San Joaquin Valley
AIR POLLUTION CONTROL DISTRICT

2008 Area Source Emissions Inventory Methodology
540 – ASPHALT PAVING

I. Purpose

This document describes the Area Source Methodology used to estimate emissions of volatile organic compounds (VOC) from asphalt paving operations 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). An area source category collectively represents individual sources that are small and numerous and that 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 operations that are identified by the following Category of Emission Source (CES) codes and Reconciliation Emission Inventory Codes (REIC):

Table 1. Emission inventory codes.

CES	REIC	Description
46870	540-560-0400-0000	Asphalt Paving –Cutback Asphalt
46888	540-562-0400-0000	Asphalt Paving –Road Oils (Slow Cure)
46896	540-564-0400-0000	Asphalt Paving –Hot Mix Asphalt
46904	540-566-0400-0000	Asphalt Paving –Emulsified Asphalt
82057	540-995-0400-0000	Asphalt Paving –Unspecified

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. While the production of asphalt at refineries and asphalt plants is permitted by the District and their emissions included in the point source inventory, the application of asphalt to roads and parking lots is not subject to District permit. Therefore, the area sources

in this methodology are not represented within our point source inventory and reconciliation is not necessary.

IV. Methodology Description

This methodology estimates emissions of Volatile Organic Compounds (VOC) from asphalt paving materials during and after paving. It does not include VOC emissions from the manufacture of asphaltic materials, since these processes are subject to District permit and their emissions are included in our point source inventory.

Asphalt and road oils are used to pave, seal, and repair surfaces such as roads, parking lots, drives, walkways, and airport runways. The most commonly used forms of asphalt are hot-mix, cutback, and emulsified. Hot-mix asphalt is a mixture of heated asphalt cement and aggregate. Asphalt cutbacks are asphalt cements thinned with petroleum distillates (diluents). Asphalt emulsions are mixtures of asphalt cement with water and emulsifiers. Each is discussed below.

- **Hot mix asphalt** is prepared at a hot-mix asphalt plant by heating asphalt cement before adding the aggregate. Mixing is generally performed with the aggregate at about 300-330°F, and the asphalt cement at 200°F. Paving and compaction must be performed while the asphalt is still hot. To maintain a liquid mixture, hot mix asphalt plants must be near the paving site. In some cases, mobile facilities are used. For hot-mix asphalt, the organic components have high molecular weights and low vapor pressures. Therefore, hot-mix asphalts emit little VOC.

- **Cut-back asphalt** is produced by dissolving ("cutting back") asphalt cement with diesel or another diluent. While in its dissolved state, the asphalt is less viscous and the mix is easy to work and compact. After the mix is applied, the solvent evaporates and the asphalt hardens. Cutback asphalt is used in tack and seal operations, in priming roadbeds for hot-mix application, and for pavements up to several inches thick. Cutback asphalt is prepared at a refinery. For cutback asphalt, emissions are primarily from the diluents that contain VOCs. Cutback asphalt has the highest levels of VOCs emissions of the three asphalt categories. There are three basic types of cutback asphalt cement based upon the diluents used:

    - **Slow cure cut-back asphalt**, which includes **road oil**, conforms to the specification of the American Society for Testing & Materials (ASTM) D2026-72 and uses low volatility fuel solvents (such as diesel) as diluents. .

    - **Medium cure cut-back asphalt** conforms to specification of ASTM D2027-76 and uses kerosene as a diluent.

    - **Rapid cure cut-back asphalt** conforms to the specification of ASTM D2028-76 and uses gasoline or naphthas as diluents.

- **Emulsified asphalt** is produced by emulsifying the asphalt in water with a surfactant (soap) prior to mixing with the aggregate. While emulsified, the asphalt is easy to work and compact. When the water evaporates, the emulsified asphalt will harden. Emulsified asphalts have lower VOC emissions than cutback asphalts since they have little or no diluent.

Asphalt may also be modified through the addition of rubbers, plastics, fillers, extenders, fibers, oxidants, antioxidants or hydrocarbons to improve their performance. The California Department of Transportation (Caltrans) has been testing the use of rubberized asphalt concrete (RAC). California Assemble Bill 338 requires Caltrans to gradually phase in the use of crumb rubber on state highway construction and repair projects, to the extent feasible.

Hot mix asphalt process rates were obtained from the District's point source inventory. Cut back and emulsified asphalt consumption for the state of California was obtained from the Asphalt Institute. Asphalt consumption was disaggregated to the counties using vehicles miles traveled as a surrogate. VOC emissions from asphalt paving were calculated by multiplying the amount of asphalt paving material applied in the District by emission factors.

V. Activity Data

A. Hot mix asphalt.

The total amount of hot mix asphalt paving material produced in the District in 2008 was obtained from the point source inventory. Since hot mix asphalt needs to be applied within a few hours of being produced, it was assumed that all hot mix asphalt produced in the District was applied in the District. The total amount of hot mix asphalt produced in the District was then disaggregated to the county level using vehicle miles traveled (CARB, 2010) as a surrogate. The amount of hot mix asphalt applied in each county in the District in 2008 is presented in the following table:

Table 2. SJVAPCD hot mix asphalt paving material applied, 2008.

County	Vehicle Miles Traveled[1] (1,000's)	Vehicle Miles Traveled (% of District)	Hot Mix Paving Material (tons)	Asphaltic Oil[2] (tons)	Aggregate[2] (tons)
Fresno	21,694	22.41%	1,119,066	55,953	1,063,113
Kern	18,707	19.32%	964,984	48,249	916,735
Kings	3,892	4.02%	200,765	10,038	190,727
Madera	5,059	5.22%	260,964	13,048	247,916
Merced	8,413	8.69%	433,977	21,699	412,278
San Joaquin	17,241	17.80%	889,362	44,468	844,894
Stanislaus	11,479	11.85%	592,134	29,607	562,528
Tulare	10,351	10.69%	533,947	26,697	507,250
District Total	**96,836**	**100.00%**	**4,995,199**	**249,759**	**4,745,441**

[1]CARB, 2010.
[2]Hot mix asphalt paving material assumed to be 95% aggregate and 5% asphaltic oil.

B. Cutback and emulsified asphalt.

The total amount of cutback asphalt cement (slow, medium and rapid cure) and emulsified asphalt cement used in California in 2008 was obtained from the Asphalt Institute and is presented in the following table:

Table 3. Amount of asphalt paving material consumed in the State of California in 2008 (Asphalt Institute, 2010).

Asphalt Type	Tons of Material
Cutback Asphalt Cement	30,657
Emulsified asphalt	151,767

Cutback asphalt was assumed to be 95% slow cure, 5% medium cure and 0% rapid cure based on a survey of permitted refineries. Asphalt usage was distributed to the counties in the District using vehicle miles traveled. The total vehicle miles traveled in 2008 by county was obtained from CARB (2010). The amount of medium cure cutback, slow cure cutback (road oil), modified asphalt, and emulsified asphalt distributed to each county in the District is presented in the table below:

Table 4. SJVAPCD cold applied asphalt usage, 2008.

County	Vehicle Miles Traveled[1] (1,000's)	Vehicle Miles Traveled (% of State)	Slow Cure Cutback (tons)	Medium Cure Cutback (tons)	Emulsified Asphalt (tons)
Fresno	21,694	2.33%	678	36	678
Kern[2]	18,707	2.01%	585	31	585
Kings	3,892	0.42%	122	6	122
Madera	5,059	0.54%	158	8	158
Merced	8,413	0.90%	263	14	263
San Joaquin	17,241	1.85%	539	28	539
Stanislaus	11,479	1.23%	359	19	359
Tulare	10,351	1.11%	324	17	324
District Total	**96,836**	**10.39%**	**3,028**	**159**	**3,028**
State Total	**931,495**	**100.00%**	**29,124**	**1,533**	**151,767**

[1]CARB, 2010.
[2]Includes only the valley portion of Kern County.

VI. Emission Factors

Asphalt paving emission factors are summarized in the following table:

Table 5. Asphalt paving emission factors.

Asphalt Type	Emission Factor (lbs VOC/ton)	Source
Hot mix asphalt paving (5% asphaltic oil plus 95% aggregate)	0.002	KVB (1978)
Slow cure asphalt/road oil	70.4	Sonoma Technology, Inc. (2003)
Medium cure asphalt	268.3	Sonoma Technology, Inc. (2003)
Emulsified asphalt	17.9	Sonoma Technology, Inc. (2003)

VII. Emissions Calculations

A. Assumptions

1. VOC is the only pollutant emitted from paving operations.
2. Each ton of applied hot-mix asphalt paving emits 0.002 pounds VOC.

B. Sample Calculation

Given:

1. There were 1,119,066 tons of hot-mix asphalt consumed in Fresno County in 2008.
2. Each ton of applied hot-mix asphalt paving emitted 0.002 pounds VOC.

Calculate Emissions:

Emissions from asphalt paving operations can be calculated using the following equation:

$$\frac{Tons\ VOC}{Year} = Tons\ Paving\ Applied\ x\ \frac{Pounds\ VOC}{Ton\ Paving}\ x\ \frac{1\ Ton}{2{,}000\ Pounds}$$

VOC emissions from hot-mix asphalt paving in Fresno county is calculated as follows:

$$\frac{Tons\ VOC_{Hot-Mix}}{Year} = 1{,}119{,}066\ Tons\ Paving\ Applied\ x\ \frac{0.002\ Pounds\ VOC}{Ton\ Paving}\ x\ \frac{1\ Ton}{2{,}000\ Pounds}$$

$$\frac{Tons\ VOC_{Hot-Mix}}{Year} = 1.12$$

VIII. Temporal Variation

A. Daily

ARB Code 24. 24 hours per day - uniform activity during the day

B. Weekly

ARB Code 7. 7 days per week - uniform activity every day of the week

C. Monthly

Monthly activity within the District is assumed to be uniform throughout the year (Eastern Research Group, 2001).

IX. Spatial Variation

Emissions within each county may be distributed to paved roads.

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

Control levels are developed by either the District's Strategies and Incentives Department or CARB for each EIC. Control levels are used to estimate emissions reductions in future years due to implementation of District rules. These control levels take into account the effect of control technology, compliance and exemptions at full implementation of the rules. The application and manufacturing of certain types of asphalt for paving and maintenance operations is subject to District Rule 4641 (Cutback, Slow Cure, and Emulsified Asphalt, Paving and Maintenance Operations). Control levels associated with this emissions category may be obtained from the District's Strategies and Incentives Department.

XII. ARB Chemical Speciation

CARB has developed organic gas profiles in order to calculate reactive organic gasses (ROG), volatile organic compounds (VOC) or total organic gas (TOG) given any one of the three values. For each speciation profile, the fraction of TOG that is ROG and VOC is given. The organic gas profile codes can also be used to lookup associated toxics. CARB's speciation profiles for asphalt paving operations are presented in the table below. Organic gas profile #716 is applied to cutback asphalt (REIC 540-560-0400-0000). Organic gas profile #715 is applied to road oils (slow cure asphalt (REIC 540-562-0400-0000), hot mix asphalt (REIC 540-564-0400-0000), emulsified asphalt (REIC 540-566-0400-0000) and unspecified asphalt (REIC 540-995-0400-0000).

Table 6. CARB chemical speciation profiles for Asphalt Paving Operation.

Profile Description	ARB Organic Gas Profile#	Fractions	
		ROG	VOC
Medium Cure Asphalt	716	1	1
Slow Cure Asphalt	715	1	1

XIII. Assessment Of Methodology

The amount of hot-mix asphalt paving material produced by asphalt plants permitted to operate in the District was queried from the District's point source emissions inventory database. In estimating emissions from hot-mix asphalt paving operations, the District assumes that all hot-mix asphalt produced in the District is consumed in the District, and that no hot-mix asphalt produced outside of the District is consumed in the District. Since hot-mix asphalt must be applied before it cools (within a few hours of leaving the plant), this assumption is reasonable.

The amount of cutback and emulsified asphalt applied in the District was estimated from statewide production data obtained from the Asphalt Institute. This statewide data was disaggregated to the county level using VMT. For this estimate we assume that the data from the Asphalt Institute accurately represents the state's production, and that VMT is a good surrogate for disaggregating state level data to

the counties in the District. The Asphalt Institute also reports the amount of modified asphalt produced in the state. Based on information from our permit holders, we assume that modified asphalt is used as a hot mix and is included in the hot mix process rate submitted to the District's point source inventory.

This estimate could be improved by surveying local contractors and public works agencies to determine the actual amounts and types of material applied.

XIV. Emissions

Following are the 2008 total unreconciled emissions for asphalt paving operations. These area source categories do not have point sources associated with them. Emissions are reported for each county in the District

Table 7. Total emissions for asphalt paving in the SJVAPCD, 2008.

County	Emissions (tons/year)					
	NOx	CO	SOx	VOC[1]	PM_{10}	$PM_{2.5}$[2]
Asphalt Paving –Cutback Asphalt (540-560-0400-0000)						
Fresno	--	--	--	4.79	--	--
Kern[3]	--	--	--	4.13	--	--
Kings	--	--	--	0.86	--	--
Madera	--	--	--	1.12	--	--
Merced	--	--	--	1.86	--	--
San Joaquin	--	--	--	3.81	--	--
Stanislaus	--	--	--	2.53	--	--
Tulare	--	--	--	2.29	--	--
TOTAL	--	--	--	21.39	--	--
Asphalt Paving –Road Oils, Slow Cure (540-562-0400-0000)						
Fresno	--	--	--	23.88	--	--
Kern[3]	--	--	--	20.59	--	--
Kings	--	--	--	4.28	--	--
Madera	--	--	--	5.57	--	--
Merced	--	--	--	9.26	--	--
San Joaquin	--	--	--	18.97	--	--
Stanislaus	--	--	--	12.63	--	--
Tulare	--	--	--	11.39	--	--
TOTAL	--	--	--	106.57	--	--
Asphalt Paving –Hot Mix Asphalt (540-564-0400-0000)						
Fresno	--	--	--	1.12	--	--
Kern[3]	--	--	--	0.96	--	--
Kings	--	--	--	0.20	--	--
Madera	--	--	--	0.26	--	--
Merced	--	--	--	0.43	--	--
San Joaquin	--	--	--	0.89	--	--
Stanislaus	--	--	--	0.59	--	--
Tulare	--	--	--	0.53	--	--
TOTAL	--	--	--	4.98	--	--

Table 7 cont. Total emissions for asphalt paving in the SJVAPCD, 2008.

County	Emissions (tons/year)					
	NOx	CO	SOx	VOC[1]	PM_{10}	$PM_{2.5}$
Asphalt Paving – Emulsified Asphalt (540-566-0400-0000)						
Fresno	--	--	--	31.63	--	--
Kern[3]	--	--	--	27.28	--	--
Kings	--	--	--	5.68	--	--
Madera	--	--	--	7.38	--	--
Merced	--	--	--	12.27	--	--
San Joaquin	--	--	--	25.14	--	--
Stanislaus	--	--	--	16.74	--	--
Tulare	--	--	--	15.09	--	--
TOTAL	--	--	--	141.21	--	--
Asphalt Paving – Unspecified (540-995-0400-0000)						
Fresno	--	--	--	0.00	--	--
Kern[2]	--	--	--	0.00	--	--
Kings	--	--	--	0.00	--	--
Madera	--	--	--	0.00	--	--
Merced	--	--	--	0.00	--	--
San Joaquin	--	--	--	0.00	--	--
Stanislaus	--	--	--	0.00	--	--
Tulare	--	--	--	0.00	--	--
TOTAL	--	--	--	0.00	--	--

[1] The District only reports ROG to ARB. As noted in Section XII, ROG is the same as VOC.
[2] Reflects only the Valley portion of Kern County.

Following is the net change in total unreconciled emissions between this update (2008 inventory year) and the previous update (2007 inventory year) for asphalt paving operations. The changes in emissions are reported for each county in the District.

Table 8. Net change in emissions for asphalt paving in the SJVAPCD (2008-2007).

County	Emissions (tons/year)					
	NOx	CO	SOx	VOC[1]	PM_{10}	$PM_{2.5}$[2]
Asphalt Paving –Cutback Asphalt (540-560-0400-0000)						
Fresno	--	--	--	4.79	--	--
Kern[3]	--	--	--	4.13	--	--
Kings	--	--	--	0.86	--	--
Madera	--	--	--	1.12	--	--
Merced	--	--	--	1.86	--	--
San Joaquin	--	--	--	3.81	--	--
Stanislaus	--	--	--	2.53	--	--
Tulare	--	--	--	2.29	--	--
TOTAL	--	--	--	21.39	--	--
Asphalt Paving –Road Oils, Slow Cure (540-562-0400-0000)						
Fresno	--	--	--	17.94	--	--
Kern[3]	--	--	--	15.61	--	--
Kings	--	--	--	3.07	--	--
Madera	--	--	--	3.37	--	--
Merced	--	--	--	7.39	--	--
San Joaquin	--	--	--	17.66	--	--
Stanislaus	--	--	--	11.20	--	--
Tulare	--	--	--	6.59	--	--
TOTAL	--	--	--	82.83	--	--
Asphalt Paving –Hot Mix Asphalt (540-564-0400-0000)						
Fresno	--	--	--	-26.43	--	--
Kern[3]	--	--	--	-19.47	--	--
Kings	--	--	--	-3.75	--	--
Madera	--	--	--	-2.67	--	--
Merced	--	--	--	-6.10	--	--
San Joaquin	--	--	--	-15.54	--	--
Stanislaus	--	--	--	-13.45	--	--
Tulare	--	--	--	-10.61	--	--
TOTAL	--	--	--	-98.02	--	--
Asphalt Paving – Emulsified Asphalt (540-566-0400-0000)						
Fresno	--	--	--	-59.11	--	--
Kern[3]	--	--	--	-40.16	--	--
Kings	--	--	--	-7.51	--	--
Madera	--	--	--	-2.66	--	--
Merced	--	--	--	-8.88	--	--
San Joaquin	--	--	--	-31.24	--	--
Stanislaus	--	--	--	-30.22	--	--
Tulare	--	--	--	-20.99	--	--
TOTAL	--	--	--	-200.77	--	--

Table 8 cont. Net change in emissions for asphalt paving in the SJVAPCD (2008-2007).

County	Emissions (tons/year)					
	NOx	CO	SOx	VOC[1]	PM_{10}	$PM_{2.5}$
Asphalt Paving – Unspecified (540-995-0400-0000)						
Fresno	--	--	--	0.00	--	--
Kern[2]	--	--	--	0.00	--	--
Kings	--	--	--	0.00	--	--
Madera	--	--	--	0.00	--	--
Merced	--	--	--	0.00	--	--
San Joaquin	--	--	--	0.00	--	--
Stanislaus	--	--	--	0.00	--	--
Tulare	--	--	--	0.00	--	--
TOTAL	--	--	--	0.00	--	--

[1] The District only reports ROG to ARB. As noted in Section XII, ROG is the same as VOC.
[2] Reflects only the Valley portion of Kern County.

XV. Revision History

2008. This is a new District methodology.

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 9. 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 the VOC emissions from this category are less than one (1) ton per day, it is recommended that this methodology be updated and revised every four years.

XVII. References

1) American Society for Testing and Materials. 1972. ASTM D2026-72: Standard Specification for Cutback Asphalt (Slow-Curing Type). 2 pages.

2) American Society for Testing and Materials. 1976. ASTM D2027-76: Standard Specification for Cutback Asphalt (Medium-Curing Type). 2 pages.

3) American Society for Testing and Materials. 1976. ASTM D2028-76: Standard Specification for Cutback Asphalt (Rapid-Curing Type). 2 pages.

4) Asphalt Institute. 2009. 2008 Asphalt Usage Survey for the United States and Canada. <http://www.asphaltinstitute.org>

5) California Air Resources Board. 2010. CEPAM: 2009 Almanac - Population and Vehicle Trends. (Accessed June 16, 2010). <http://www.arb.ca.gov/app/emsinv/trends/ems_trends.php>

6) California Air Resources Board. 2005. Draft memo dated 5/11/05: Comparison of Asphalt Paving Emission Factors. 2 pages. <www.arb.ca.gov/ei/areasrc/draftmeth/asphcompar.pdf>

7) California Assembly Bill No. 338, Chapter 709 (Levine). Recycling: Crumb Rubber. <http://info.sen.ca.gov/pub/05-06/bill/asm/ab_0301-0350/ab_338_bill_20051007_chaptered.pdf>

8) Eastern Research Group, Inc. 2001. Emission Inventory Improvement Program (EIIP) (2000). Volume III: Chapter 17 - Asphalt Paving. Report prepared for the Area Source Committee of the Emission Inventory Improvement Committee, and for Charles Mann of the Air Pollution Prevention and Control Division, U.S. Environmental Protection Agency. 54 pages. <http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii17_apr2001.pdf>

9) KVB . 1978. Control of Hydrocarbon Emissions from Stationary Sources in the California South Coast Air Basin. Section 2, page 88.

10) Lutes, C.C., R.J. Thomas, and R. Burnette. 1994. Final Report - Evaluation of Emissions from Paving Asphalts. Report prepared for the United States Environmental Protection Agency, Office of Air Quality Planning and Standards EPA-600/R-94-135. Research Triangle Park, North Carolina. 207 pages.

11) Sonoma Technology, Inc. 2003. Central California Ozone Study, Attachment C: Asphalt Paving and Roofing. 27 pages. <http://www.arb.ca.gov/ei/areasrc/ccosmeth/att_c_asphalt.doc>

12) State of California Department of Transportation, Division of Maintenance. 2008. 2007 State of the Pavement. 34 pages. <http://www.dot.ca.gov/hq/maint/2007_SOP_8_7_08.pdf>

13) State of California Department of Transportation. 2008. Analysis of Cost Differential Between Asphalt Containing Crumb Rubber and conventional Asphalt for 2007 Public Resources Code Section 42703. Report prepared for the State of California Business, Transportation and Housing Agency. 17 pages. <http://www.dot.ca.gov/hq/oppd/rescons/ab338/Analysis-of-Cost-Differential-Btwn-AC-w-Crumb-Rubber-&-Conventionial-AC-2007-Data-FINAL.pdf>

14) State of California Department Of Transportation, Division of Transportation System Information. 2009. 2008 Californian Public Road Data. 86 pages. <http://www.dot.ca.gov/hq/tsip/hpms/hpmslibrary/hpmspdf/2008PRD.pdf>