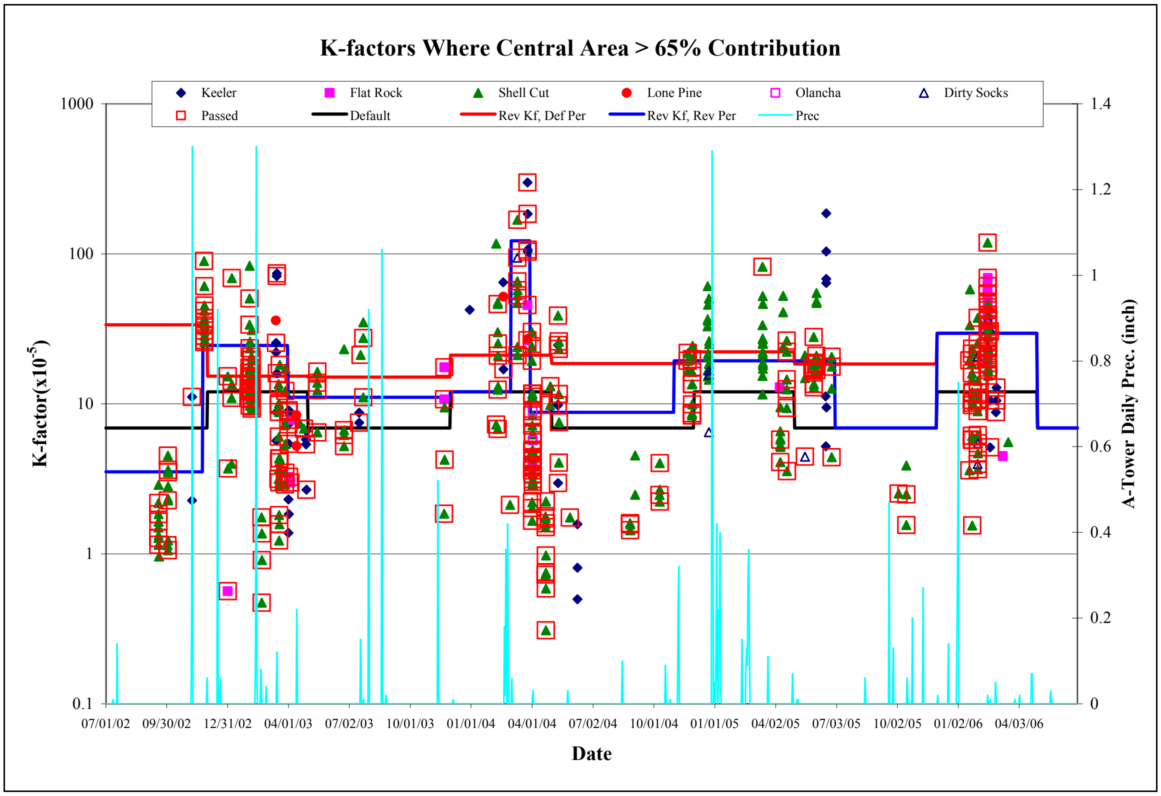


Figure 4.12 – Hourly and period K-factors for the Central area.

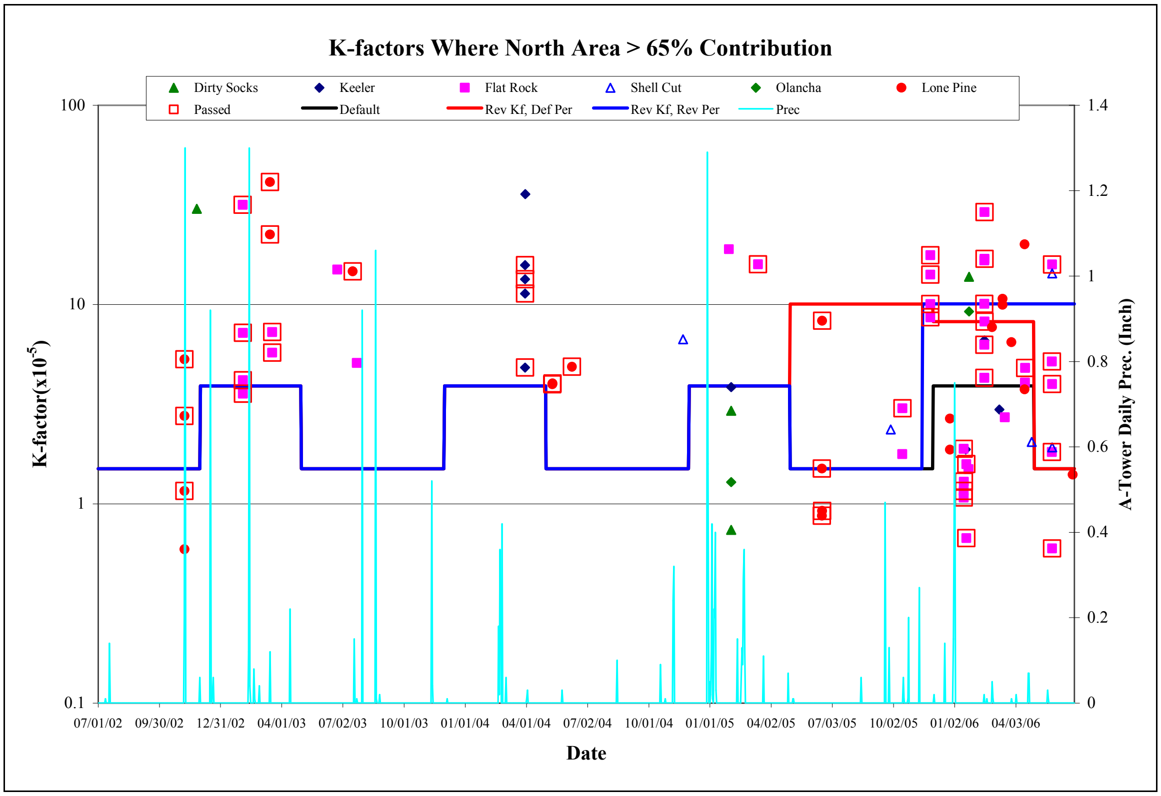


Figure 4.13 – Hourly and period K-factors for the North area.

Table 4.1 – 75-percentile storm-average K-factors were determined to provide spatial and temporal values to estimate hourly emissions and model ambient PM$_{10}$ impacts.

Period		**K-factors (10^{-5}) For Different Source Areas**			
Start	**End**	**Keeler Dunes**	**North Area**	**Central Area**	**South Area**
1/1/2000	2/3/2001	5.1	2.1	6.6	1.9
2/4/2001	4/18/2001	5.1	2.1	25.7	6.7
4/19/2001	11/30/2001	5.1	2.1	6.3	1.9
12/1/2001	3/8/2002	20.1	7.7	35.7	5.8
3/9/2002	4/18/2002	5.5	5.1	6.9 *	9.0
4/19/2002	6/30/2002	5.5	5.0	6.6	1.8
7/1/2002	11/23/2002	6.0 *	1.5 *	3.5	1.5
11/24/2002	11/30/2002	4.1	1.5 *	24.5	22.3
12/1/2002	3/31/2003	4.1	3.9 *	24.5	22.3
4/1/2003	4/30/2003	3.4	3.9 *	11.0	3.4
5/1/2003	11/30/2003	3.4	1.5 *	11.0	3.4
12/1/2003	2/29/2004	2.8	3.9 *	12.0 *	11.7
3/1/2004	3/29/2004	7.4 *	3.9 *	122.1	44.0
3/30/2004	4/30/2004	3.1	3.9 *	8.8	5.4
5/1/2004	10/31/2004	3.1	1.5 *	8.8	5.4
11/1/2004	11/30/2004	3.1	1.5 *	19.3	12.9
12/1/2004	4/30/2005	3.5	3.9 *	19.3	4.0 *
5/1/2005	6/30/2005	2.1	1.5 *	19.3	1.9 *
7/1/2005	11/14/2005	2.1	1.5 *	6.9 *	1.9 *
11/15/2005	11/30/2005	2.1	10.1	6.9 *	11.6
12/1/2005	3/24/2006	7.4 *	10.1	29.6	11.6
3/25/2006	4/30/2006	7.4 *	10.1	29.6	4.0 *
5/1/2006	6/30/2006	6.0 *	10.1	6.9 *	1.9 *

* *Denotes default K-factors from the 2003 SIP. Other K-factors are based on the 75th percentile average over at least 9 samples passing the Dust ID Program screening criteria.*

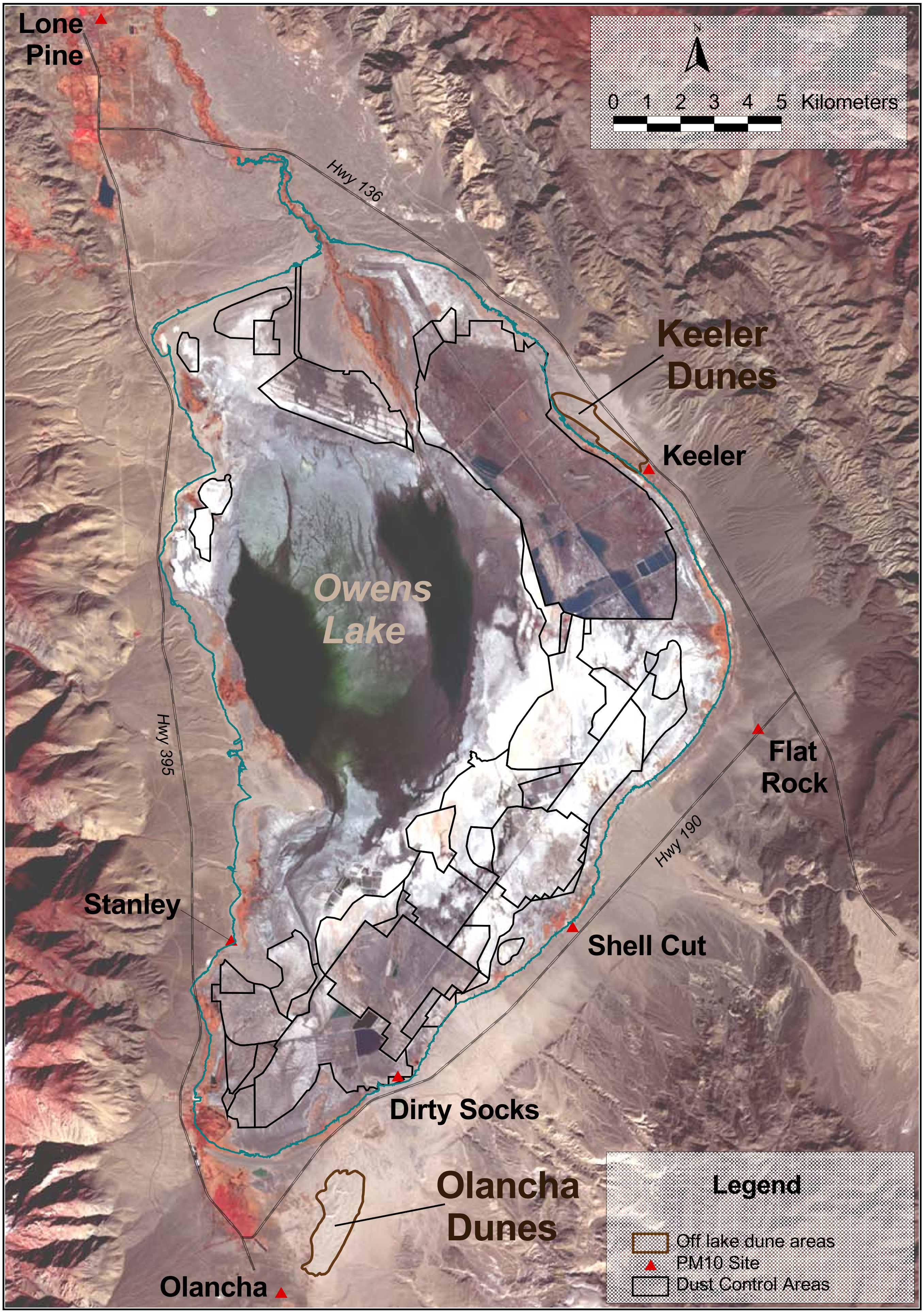


Figure 4.14 - Map of off-lake dune areas

Table 4.2 Summary of the annual emissions forecast for all PM$_{10}$ emission source categories in the planning area for the period from 1997 through 2017.

	TONS OF PM$_{10}$ PER YEAR										
SOURCE CATEGORY	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total - All Sources	***83,212***	***83,212***	***83,212***	***83,212***	***83,197***	***60,938***	***59,758***	***46,729***	***50,412***	***85,684***	***46,279***
Lake Bed Emissions											
2003 DCA	76,191	76,191	76,191	76,191	76,191	52,716	51,958	40,416	40,416	40,167	762
2008 Moat & Row										10,787	10,787
2008 SF SDCA										21,117	21,117
2008 Study Area										883	883
Other Lake Bed Areas										220	220
Subtotal	***76,191***	***76,191***	***76,191***	***76,191***	***76,191***	***52,716***	***51,958***	***40,416***	***40,416***	***73,174***	***33,769***
Off-Lake Dunes											
Keeler Dunes	2,909	2,909	2,909	2,909	2,894	4,110	3,688	2,201	5,872	8,386	8,386
Olancha Dunes	1,298	1,298	1,298	1,298	1,298	1,298	1,298	1,298	1,298	1,298	1,298
Subtotal	***4,207***	***4,207***	***4,207***	***4,207***	***4,192***	***5,408***	***4,986***	***3,499***	***7,170***	***9,684***	***9,684***
Other Emission Sources											
Prescribed Burning	2,532	2,532	2,532	2,532	2,532	2,532	2,532	2,532	2,532	2,532	2,532
Unpaved Road Dust	84	84	84	84	84	84	84	84	84	84	84
Paved Road Dust	77	77	77	77	77	77	77	77	88	88	88
Industrial Facilities	81	81	81	81	81	81	81	81	81	81	81
Residential Woodburning	36	36	36	36	36	36	36	36	36	36	36
Vehicle Tailpipe	3	3	3	3	3	3	3	3	4	4	4
Agricultural Operations	1	1	1	1	1	1	1	1	1	1	1
Subtotal	***2,814***	***2,814***	***2,814***	***2,814***	***2,814***	***2,814***	***2,814***	***2,814***	***2,826***	***2,826***	***2,826***

Table 4.2 Continued

	TONS OF PM_{10} PER YEAR									
SOURCE CATEGORY	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total - All Sources	***46,279***	***46,279***	***36,361***	***15,832***	***15,832***	***15,832***	***7,530***	***7,535***	***7,535***	***7,535***
Lake Bed Emissions										
2003 DCA	762	762	762	762	762	762	762	762	762	762
2008 Moat & Row	10,787	10,787	865	865	865	865	865	865	865	865
2008 SF SDCA	21,117	21,117	21,117	588	588	588	588	588	588	588
2008 Study Area	883	883	883	883	883	883	883	883	883	883
Other Lake Bed Areas	220	220	220	220	220	220	220	220	220	220
Subtotal	***33,769***	***33,769***	***23,847***	***3,318***	***3,318***	***3,318***	***3,318***	***3,318***	***3,318***	***3,318***
Off-Lake Dunes										
Keeler Dunes	8,386	8,386	8,386	8,386	8,386	8,386	84	84	84	84
Olancha Dunes	1,298	1,298	1,298	1,298	1,298	1,298	1,298	1,298	1,298	1,298
Subtotal	***9,684***	***9,684***	***9,684***	***9,684***	***9,684***	***9,684***	***1,382***	***1,382***	***1,382***	***1,382***
Other Emission Sources										
Prescribed Burning	2,532	2,532	2,532	2,532	2,532	2,532	2,532	2,532	2,532	2,532
Unpaved Road Dust	84	84	84	84	84	84	84	84	84	84
Paved Road Dust	88	88	92	92	92	92	92	97	97	97
Industrial Facilities	81	81	81	81	81	81	81	81	81	81
Residential Woodburning	36	36	36	36	36	36	36	36	36	36
Vehicle Tailpipe	4	4	4	4	4	4	4	4	4	4
Agricultural Operations	1	1	1	1	1	1	1	1	1	1
Subtotal	***2,826***	***2,826***	***2,830***	***2,830***	***2,830***	***2,830***	***2,830***	***2,835***	***2,835***	***2,835***

Olancha dunes emissions are estimated using research on alluvial fan areas east of the Keeler dunes (Nickling *et al*., 2001). Emissions from these two dune fields are calculated below and are included in the emission inventory.

There are additional off-lake source areas present along the east and southeastern portion of the lakeshore. These sources consist of natural alluvial fan sand deposits on the lower slopes of the Inyo and Coso Mountains mixed with secondary source material blown up from the exposed Owens Lake playa. The boundaries of these areas are diffuse and poorly defined and the PM_{10} emission rates associated with these areas are unknown. Emissions from these diffuse areas are assumed to be much less than both the lake bed and the two dune fields and are not included in the emission inventory.

Most of these off-lake sources of wind-blown dust were formed by material that was initially entrained from the exposed playa and then deposited in areas off the lake bed (Holder, 1997). The Olancha dunes were present prior to the early 20th century desiccation of Owens Lake, but subsequent lake bed dust storms have deposited additional sand and dust in the dune field. These dust deposition areas are secondary sources of dust that can be entrained under windy conditions. After the lake bed source areas are controlled, PM_{10} emissions from the off-lake dunes are expected to decline (Niemeyer, 1996).

Peak daily and annual PM_{10} emissions from the Olancha dunes were estimated from the Keeler dune emissions, which were measured as part of the Dust ID network. An estimate of PM_{10} emissions was made using Equation 4.4.

Equation 4.4

$$PM\text{-}10 = \left(\frac{F_{KD}}{A_{KD.}}\right) \times A_D \times R_D$$

Where,

F_{KD} = PM_{10} emissions from the Keeler dunes (252 tons/day or 2,909 tons/year)
A_{KD} = Area size of the Keeler dunes = 1.84 sq. km
A_D = Area size of Olancha dunes = 3.04 sq. km
R_D = Ratio of Olancha dunes to Keeler dune K-factors (0.27)

The Olancha dune emission estimate is based on comparing the Olancha dune area to the Keeler dune emissions from 2000. Since there were no sand-flux monitors on the Olancha dunes, the Olancha dunes are assumed to have similar activity levels (sand flux per unit area per time) as the Keeler dunes, and to have a K-factor similar to the alluvial fan sand deposits east of the Keeler dunes. The Olancha dunes K-factor is expected to be similar to the alluvial fan area, because they are both farther from the lake bed than the Keeler dunes. Because of the greater distance from the lake bed, more PM_{10} is winnowed out of the dune material as it is transported farther from the lake bed. Wind tunnel tests showed that dunes located on the alluvial fan east of the Keeler dunes had an average K-factor of 1.0×10^{-5}, while the average Keeler dune K-factor was 3.7×10^{-5} for the same period (Nickling, *et al*., 2001). This yields a K-factor ratio between the two areas of 0.27. Dune area sizes are based on estimates made for the 1998 SIP (GBUAPCD, 1998a).

4.4 PM_{10} EMISSIONS FORECAST

Table 4.2 provides a summary of the annual emissions forecast for all the emission source categories in the planning area for the period form 1997 to 2017. Wind blown dust emissions are broken out into the emissions from the areas that are discussed in the proposed control strategy. PM_{10} emissions from the control areas are projected based on the 2006 emission inventory and emission reductions using the target minimum dust control efficiency for each control area.

4.5 REFERENCES

Caltrans, 2005. California Department of Transportation, California Motor Vehicle Stock, Travel and Fuel Forecast, Sacramento, California, December 30, 2005.

CARB, 1997. Memorandum from Patrick Gaffney to Duane Ono, Re: Owens Valley Emissions Data, California Air Resources Board, Sacramento, California, January 8, 1997.

CARB, 2007a. California Air Resources Board, website for California Emissions Inventory Data, accessed July 25, 2007, http://www.arb.ca.gov/ei/ei.htm.

GBUAPCD, 1998a. Great Basin Unified Air Pollution Control District, Owens Valley PM_{10} Planning Area Demonstration of Attainment State Implementation Plan, GBUAPCD, Bishop, CA, November 16, 1998.

GBUAPCD, 2005. Great Basin Unified Air Pollution Control District, Inyo National Forest, USDI Bureau of Land Management, Operations Plan for Wildland Fire Use Smoke Management, GBUAPCD, Bishop, California, May 2, 2005.

GBUAPCD, 2007a. Great Basin Unified Air Pollution Control District, Owens Lake Dust ID Field Manual, GBUAPCD, Bishop, California, Draft: January 24, 2007.

GBUAPCD, 2007b. Great Basin Unified Air Pollution Control District, 2008 Owens Valley PM_{10} Planning Area Demonstration of Attainment State Implementation Plan Draft Subsequent Environmental Impact Report, State Clearing House Number 2007021127, GBUAPCD, Bishop, California**,** September 14, 2007.

Gillette, *et al*., 2004. Gillette, Dale, Duane Ono, Ken Richmond, *A Combined Modeling and Measurement Technique for Estimating Wind-Blown Dust Emissions at Owens (dry) Lake, CA,* Journal of Geophysical Research, Volume 109, January 17, 2004.

Holder, 1997. Holder, Grace M., Off-Lake Dust Sources, Owens Lake Basin, Great Basin Unified Air Pollution Control District, Bishop, California, June 1997.

Keisler, 1997. Keisler, Mark, memorandum from Great Basin Unified Air Pollution Control District, to Duane Ono, GBUAPCD, regarding crop acreage for Southern Inyo County, GBUAPCD, Bishop, California, March 1997.

McKee, 1996. McKee, Lucinda, letter from U.S. Department of Agriculture-Forest Service, to Duane Ono, Great Basin Unified Air Pollution Control District, regarding historic smoke emissions for inclusion in the State Implementation Plans for Owens Valley, Mammoth Lakes and Mono Basin, Bishop, California, June 13, 1996.

Murphy, 1997. Murphy, Timothy P., memorandum from Great Basin Unified Air Pollution Control District Soil Scientist to Mark Kiesler, GBUAPCD, regarding silt analysis results for unpaved road surfaces in Keeler and the Cerro Gordo Road, GBUAPCD, Bishop, California, January 14, 1997.

Nickling, *et al*., 2001. Nickling, W.G., C. Luttmer, D.M. Crawley; J.A. Gillies; and N. Lancaster, Comparison of On- and Off-Lake PM_{10} Dust Emissions at Owens Lake, CA, University of Guelph, Guelph, Ontario, Canada, February 2001.

Niemeyer, 1996. Niemeyer, Tezz C., Characterization of Source Areas, Size and Emission Rates for Owens Lake, CA: Fall 1995 through June 1996, Environmental Consulting, Olancha, California, November 1996.

Ono, 1997. Ono, Duane, PM_{10} Emission Factors for Owens Lake Based on Portable Wind Tunnel Tests from 1993 through 1995, Great Basin Unified Air Pollution Control District, Bishop, California, January 1997.

Ono, *et al*., 2003a. Ono, Duane, Ellen Hardebeck, Scott Weaver, Billy Cox, Nikolai Barbieri, William Stanley, Ken Richmond, and Dale Gillette, Locating and Quantifying Wind-Blown Dust PM_{10} Emissions at Owens Lake, California, *A&WMA's 96th Annual Conference & Exhibition*, June 2003, San Diego, California, Paper #69487, Air & Waste Management Association, Pittsburgh, Pennsylvania, June 2003.

Ono, *et al*., 2003b. Ono, Duane, Scott Weaver, Ken Richmond, Quantifying Particulate Matter Emissions from Wind Blown Dust Using Real-time Sand Flux Measurements, *USEPA 2003 Emission Inventory Conference*, April 29-May 1, 2003, San Diego, California, United States Environmental Protection Agency, Research Triangle Park, North Carolina, May 2003.

Richmond, *et al*., 2003. Richmond, Ken, Duane Ono, Ellen Hardebeck, Scott Weaver, Billy Cox, Nikolai Barbieri, William Stanley,and Dale Gillette, Modeling Wind-Blown Dust Emissions and Demonstrating Attainment with National Ambient Air Quality Standards at Owens Lake, California, *A&WMA's 96th Annual Conference & Exhibition*, June 2003, San Diego, California, Paper #69495, Air & Waste Management Association, Pittsburgh, Pennsylvania, June 2003.

Scire, et al., 2000. Scire, J.S.; Strimaitis, D.G.; Yamartino, R.J. A User's Guide for the CALPUFF Dispersion Model (Version 5). Earth Tech, Inc., 196 Baker Avenue, Concord, MA 01742, January 2000.

US Census Bureau, 2007. U.S. Census Bureau, State and County QuickFacts, accessed July 25, 2007, http://quickfacts.census.gov/qfd/states/06/06027.html .

USEPA, 2006a. United States Environmental Protection Agency, Compilation of Air Pollutant Emission Factors, AP-42, http://www.epa.gov/ttn/chief/ap42/index.html at http://www.epa.gov/ttn/chief/ap42/ch13/index.html at http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0202.pdf

USEPA, 2006b. United States Environmental Protection Agency, Compilation of Air Pollutant Emission Factors, AP-42, http://www.epa.gov/ttn/chief/ap42/index.html at http://www.epa.gov/ttn/chief/ap42/ch13/index.html at http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0205.pdf