San Joaquin Valley
AIR POLLUTION CONTROL DISTRICT

2009 Area Source Emissions Inventory Methodology
650 - FUGITIVE WINDBLOWN DUST - EXPOSED LAKE BEDS

I. Purpose

This document describes the Area Source Methodology used to estimate emissions of fine particulate matter less than 10 microns (PM_{10}) from exposed lake beds in the San Joaquin Valley Air Basin. An area source category is a collection of similar emission units within a geographic area (i.e., a County) that are small and numerous and may not have been inventoried as specific point, mobile, or biogenic sources. The California Air Resources Board (CARB) has grouped these individual sources with other like sources into area source categories. These source categories are grouped in such a way that they can be estimated collectively using one methodology.

II. Applicability

The emission calculations from this Area Source Methodology apply to facilities that are identified by the following Category of Emission Source (CES) code and Reconciliation Emission Inventory Code (REIC):

Table 1. Emission inventory codes.

CES	REIC	Description
89508	650-653-5400-0000	Exposed Lake Beds

III. Point Source Reconciliation

Emissions from the area source inventory and point source inventory are reconciled against each other to prevent double counting. This is done using relationships created by the California Air Resources Board (CARB) between the area source REIC and the point sources' Standard Industry Classification (SIC) code and emissions process Source Category Code (SCC) combinations. The area source in this methodology is not represented within our point source inventory so reconciliation is not necessary.

IV. Methodology Description

This methodology estimates emissions of fugitive windblown dust from exposed lake beds. An exposed lake bed may include both the lake's bottom and any exposed shorelines that may appear due to the lowering of water levels. Emissions are generated whenever a wind event occurs over one of these exposed surfaces. For this methodology, the District is using EPA's method of estimating emissions from industrial wind erosion over storage piles (EPA, 2006) as a surrogate for estimating emissions from this category.

An exposed lake bed shall be treated similarly to a storage pile and a wind event will be defined as any time period when the surface friction velocity (u*) generated by the "fastest mile" of wind (maximum 2-minute wind speed) exceeds the threshold friction velocity (u_t) of the exposed surface (see Glossary, Section XVIII). These friction velocities are used to estimate an erosion potential and subsequently, an emission factor for each wind event. For each wind event, emissions may be estimated by multiplying the emission factor by the total exposed surface area of the lake bed at the time of the event. Summing up the emissions from each wind event for the year will give the annual emissions associated with this category. There are six reservoirs (San Luis, Pine Flat, Success, Millerton, Hensley, and Kaweah) within the District for which lake depth data may be obtained. This methodology will focus on the emissions from the exposed lake beds of those six reservoirs.

V. Activity Data

In order to estimate emissions from fugitive windblown dust over exposed lake beds the following information is required:

<u>Wind Velocity Data:</u> Wind velocity data was obtained from the National Climatic Data Center in the form of Quality Controlled Local Climatological Data (QCLCD) (NCDC, 2010). This data includes the fastest mile of wind and weather information (i.e. rainfall, fog, etc.) for each day of the year for each station. As the data only displays the maximum daily fastest mile, it is assumed that only one wind event may occur each day. This methodology also assumes that the wind velocity remains uniform over the entire exposed portions of lake beds, and that any days with precipitation greater than 0.01 inches have zero emissions.

<u>Surface Area of Exposed Lake Bed:</u> In order to estimate the exposed surface area of the six reservoir lake beds, Geographic Information Systems (GIS) (DFG, 2010) data and reservoir depth data obtained from the California Department of Water Resources (CWRB, 2010) was used. GIS data was used to estimate the perimeters for the six reservoirs. The Department of Water Resources lists the maximum elevation of each reservoir as well as the elevation of the current water level. It is assumed that multiplying the drop in reservoir depth by the perimeter of the reservoir would give a conservative estimate of the exposed lake bed surface area. This

methodology assumes that the soil type for all exposed lake beds is undisturbed playa.

A table with reservoir characteristics may be seen in Appendix A. Non-reservoir lakes are not included in this estimate because currently there is insufficient data to determine the levels for those lakes.

In 2009, there were zero days in which the wind velocity exceeded the threshold wind velocity. Therefore, no emissions were reported for 2009.

VI. Emission Factors

The emission factor for this category is based on the erosion potential of each wind event that occurs. It is expressed as such (EPA, 2006):

$$\text{Emission Factor} = k \sum_{i=1}^{N} P_i \qquad (1)$$

Where,

k = Particle size multiplier (for PM_{10}, use 0.5) (dimensionless)
N = Number of disturbances (wind events) per year
P_i = Erosion potential corresponding to the observed (or probable) fastest mile of wind for the i^{th} period between disturbances (g PM_{10}/m^2)

Since the erosion potential and the amount of exposed surface area may vary with each wind event, each wind event shall have it's own emission factor. The erosion potential may be estimated using the following equation (EPA, 2006):

$$P = 58\,(u_p{*} - u_{pt}{*})^2 + 25\,(u_p{*} - u_{pt}{*}) \qquad (2)$$
$$P = 0 \text{ for } u_p{*} \le u_{pt}{*}$$

Where,

$u_p{*}$ = Friction velocity (m/s)
$u_{pt}{*}$ = Threshold friction velocity (m/s)

As seen above, if the friction velocity does not exceed the threshold friction velocity of the soil, then there is no erosion potential and therefore, zero emissions. Friction velocity is a function of wind velocity and may be calculated by manipulating the wind velocity profile equation (Equation 3) (EPA, 2006) below:

$$u(z) = \frac{u*}{0.4} \times \ln\left(\frac{z}{z_0}\right) \quad \text{where } z > z_0 \qquad (3)$$

Where,

$u(z)$ = Wind speed as a function of z (cm/s)
u^* = Friction velocity (cm/s)
z = Height above test surface (anemometer height) (cm)
z_0 = Roughness Height (cm)
0.4 = von Karman's constant (dimensionless)

Manipulating Equation 3 leads to the following equation which may be used to estimate friction velocity:

$$u^* = \frac{(0.4) \times u(z)}{\ln\left(\frac{z}{z_0}\right)} \quad \text{where } z > z_0 \qquad (4)$$

For estimating the friction velocity, EPA recommends using the fastest mile of wind as the wind speed (u(z)).

VII. Emissions Calculations

A. Assumptions

1) EPA's method to estimate dust emissions from industrial wind erosion events accurately estimates the emissions from fugitive windblown dust from exposed lake beds.

2) The surfaces of exposed lake beds are accurately characterized as undisturbed playa. Undisturbed playa has an average threshold friction velocity (u_t^*) of 1.46 m/s and an average roughness height (z_0) of 0.057 cm (Mansell, 2004).

3) All anemometers used by National Climatic Data Center stations are at a reference height of 10 meters (1000 cm) above the surface. The wind velocity measured at each station is representative of the wind velocity at the nearest lake(s).

4) Only one wind event may occur for each day of the year.

5) Wind velocity is uniform across all exposed surfaces.

B. Example Calculation

1) Estimate the Threshold Wind Velocity

Setting the friction velocity equal to threshold friction velocity ($u^* = u_t^*$) and using the parameters for undisturbed playa (z = 1000 cm, z_0 = 0.057 cm, and

u_t^* = 1.46 m/s or 146 cm/s) then Equation 3 may be used to estimate the velocity of the fastest mile of wind, u(z), that would have to be exceeded in order to generate some erosion potential.

$$u(z) = \frac{146\ \text{cm/s}}{0.4} \times \ln\left(\frac{1000}{0.057}\right) = 3{,}567\ \text{cm/s} = 79.8\ \text{mph}$$

Therefore, the fastest mile of wind for any day must exceed 79.8 mph in order to generate some erosion potential. In 2009, there were zero wind events within the District. Therefore, the following calculations would be performed only in the case where a wind event occurs.

2) Wind Event

If, on January 1, 2009, there was one wind event for a reservoir at 85 mph (38 m/s), the friction velocity would be calculated as follows:

$$u^* = \frac{(0.4) \times (38\ \text{m/s})}{\ln\left(\frac{1000\ \text{cm}}{0.057\ \text{cm}}\right)} = 1.56\ \text{m/s}$$

The Erosion Potential, P, for this wind event is then calculated as follows:

$$P = 58\,(u_p^* - u_{pt}^*)^2 + 25\,(u_p^* - u_{pt}^*)$$

$$P = 58\,(1.56 - 1.46)^2 + 25\,(1.56 - 1.46) = 3.08\ \text{g/m}^2$$

3) Emission Factor

The emission factor for this event would be calculated as follows (k = 0.5 for PM_{10}):

$$\text{Emission Factor} = k\sum_{i=1}^{N} P_i = (0.5) \times (3.08\ \text{g/m}^2) = 1.54\ \text{g}\ PM_{10}/\text{m}^2$$

4) Surface Area of Exposed Lake Bed

The lake level on January 1, 2009 for this reservoir was 396 feet and the maximum elevation was 543 feet. The perimeter of the lake was estimated at 370,630 feet. Therefore:

Area of Exposed Lake Bed = (543 ft - 396 ft) x (370,630 ft) x (0.0929 m^2/ft^2)

Area of Exposed Lake Bed = 5,061,434 m^2

Emissions

Emissions from this source are calculated by multiplying the emission factor by the surface area of exposed lake bed.

Emissions = EF x Area of Exposed Lake Bed (m^2)

Emissions = (1.54 g PM_{10}/m^2) x (5,061,434 m^2) = 7,794,608 g PM_{10}

Emissions = 7,794,608 g PM_{10} x (1.1025 x 10^{-6} tons/g) = 8.59 tons PM_{10}

Therefore, 8.59 tons of PM_{10} would have been emitted in 2009 from this reservoir.

VIII. Temporal Variation

Emissions in this category are expected to occur most likely during the Spring and Summer months when temperatures are higher and precipitation is minimal. Conversely, during the Winter and Fall months, when precipitation and fog are likely to occur, emissions are expected to be minimal or zero most days.

IX. Spatial Variation

Within each county, activity can be assigned to the six reservoirs covered in this methodology.

X. Growth Factor

Growth factors are developed by either the District's Strategies and Incentives Department or CARB for each EIC. These factors are used to estimate emissions in future years. The growth factors associated with this emissions category may be obtained from the District's Strategies and Incentives Department.

XI. Control Level

Fugitive windblown dust emissions from exposed lake beds are not subject to District rules. Control levels associated with this emissions category may be obtained from the District's Strategies and Incentives Department.

XII. CARB Chemical Speciation

As of the writing of this methodology, CARB has not assigned a PM Speciation Profile to this source category.

XIII. Assessment Of Methodology

This methodology uses industrial wind erosion over storage piles as a surrogate for estimating windblown dust emissions from exposed lake beds. Erosion potentials are calculated using wind velocity data acquired by the National Climatic Data Center and then used to calculate PM_{10} emissions from wind events that may occur throughout the year.

There are several areas of this methodology that may be improved upon. The use of industrial storage piles as a surrogate may or may not accurately reflect the actual conditions for exposed lake beds. Further studies are needed in order to validate or invalidate this assumption.

Wind data obtained from the National Climatic Data Center only reflects the conditions near each individual monitoring station, many of which are a significant distance away from the nearest lakes. In order to achieve greater accuracy, each lake should have its own monitoring station so it can generate data specific to its own location.

This methodology also assumes that the soil type for all exposed lake beds is that of undisturbed playa. As with the wind data, a more accurate emissions estimate would be achieved if the threshold friction velocity and surface roughness of each lake were estimated with it’s own data.

The manner in which the surface area of an exposed lake bed is estimated is not ideal. However, lacking sufficient information on the grading and terrain of lakes, this approach was used as a conservative estimate.

XIV. Emissions

Following is the 2009 area source emissions inventory for REIC 650-653-5400-0000 estimated by this methodology. Emissions are reported for each county in the District.

Table 2. Area source emissions for REIC 650-653-5400-0000 (2009).

County	Emissions (tons/year)					
	NOx	CO	SOx	VOC	PM_{10}	$PM_{2.5}$
Fresno	N/A	N/A	N/A	N/A	0.00	N/A
Kern	N/A	N/A	N/A	N/A	0.00	N/A
Kings	N/A	N/A	N/A	N/A	0.00	N/A
Madera	N/A	N/A	N/A	N/A	0.00	N/A
Merced	N/A	N/A	N/A	N/A	0.00	N/A
San Joaquin	N/A	N/A	N/A	N/A	0.00	N/A
Stanislaus	N/A	N/A	N/A	N/A	0.00	N/A
Tulare	N/A	N/A	N/A	N/A	0.00	N/A
TOTAL	N/A	N/A	N/A	N/A	0.00	N/A

Following is the net change in total emissions between this update (2009 inventory year) and the previous update (2008 inventory year) for REIC 650-653-5400-0000. The change in emissions are reported for each county in the District.

Table 3. Net emissions change for REIC 650-653-5400-0000 (2008-2009).

County	Emissions (tons/year)					
	NOx	CO	SOx	VOC(1)	PM_{10}	$PM_{2.5}$
Fresno	N/A	N/A	N/A	N/A	0.00	N/A
Kern	N/A	N/A	N/A	N/A	0.00	N/A
Kings	N/A	N/A	N/A	N/A	0.00	N/A
Madera	N/A	N/A	N/A	N/A	0.00	N/A
Merced	N/A	N/A	N/A	N/A	0.00	N/A
San Joaquin	N/A	N/A	N/A	N/A	0.00	N/A
Stanislaus	N/A	N/A	N/A	N/A	0.00	N/A
Tulare	N/A	N/A	N/A	N/A	0.00	N/A
TOTAL	N/A	N/A	N/A	N/A	0.00	N/A

XV. Revision History

2009. This is a new District methodology. There are no previous estimates.

XVI. Update Schedule

In an effort to provide inventory information to CARB and other District programs and maximize limited resources, the District has developed an update cycle based on emissions within the source category as shown in the following table.

Table 4. Area source update frequency criteria.

Total Emissions (tons/day)	Update Cycle (years)
<=1	4
>1 and <= 2.5	3
>2.5 and <=5	2
>5	1

Since there is currently less than one ton per day of emissions in this category, the District will revisit this category in four years.

Table 5. Exposed lake bed methodology update frequency.

EIC	Frequency (years)	Source of Emissions (Point Source Inventory / Data Gathering)
650-653-5400-0000	4	Data Gathering

XVII. References

1) California Air Resources Board (2011). CEIDARS Emission Inventory Categorization Database. (Accessed January 6, 2011) (Login required) https://secure.arb.ca.gov/sslapp/emsinv/dist/rpts/sub_eic.php

2) California Department of Fish and Game (DFG) (2010). GIS Layer for California Lakes. (Accessed September 30, 2010). http://gis.ca.gov/catalog/BrowseRecord.epl?id=31272

3) California Water Resources Board (CWRB) (2010). Reservoir Information - Reservoir Elevation (Hensley, Kaweah, Millerton, Pine Flat, San Luis, and Success Reservoirs). http://cdec.water.ca.gov/misc/resinfo.html

4) Mansell, Gerard E.; Wolf, Martinus; Gillies, John; Barnard, William; and Omary, Mohammad (2004). Final Report: Determining Fugitive Dust Emissions from Wind Erosion. Prepared for the Western Governors' Association. 1515 Cleveland Place, Suite 200, Denver, CO 80202.

5) National Climatic Data Center (NCDC) (2010). 2009 Quality Controlled Local Climatological Data (Bakersfield, Fresno, Hanford, Madera, Merced, Modesto, and Stockton Stations). (Accessed October 21, 2010). http://lwf.ncdc.noaa.gov/oa/ncdc.html

6) United States Environmental Protection Agency (EPA) (2006). AP-42 Fifth Edition, Volume I, Section 13.2.5: Industrial Wind Erosion. Washington D.C. http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0205.pdf

XVIII. Glossary

Fastest Mile: The wind speed corresponding to the whole mile of wind movement that has passed by the one mile contact anemometer in the least amount of time. Typically represented by the maximum 2-minute wind speed, as reported by the National Climatic Data Center (EPA, 2006).

Friction Velocity (u*): A measure of wind shear stress on a erodible surface (EPA, 2006).

Threshold Friction Velocity (u_t): The friction velocity at which the actual friction velocity over a given surface must exceed in order for wind erosion to occur.

Roughness Height: A measure of the roughness of an exposed surface (EPA, 2006).

XIX. Appendix A - Reservoir Parameters

Table 6. Reservoir Parameters

Reservoir	Maximum Elevation (ft)	Nearest NCDC Monitoring Station
San Luis Reservoir	543	Modesto
Pine Flat Lake	970	Fresno
Lake Success	692	Hanford
Millerton Lake	581	Fresno
Hensley Lake	561	Madera
Lake Kaweah	752	Hanford