Appendix D

MOBILE EMISSIONS

USED FOR THE CONFORMITY BUDGET

SUPPORT DOCUMENTATION

FOR THE

FINE PARTICULATE SIP

January 2008

Southeast Michigan On-Road Mobile Source Emissions Inventory

Developed for the 2008 $PM_{2.5}$ State Implementation Plan Submittal

January 28, 2008

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$PM_{2.5}$ On-Road Mobile Source Emissions Inventory
Developed for the 2008 $PM_{2.5}$ State Implementation Plan

The Southeast Michigan Council of Governments (SEMCOG) is the Metropolitan Planning Organization (MPO) and lead local air quality planning agency for a seven-county region that comprises Southeast Michigan's $PM_{2.5}$ nonattainment area (Livingston, Macomb, Monroe, Oakland, Washtenaw, and Wayne counties). Under an agreement with the State of Michigan, SEMCOG is responsible for developing the on-road mobile source emissions inventories for this region.

This document provides detailed information on the air quality emissions modeling process used by SEMCOG to develop the on-road mobile source emissions inventory for the Southeast Michigan $PM_{2.5}$ State Implementation Plan (SIP).

I. Overview of On-Road Mobile Modeling Process

The general process for developing on-road mobile source emissions inventories involves applying emission factors to estimates of vehicle miles of travel (VMT) within the Southeast Michigan nonattainment area. The emission factors are generated by the U.S. Environmental Protection Agency's (EPA) Mobile6 model. The VMT is estimated using SEMCOG's Travel Demand Forecast Model. Actual emissions calculation is done using a post-processing model, developed by SEMCOG. The post-processor multiplies the travel model VMT by the appropriate Mobile6 emission to calculate link-level emissions of volatile organic compounds (VOC), carbon monoxide (CO), nitrogen oxides (NOx), fine particulate ($PM_{2.5}$), sulfur dioxide (SO_2), and ammonia (NH3).

Emission inventories were developed for four different analysis years: 2002, 2005, 2009 and 2018. In keeping with EPA guidance on the preparation of annual inventories, the analysis involved the development of seasonal inventories that were then summed to create an annual inventory for each analysis year.

II. Modeling Inputs and Assumptions

The following paragraphs explain the various model inputs and assumptions used to create the emissions inventories.

A. Mobile6.2 Input Parameters

As required by the U.S. Environmental Protection Agency (EPA), the inventory was developed using emission rates generated by EPA's Mobile6.2 emission factor model. It also used the updated PM rate table for heavy-duty vehicles, which EPA released on March 17, 2006. This rate table corrects an over estimation of PM_{10} and $PM_{2.5}$ heavy-duty vehicle emissions by the previous version of the model for years 2007 and beyond.

The Mobile6.2 model allows for input of certain localized data in order to provide better emissions estimates for a given region. Six localized data inputs were used in SEMCOG's analysis:

- **Minimum & Maximum Daily Temperatures:** Table 1 shows the temperatures used to simulate an average day in each of the four seasons. The values were derived from National Weather Service local climatological data reports, provided by the Michigan Department of Environmental Quality (MDEQ). 2002 values were calculated by averaging the monthly minimum and maximum temperatures between 2001 and 2003. Values for years 2005 through 2018, used the average monthly minimum and maximum temperatures observed between 2004 and 2006.

Table 1
Minimum and Maximum Daily Temperatures Used in Mobile6

Analysis Year	Season							
	Winter		Spring		Summer		Fall	
	Min	Max	Min	Max	Min	Max	Min	Max
2002	22.8	35.6	38.1	56.8	62.5	81.9	44.6	61.8
2005-2018	22.3	35.2	39.8	58.7	62.8	81.7	45.1	62.6

- **Reid Vapor Pressure (RVP):** Mobile6 summer runs for years 2002 and 2005 used an RVP of 7.8 pounds per square inch (psi), which was the maximum level allowed by law in Southeast Michigan during the summer months until 2007. In 2007, a new law went into affect, requiring 7.0 psi vapor pressure gasoline between June 1st and September 15th of each year. Thus, an RVP of 7.0 was used for summer runs in years 2009 and 2018.

  For the other three seasons, 2002 fuel sample data, obtained from the Michigan Department of Agriculture, were used to compute the average RVP for each season in each year. The averages were 12.3 psi for winter, 11.1 psi for spring, and 10.7 psi for fall. These values were used for all analysis years.

- **Gasoline Sulfur Values:** The 2002 values were derived from Alliance of Automobile Manufacturers North American Fuel Survey data for Wayne County, Michigan. The summer value was 439 ppm. The value for the other three seasons was 424 ppm. As new gasoline sulfur standards should be phased-in by 2009 in Midwest states, the Mobile6 default value of 30 ppm was used for all seasons in years 2009 and 2018.

- **Diesel Sulfur Values**: As with gasoline, the 2002 diesel sulfur level was derived from the 2002 Alliance of Automobile Manufacturers fuel survey. This value was 380 ppm. As data on seasonal variation was not available, the same value was used for all 2002 runs. For future years, the new diesel sulfur standard of 15 ppm, which begins phasing in during 2006, was used. A value of 106.3 was used for 2005, which was derived through linear interpolation of the 2002 and 2006 values.

- **Oxygenated Fuels Inputs**: In addition to providing the local gasoline sulfur values, the 2002 North American Fuel Survey data showed that approximately 25% of the fuel sold in Southeast Michigan contained an oxygenate. The vast majority of this oxygenate was ethanol. A small fraction was MTBE. The observed values from the fuel survey were used in SEMCOG's 2002 base year modeling. For 2005 and all future years, SEMCOG assumed that oxygenate would continue to be present in 25% of the region's gasoline. However, as use of MTBE was banned in Michigan in 2003, it was assumed that all of the oxygenate in these years would be ethanol. Table 6 shows the specific oxygenate inputs used in Mobile6.

Table 2
Oxygenated Fuel Inputs Used in Mobile6

Year	Oxygenate	% Market Share	% Weight
2002	Ethanol MTBE	20.7 3.5	3.2 1.9
2005 - 2018	Ethanol MTBE	25.0 0.0	3.2 0.0

- **Age Distribution of Vehicle Fleet:** Table 3 shows the vehicle fleet age distribution data used in Mobile6. The light-duty distribution was developed by the Lake Michigan Air Directors Consortium (LADCO), using 2004 vehicle registration data for Southeast Michigan. The heavy-duty distribution was developed from national data, using EPA guidance.

Table 3
Age Distribution of Southeast Michigan Fleet

Vehicle Age (Years)	Vehicle Class							
	Light Duty Vehicle	Light Duty Truck 1	Light Duty Truck 2	Light Duty Truck 3	Light Duty Truck 4	Heavy Duty Truck	Heavy Duty Bus	Motorcycle
1	0.0919	0.1267	0.1563	0.1325	0.1375	0.031	0.029	0.017
2	0.1225	0.1689	0.2084	0.1767	0.1833	0.082	0.078	0.098
3	0.1262	0.1740	0.2147	0.1820	0.1888	0.068	0.065	0.088
4	0.0866	0.0421	0.1114	0.0940	0.1255	0.077	0.074	0.071
5	0.0438	0.0207	0.0500	0.0383	0.0567	0.065	0.062	0.072
6	0.0452	0.0155	0.0455	0.0500	0.0757	0.082	0.097	0.063
7	0.0359	0.0166	0.0370	0.0256	0.0429	0.062	0.069	0.052
8	0.0345	0.0123	0.0278	0.0233	0.0351	0.047	0.059	0.040
9	0.0337	0.0210	0.0225	0.0228	0.0256	0.037	0.044	0.027
10	0.0419	0.0260	0.0217	0.0300	0.0252	0.036	0.046	0.020
11	0.0401	0.0391	0.0213	0.0296	0.0289	0.042	0.051	0.020
12	0.0409	0.0357	0.0204	0.0248	0.0087	0.048	0.053	0.432
13	0.0390	0.0290	0.0160	0.0227	0.0115	0.045	0.048	0.000
14	0.0374	0.0435	0.0112	0.0175	0.0041	0.041	0.046	0.000
15	0.0351	0.0390	0.0080	0.0208	0.0069	0.038	0.042	0.000
16	0.0338	0.0426	0.0075	0.0228	0.0045	0.031	0.034	0.000
17	0.0270	0.0322	0.0084	0.0179	0.0050	0.026	0.028	0.000
18	0.0194	0.0354	0.0022	0.0140	0.0037	0.014	0.013	0.000
19	0.0174	0.0279	0.0026	0.0132	0.0071	0.010	0.011	0.000
20	0.0133	0.0201	0.0019	0.0101	0.0056	0.010	0.010	0.000
21	0.0094	0.0115	0.0018	0.0075	0.0028	0.010	0.007	0.000
22	0.0049	0.0054	0.0011	0.0040	0.0016	0.018	0.008	0.000
23	0.0027	0.0041	0.0005	0.0021	0.0007	0.017	0.007	0.000
24	0.0026	0.0030	0.0004	0.0012	0.0002	0.014	0.005	0.000
25+	0.0148	0.0078	0.0016	0.0168	0.0125	0.049	0.015	0.000

B. Vehicle Miles of Travel (VMT) Estimation & Emissions Calculation

- **Demographic Data:** Travel forecasts used in the conformity analysis are based on demographic data from SEMCOG's 2030 Regional Development Forecast (RDF), which was published in 2001.

- **Description of SEMCOG's travel forecasting model**: VMT forecasts for the conformity analysis were developed using SEMCOG's TransCAD travel forecasting model (version E4-enhanced). A more detailed description of the model is available from SEMCOG upon request.

- **HPMS Normalization Factors:** EPA and FHWA guidance stipulates that VMT used to construct mobile source emissions inventories be consistent with that reported through the Highway Performance Monitoring System (HPMS), In accordance with this guidance, SEMCOG developed factors to normalize the TransCAD travel model VMT to the Michigan Department of Transportation (MDOT) HPMS VMT. The factors were developed in a four-step process:

  1. 2002 HPMS universe data, aggregated by county and functional class, were obtained from MDOT.
  2. 2002 average weekday TransCAD model VMT were also aggregated by county and functional class.
  3. TransCAD VMT was converted to average annual daily VMT (AADVMT) using day-of-week adjustment factors from MDOT's publication *Seasonal Analysis of Michigan's Permanent Traffic Recorder (PTR) Data For 2001, 2002, 2003.*
  4. Normalization factors for each county and functional class were computed by dividing the HPMS VMT by the corresponding TransCAD AADVMT.

  The daily adjustment factors used in step 3, along with the resulting normalization factors, are provided in tables 4 and 5. These factors were applied to all travel model VMT, in both current and future years, prior to calculating vehicle emissions.

Table 4
Average Annual Daily Travel Adjustment Factors

Area Type[1]	Urban	Urban Area Limit	Rural
AADT Adj. Factor	0.8597	0.9214	1.0209

[1] Urban includes the city of Detroit; Urban Area Limit includes Macomb, Oakland and Wayne counties (excluding Detroit); Rural includes Livingston, Monroe, St. Clair and Washtenaw counties.

Table 5
HPMS Normalization Factors

County	Freeway	Principal Arterial	Minor Arterial	Collector
Livingston	0.688099	1.585526	1.015991	0.535365
Macomb	1.040133	1.204916	1.136826	0.855788
Monroe	0.855686	1.007290	1.093279	0.689459
Oakland	1.074974	1.043694	1.009170	0.697480
St. Clair	0.867815	1.066117	1.363675	1.033534
Washtenaw	0.829980	0.930350	0.900897	0.793497
Wayne				
Detroit	1.137798	1.184245	1.372235	1.784939
Outer-Wayne	1.061630	1.344744	1.280373	1.665449

- **VMT Seasonal Adjustment**: Once the travel model VMT had been normalized to HPMS data, seasonal adjustment factors were applied to generate average daily VMT for each of the four seasons. The factors are shown in Table 6 below. They were developed using data from the MDOT report *Seasonal Analysis of Michigan's Permanent Traffic Recorder (PTR) Data for 2001, 2002, 2003.*

Table 6
VMT Seasonal Adjustment Factors

Area Type[1]	Season			
	Winter	Summer	Spring	Fall
Urban	0.9417	1.0384	1.0080	1.0172
Urban Area Limit	0.9491	1.0095	1.0528	0.9940
Rural	0.8685	1.1682	0.9737	1.0357

[1] Urban include the city of Detroit; Urban Area Limit includes Macomb. Oakland and Wayne counties (excluding Detroit); Rural includes Livingston, Monroe, St. Clair and Washtenaw counties.

- **VMT Distribution by Vehicle Class**: SEMCOG's emissions post-processor apportions each roadway link's hourly VMT among the eight different vehicle classes contained in the Mobile6 default "descriptive" emissions rate tables. This is done by multiplying the hourly VMT by the appropriate vehicle mix factors, listed in Table 7.

  The factors were developed using vehicle classification count data for Southeast Michigan. Freeway factors were computed from year 2000 MDOT PTR data. Arterial factors were developed from 1999 and 2000 screen line traffic counts taken by SEMCOG. The conversion of traffic count data from the standard 13 FHWA bins to the eight vehicle classes in Mobile6 was done using vehicle sales and mileage accumulation data from EPA's technical memorandum: *Fleet Characterization Data for Mobile6*[1]. Table 8 shows this apportionment.

Table 7
Southeast Michigan VMT Vehicle Mix Factors for Typical Weekday - Freeways

Road Type	Hour	Vehicle Type								
		LDGV	LDDV	LDGT 1&2	LDGT 3&4	LDDT	HDGV	HDDV	MC	Total
Freeway	1	46.05	0.34	26.37	9.36	0.25	5.38	12.25	0.00	100.00
	2	43.18	0.32	24.47	8.68	0.23	7.05	16.07	0.00	100.00
	3	39.97	0.30	24.63	8.74	0.23	7.66	17.46	0.00	98.99
	4	37.94	0.28	24.76	8.79	0.23	8.54	19.46	0.00	100.00
	5	40.14	0.30	26.98	9.58	0.26	7.17	16.33	0.00	100.76
	6	44.87	0.33	30.45	10.82	0.29	4.04	9.21	0.00	100.00
	7	45.71	0.34	30.83	10.95	0.29	3.36	7.65	0.87	100.00
	8	49.01	0.36	28.31	10.05	0.26	3.39	7.73	0.87	99.99
	9	46.39	0.34	26.67	9.47	0.25	4.88	11.12	0.87	100.00
	10	41.91	0.31	26.50	9.40	0.25	6.37	14.51	0.87	100.13
	11	40.56	0.30	25.94	9.21	0.24	6.98	15.90	0.87	100.00
	12	40.56	0.30	25.94	9.21	0.24	7.02	15.99	0.87	100.13
	13	41.15	0.30	26.06	9.25	0.24	6.75	15.38	0.87	100.00
	14	41.83	0.31	26.93	9.56	0.25	6.44	14.68	0.87	100.87
	15	42.50	0.31	27.89	9.91	0.27	5.57	12.68	0.87	100.01
	16	43.85	0.32	29.18	10.37	0.27	4.65	10.60	0.87	100.13
	17	46.39	0.34	28.69	10.18	0.27	3.74	8.51	0.87	99.00
	18	48.42	0.36	28.11	9.98	0.26	3.39	7.73	0.87	99.12
	19	48.42	0.36	28.11	9.98	0.26	3.39	7.73	0.87	99.12
	20	47.74	0.35	27.87	9.89	0.26	3.97	9.04	0.87	99.99
	21	48.33	0.36	28.08	9.97	0.26	3.70	8.43	0.87	99.99
	22	48.33	0.36	27.99	9.93	0.26	3.70	8.43	0.00	98.99
	23	48.25	0.36	27.87	9.89	0.26	4.08	9.30	0.00	99.99
	24	47.40	0.35	27.39	9.72	0.25	4.77	10.86	0.00	100.74

Table 7 continued
Southeast Michigan VMT Vehicle Mix Factors for Typical Weekday - Arterials

Road Type	Hour	Vehicle Type								
		LDGV	LDDV	LDGT 1&2	LDGT 3&4	LDDT	HDGV	HDDV	MC	Total
Arterial	1	53.71	0.40	29.24	10.38	0.27	1.53	3.48	1.00	100.00
	2	53.04	0.39	29.51	10.47	0.28	1.57	3.58	1.15	100.00
	3	51.58	0.38	29.97	10.64	0.27	1.88	4.28	1.15	100.15
	4	50.23	0.37	30.97	10.99	0.29	1.88	4.28	1.00	100.00
	5	49.08	0.36	31.08	11.04	0.29	2.18	4.97	1.00	100.01
	6	47.42	0.35	31.45	11.17	0.29	2.53	5.77	1.00	100.00
	7	47.63	0.35	30.57	10.86	0.29	3.05	6.95	1.00	100.70
	8	47.94	0.35	28.59	10.15	0.26	3.61	8.23	1.00	100.15
	9	46.59	0.34	28.12	9.98	0.26	3.97	9.04	1.00	99.30
	10	45.70	0.34	29.29	10.39	0.28	4.01	9.14	1.00	100.16
	11	45.70	0.34	29.79	10.58	0.28	3.75	8.55	1.00	100.01
	12	46.28	0.34	29.49	10.46	0.28	3.71	8.45	1.00	100.00
	13	46.95	0.35	28.99	10.29	0.27	3.71	8.45	1.00	100.00
	14	46.95	0.35	28.99	10.29	0.27	3.66	8.34	1.00	99.85
	15	47.16	0.35	28.95	10.27	0.27	3.61	8.23	1.00	99.85
	16	47.16	0.35	29.06	10.31	0.27	3.87	8.82	1.00	100.85
	17	47.84	0.35	28.67	10.18	0.26	3.82	8.71	1.00	100.84
	18	48.72	0.36	28.13	9.98	0.26	3.52	8.02	1.00	100.00
	19	49.87	0.37	28.64	10.17	0.27	2.91	6.63	1.00	99.85
	20	51.11	0.38	29.07	10.32	0.27	2.39	5.45	1.15	100.15
	21	52.26	0.39	29.47	10.46	0.28	2.09	4.76	1.00	100.69
	22	53.14	0.39	28.93	10.27	0.27	1.83	4.17	1.00	100.00
	23	53.82	0.40	29.17	10.35	0.27	1.53	3.48	1.00	100.00
	24	54.60	0.40	29.44	10.45	0.27	1.22	2.78	0.85	100.00

Table 8
Vehicle Class Conversion Process: FHWA to Mobile6

FHWA Class (Count Bin)	General Vehicle Class	Mobile6 Vehicle Class	Proportion Assigned to M6 Class
Bin 1	Motorcycle	Motorcycle	100.0
Bin 2	Light Duty Vehicle	Light Duty Gas Vehicle	67.6
		Light Duty Diesel Vehicle	0.5
		Light Duty Gas Truck 1&2	23.4
		Light Duty Gas Truck 3&4	8.3
		Light Duty Diesel Truck	0.2
Bin 3	Light Duty Truck	Light Duty Gas Truck 1&2	73.2
		Light Duty Gas Truck 3&4	26.0
		Light Duty Diesel Truck	0.8
Bins 4-13	Heavy Duty	Heavy Duty Gas Truck	30.5
		Heavy Duty Diesel Truck	69.5

- **Time of Day and Directional Split Apportioning:** SEMCOG's emission estimation process is designed to capture the temporal variation in emissions. This is accomplished through the application of hour-of-day (K) and directional split (D) factors, developed from 1985 traffic survey data[2]. Table 9 provides both the hourly distribution and directional split factors, by functional class.. The factors are applied at the link level. Thus, the daily VMT for each two-way link is divided into 48 separate values (24 hours x 2 directions for each hour). In the case of one-way links/streets, only the hourly factors are applied, creating 24 hourly VMT values per link.

Table 9
Time of Day & Directional Split Factors for Typical Weekday

Hour Ending	Time of Day Volume Factors		Directional Split Factors	
	Freeways	Arterials	Freeways	Arterials
1:00 a.m.	0.015	0.014	0.59	0.60
2:00	0.009	0.007	0.58	0.59
3:00	0.007	0.005	0.58	0.60
4:00	0.006	0.003	0.56	0.58
5:00	0.009	0.004	0.59	0.61
6:00	0.022	0.012	0.62	0.67
7:00	0.051	0.031	0.64	0.67
8:00	0.075	0.056	0.61	0.65
9:00	0.064	0.058	0.58	0.60
10:00	0.052	0.048	0.56	0.57
11:00	0.049	0.050	0.54	0.55
12:00	0.051	0.057	0.53	0.54
1:00 p.m.	0.051	0.062	0.53	0.54
2:00	0.052	0.060	0.53	0.54
3:00	0.060	0.065	0.53	0.54
4:00	0.073	0.076	0.55	0.56
5:00	0.079	0.081	0.58	0.58
6:00	0.077	0.079	0.57	0.58
7:00	0.054	0.061	0.56	0.56
8:00	0.038	0.048	0.54	0.55
9:00	0.031	0.040	0.55	0.56
10:00	0.030	0.035	0.55	0.57
11:00	0.026	0.026	0.55	0.61
12:00	0.021	0.021	0.55	0.57

Source: *Survey of Regional Traffic Volume Patterns in Southeast Michigan,* SEMCOG, September 1985.

- **Travel Speed Estimation:** Because of recognized limitations with speeds generated from most travel demand models, SEMCOG's emissions estimation process does not use link speeds from TransCAD. Instead a post-processing equation is used, based on research conducted by Richard Dowling and Alexander Skabardonis in the early 1990's[3]. Their findings, along with speed data collected by SEMCOG in 1992[4], were used to develop the following speed equation[5]:

  Avg. Link Speed = Avg. Queue Speed * (Avg. Queue Length/Length) + Uncongested Speed * (1 – (Avg. Queue Length/Length))

  where: Uncongested Speed = $1.24 * \text{Survey Speed}_{(fc,h)}/(1 + (V/C_i)^{11})$
  fc = functional class
  h = hour of day
  Avg. Queue Speed = capacity/lane * 25 ft./vehicle
  Avg. Queue Length = average Queue * 25 ft./vehicle
  Avg. Queue = (Q1 + Q2)/2
  Q1 = queue at start of time slice
  Q2 = queue at end of time slice
  = Q1 + (1-hour traffic/lane – 1-hour capacity/lane)

  Separate link speeds are calculated for each hour of the day and direction of travel (48 speeds for each two-way link, 24 speeds for each one-way link).

- **Local VMT Estimation and Emissions Calculation:** Because SEMCOG's travel model does not include local (residential) streets, the emissions post-processor uses gross level local road VMT data from MDOT's HPMS to calculate base-year local road emissions. This VMT is allocated among the different vehicle classes using the vehicle mix distribution for arterials during the noon hour (see Table 4 of Appendix G). A single set of local road emission factors, based on the Mobile6.2 default speed of 12.9 mph, is applied to the local VMT (for each vehicle class) to calculate emissions. This process can be expressed as follows:

  $$LRE = \sum_{cv} \text{Local VMT}_c * \%\text{VMT}_v * EF_v$$

  where: LRE = local road emissions
  %VMT = % VMT occurring on an urban arterial at noon hour
  c = county
  v = vehicle class
  EF = emission factor for local road at 12.9 mph

- **Emissions from Freeway and Arterial Travel:** As noted above, SEMCOG's post-processing model (EMIS_FC_M6PM) follows EPA's *Quality Review Guidelines for 1990 Base Year Inventories*. However, the program does not use the approach of assigning one emission factor for each vehicle type and road type, at a single speed. Instead emissions are calculated at the link level, based on the directional speed and VMT for each hour, on each link. The process can

be expressed by the following equation:

$$E_{a\text{-}b} = \sum_{k,d,v} VMT_{a\text{-}b}\ \textit{(in hour k, direction d)} * EF_{fc,s,v} * \%VMT_{fc,v}$$

where: $E_{a\text{-}b}$ = emissions for link a-b
k = hour of day
d = direction of travel
v = vehicle class
EF = emissions factor
fc = functional class/facility type
s = average link speed in hour k, direction d

- **Daily Emissions Summation for Each Season:** Once link-level emissions have been calculated, they are aggregated by pollutant, vehicle class, functional class and county. Summary reports are then generated showing total daily emissions of each pollutant by county, road type and vehicle type. Information on VMT and average speed is also provided. A separate post-processing run is performed for each season of each analysis year.

- **Annual Emissions Calculation**: Once average daily emissions have been calculated for each season in a given analysis year. These emissions are multiplied by the number of days in that season, then summed to obtain the annual inventory. Emissions are reported in tons per year.

II. Resulting On-Road Mobile Source Emissions Inventory

Tables 10-13 contain the on-road mobile source emissions inventories resulting from the modeling process described above. Each table lists the annual emissions of six different pollutants, by county, for a given analysis year (2002, 2005, 2009 or 2018). The six pollutants are those specified in the EPA's 2007 Clean Air Fine Particle Implementation Rule. They include volatile organic compounds (VOC), carbon monoxide (CO), nitrogen oxide (NOx), directly emitted $PM_{2.5}$, sulfur dioxide (SO_2), and ammonia (NH3).

Table 10
2002 On-Road Mobile Source Emissions

County	Tons/Year					
	VOC	CO	NOx	Primary $PM_{2.5}$*	SO_2	NH3
Livingston	2,273	41,619	7,032	118	295	189
Macomb	7,893	131,842	18,736	359	945	624
Monroe	2,372	42,803	7,124	121	305	195
Oakland	16,351	275,611	41,379	760	1,960	1,279
St. Clair	2,091	34,038	4,997	95	250	165
Washtenaw	4,536	80,205	13,071	226	575	370
Wayne	23,457	391,446	59,052	1,087	2,793	1,821
Reg. Total	58,972	997,564	151,390	2,767	7,122	4,642

* Primary $PM_{2.5}$, which includes all exhaust emissions as well as those from brake and tire wear.

Table 11
2005 On-Road Mobile Source Emissions

County	Tons/Year					
	VOC	CO	NOx	Primary $PM_{2.5}$*	SO_2	NH3
Livingston	1,697	31,039	5,418	89	71	201
Macomb	5,785	97,334	14,121	265	221	646
Monroe	1,743	31,635	5,454	91	73	206
Oakland	11,918	202,301	31,088	560	458	1,319
St. Clair	1,551	25,240	3,813	71	59	172
Washtenaw	3,350	59,242	9,962	170	137	388
Wayne	16,931	284,801	43,981	792	647	1,859
Reg. Total	42,974	731,593	113,838	2,039	1,667	4,790

* Primary $PM_{2.5}$, which includes all exhaust emissions as well as those from brake and tire wear.

Table 12
2009 On-Road Mobile Source Emissions

County	Tons/Year					
	VOC	CO	NOx	Primary $PM_{2.5}$*	SO_2	NH3
Livingston	1,303	23,364	3,650	65	20	209
Macomb	4,364	72,675	9,434	193	63	666
Monroe	1,339	23,958	3,703	67	21	215
Oakland	8,965	150,463	20,682	404	130	1,355
St. Clair	1,177	18,988	2,559	52	17	178
Washtenaw	2,580	45,167	6,801	125	40	410
Wayne	12,449	207,581	28,657	559	179	1,870
Reg. Total	32,177	542,196	75,486	1,465	469	4,903

* Primary $PM_{2.5}$, which includes all exhaust emissions as well as those from brake and tire wear.

Table 13
2018 On-Road Mobile Source Emissions

County	Tons/Year					
	VOC	CO	NOx	Primary $PM_{2.5}$*	SO_2	NH3
Livingston	802	20,339	1,375	39	23	237
Macomb	2,521	59,542	3,502	113	67	705
Monroe	802	20,286	1,357	39	23	236
Oakland	5,107	120,939	7,386	228	134	1,409
St. Clair	702	16,100	980	31	19	195
Washtenaw	1,548	38,146	2,501	74	43	449
Wayne	7,030	166,315	10,270	314	185	1,932
Reg. Total	18,511	441,665	27,372	837	493	5,164

*Primary $PM_{2.5}$, which includes all exhaust emissions as well as those from brake and tire wear.

[1] U.S. Environmental Protection Agency, *Fleet Characterization Data for Mobile6: Development and Use of Age Distributions, Average Annual Mileage Accumulation Rates, and Projected Vehicle Counts for Use in MOBILE6,* September 2001.
[2] SEMCOG, *Survey of Regional Traffic Volume Patterns in Southeast Michigan,* tables 3–7, 1985.

[3] Dowling, Richard and Alexander Skabardonis, *Improving the Average Travel Speeds Estimated by Planning Models*, Transportation Research Board, January 1992.
[4] SEMCOG, *Survey of Roadway Speeds in Southeast Michigan*, January 1993.
[5] More complete documentation of the use of SEMCOG speed survey data in the development of this equation can be found in the document *Redesignation of Southeast Michigan to Attainment for Ozone: Technical Support Document*, jointly published by MDNR, MDOT and SEMCOG in November 1993.