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The Indiana Enhanced I/M Program
Remote Sensing 1% On Road Testing 2013

Prepared for:

Indiana Department of Environmental Management

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Glossary of Terms and Abbreviations

ADT	Average Daily Traffic
ASM	Acceleration Simulation Mode
Basic I/M	A set of vehicle I/M Program inspection requirements defined by the U.S. EPA that may be used in areas not required to implement an Enhanced I/M Program; the inspection procedure usually involves idle testing
BAR	California Bureau of Automotive Repair
BMV	Bureau of Motor Vehicles
CCM	Corner Cube Mirror
Clean Screening	The process of using RSD to identify vehicles with low emissions to exempt them from the required emission inspection at an inspection station
CO	Carbon monoxide
CO_2	Carbon dioxide
Cutpoint	An emissions level used to classify vehicles as having met an emissions inspection requirement
Decile	A group containing one-tenth of the entries in a value ordered set
Enhanced I/M	A set of more rigorous vehicle I/M Program inspection requirements defined by the U.S. EPA usually involving IM240 testing
Envirotest	Envirotest Systems Corporation
Evaporative Emitters	Vehicles releasing gaseous or liquid hydrocarbons from the fuel tank or fuel system
Excess Emissions	Vehicle emissions exceeding an I/M cutpoint
FTP	Federal Test Procedure
g/mi	Grams per mile, the units of measurement for FTP and IM240 tests
GVWR	Gross Vehicle Weight Rating
HC	Hydrocarbons
HDDV	Heavy-duty diesel vehicle
High-Emitter Identification	The on-road identification of vehicles with high emission levels
I/M	Inspection and Maintenance Program
IDEM	Indiana Department of Environmental Management

Idle Test	A tailpipe emission test conducted when the vehicle is idling and the transmission is not engaged
IM240 Test	A loaded-mode transient tailpipe emission test conducted when the vehicle is driven for up to 240 seconds on a dynamometer, following a specific speed trace simulating real world driving conditions
IM93 Test	A loaded-mode transient tailpipe emission test conducted when the vehicle is driven through a 93-second cycle on a dynamometer up to three times. The 93 seconds are the same as the first 93 seconds of the IM240 test.
IR	Infrared; electromagnetic radiation with a wavelength longer than that of visible light
KW/t	Kilowatts per metric ton, the units of measurement for vehicle specific power
LDDV	Light-duty diesel vehicle
LDGV	Light-duty gasoline-powered vehicle
LDGT	Light-duty gasoline-powered truck
NO	Nitric oxide also known as nitrogen monoxide
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen, usually measured as nitric oxide (NO)
OBDII	On Board Diagnostic system to detect emissions related problems required on all 1996 and newer light–duty vehicles
OREMS	On-Road Emissions Monitoring System, a protocol and associated performance standards for remote sensing vehicle emissions testing developed by the California BAR since 1995
Positive Power	An operating mode where the engine is generating power to drive the wheels
Repairable Emissions	The emission reductions obtained by repairing a vehicle. The amount of repairable emissions is equal to or greater than the amount of excess emissions
RSD	Remote Sensing Device
SDM	Source Detector Module, an RSD component that measures emissions
Tag Edit	The transcription of vehicle license plates or tags from images to text
TSI	Two-Speed Idle test
U.S. EPA	United States Environmental Protection Agency
UV	Ultraviolet; electromagnetic radiation with a wavelength shorter than that of visible light, but longer than X-rays

UV Smoke	An RSD measurement of particulate matter using UV light
VIN	Vehicle Identification Number
VMT	Vehicle Miles Traveled
VSP	Vehicle Specific Power; estimated engine power divided by the mass of the vehicle
VTR	Vehicle Test Record

1 SUMMARY

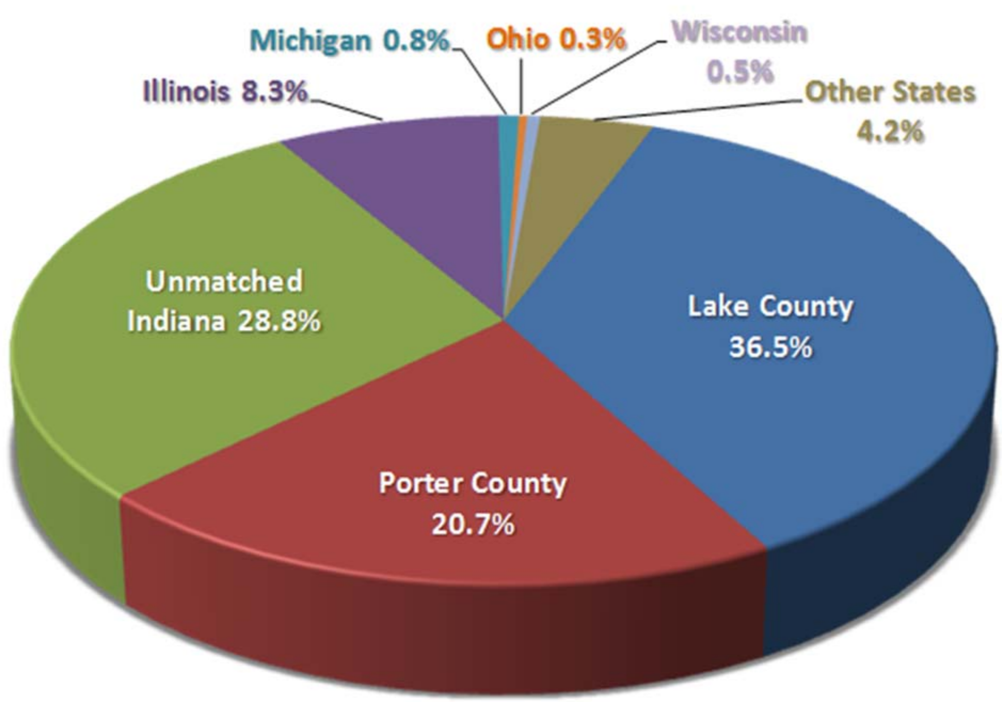
The Northern Indiana Inspection and Maintenance (I/M) Program contract between the Indiana Department of Environmental Management (IDEM) and Envirotest requires on-road testing of 1% of the subject vehicles every two years. This report covers on-road testing performed in 2013 in the Northern Indiana I/M area comprising Lake and Porter counties. A remote sensing device (RSD) was used at roadside locations to measure emissions of passing vehicles and capture images of the vehicle plates.

Envirotest collected 49,860 valid on-road vehicle emissions measurements and plate images from thirteen roadside locations from April through June 2013. License plates were decoded for 42,848 of the vehicles measured and 27,392 of these matched to vehicle registration renewal records for Lake and Porter County.

Survey Results

The chart below shows the registered jurisdiction of the vehicles measured in the nonattainment region including the adjustment noted above. Of the 42,848 vehicles measured with readable plates, 57% were registered in Lake and Porter County, 29% were from other Indiana counties and 14% were from other states.

Figure 1-1: Registration Jurisdictions of Vehicles Measured in Lake and Porter Counties



On-road Vehicle Emissions

The average emissions of vehicles registered in the jurisdictions, as adjusted, are shown in Table 1-1. Average emission rates of all vehicles measured on-road in the two counties were 0.10 % carbon monoxide (CO) 15 ppm hydrocarbon (HC) hexane and 146 ppm oxides of nitrogen (NO_x).

Vehicles registered in Indiana that were not matched to Lake and Porter County registration renewals had average HC, CO, and NO_x emissions of 39%, 14% and 35% higher respectively than the average emissions of vehicles known to be registered in Lake and Porter counties. The unmatched group may have included medium-duty trucks and other vehicles not subject to the I/M program. Compared to Lake and Porter registered vehicles, vehicles from Illinois had higher emissions of HC, CO and NO_X. Vehicles from Michigan had higher emissions of HC and NO_X. Vehicles from other more distant states had emissions similar to or lower than Lake and Porter registered vehicles, which may reflect newer models being preferred for longer trips.

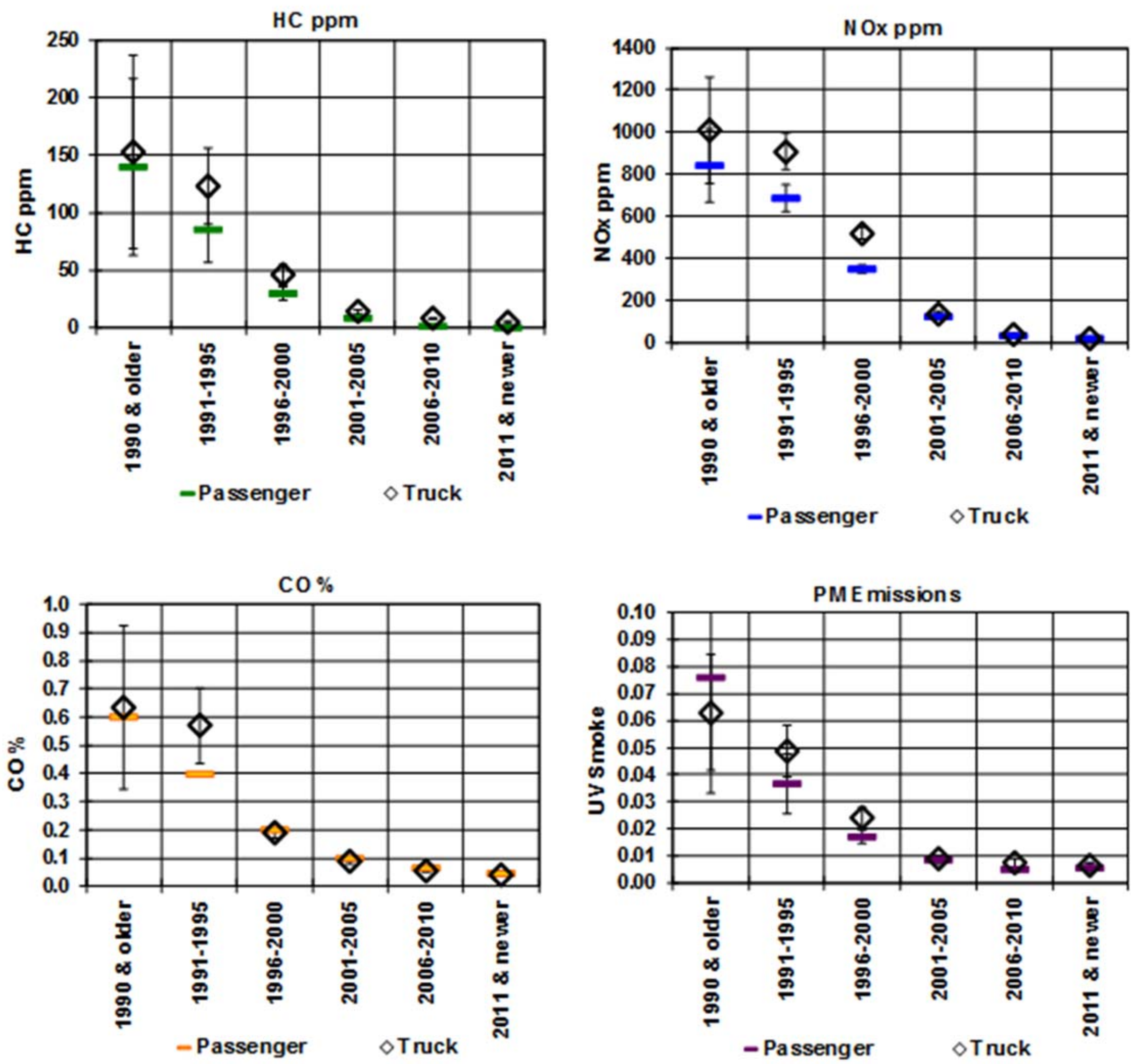
Table 1-1 Fleet Emissions by Registered I/M Area

Jurisdiction	Records	% CO	HC ppm	NOx ppm	RSD Smoke	VSP kW/t
Lake County	18,186	0.11	16	143	0.009	8.2
Porter County	10,323	0.08	10	114	0.013	8.4
Unmatched Indiana	14,339	0.11	19	179	0.013	8.2
Illinois	4,142	0.11	15	140	0.010	8.9
Michigan	377	0.09	15	143	0.007	8.5
Ohio	155	0.10	8	103	0.006	8.2
Wisconsin	240	0.09	14	124	0.010	9.6
Other States	2,098	0.10	11	120	0.010	9.1
Total	**49,860**	**0.10**	**15**	**146**	**0.011**	**8.4**
Lake & Porter combined	**28,509**	**0.10**	**14**	**133**	**0.010**	**8.3**

Figure 1-2 shows average emissions by age for Lake and Porter passenger vehicles and light-duty trucks. Vertical lines with bars indicate 95% confidence intervals of the average values. RSD UV Smoke is a measurement of particulate emissions (PM). For diesel smoke, an RSD UV smoke value of one corresponds to one gram of particulate per 100 grams of combusted fuel. For gasoline vehicles the relationship between the RSD UV smoke value and particulate mass is less well defined and depends on the type of smoke, e.g. black carbon smoke, blue oil smoke or white coolant smoke, and is the subject of ongoing research.

Emissions of 1996 and newer models were much lower than those of older models. The vast majority of 2001 and newer models had very low emissions. With the exception of the small sample of 1990 and older models, trucks consistently had higher average emissions than passenger vehicles for all pollutants. Light-duty trucks also have lower fuel economy and greater exhaust volume resulting in a larger mass of emissions.

Figure 1-2: Emissions by Vehicle Type and Model Year



Compliance with the I/M Program

Inspection records from October 2010 through the date vehicles were observed on-road were examined to determine the most recent inspection for each vehicle. I/M inspections were confirmed for 95.4% of the Lake and Porter 1976-2008 passenger models, and 95.7% of trucks with a gross vehicle weight rating (GVWR) of up to 6,000lbs. The equivalent rate for trucks between 6,000 and 10,000lbs GVWR and greater was 91.5%. Some of the latter were exempt from testing as the upper weight limit on the inspection requirement is 9,000lbs GVWR.

Among 1996 and newer models, confirmed inspection rates were higher for even model year vehicles than for odd model year vehicles – a reversal from the 2011 survey.

High-Emitters

Gasoline powered vehicles had a highly skewed emissions distribution with a small percentage of high-emitters contributing a substantial portion of total light-duty vehicle emissions.

Envirotest identified high emitters using criteria used in similar on-road surveys conducted in Maryland. The criteria required at least two measurements to confirm a vehicle as being a high emitter. Sixty-nine vehicles, 1.9% of vehicles with two or more measurements, exceeded the cutpoints on both of their last two measurements for the same pollutant. The sixty-nine vehicles had average emissions of 311 ppm HC, 0.77% CO, and 1,353 ppm NO_X.

Sixty percent of high emitters were 1999 and older models.

Recommendations

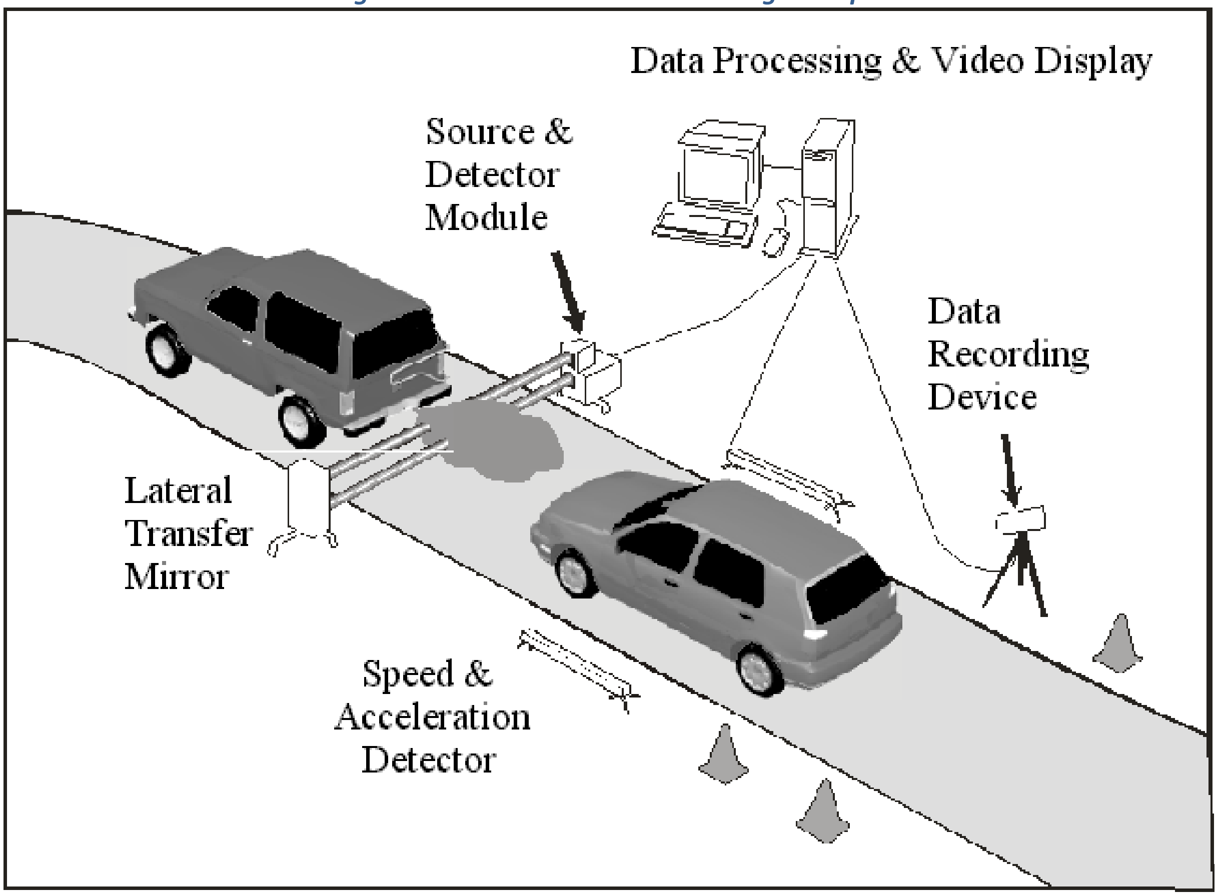
- A comprehensive on-road emissions measurement program could be a valuable supplement to the current I/M Program by:
  - Exempting clean vehicles from having to visit an inspection station;
  - Identifying on-road evaporative emitters, some of which will not be identified by OBD-II;
  - Identifying high-emitters not captured by the I/M Program, or failing between tests;
  - Identifying smoking vehicles;
  - Monitoring on-road vehicles for compliance;
  - Providing feedback on the effectiveness of the Program and repairs; and,
  - Examining the impact of OBD-II readiness exemptions and other I/M Program design decisions and options, e.g. the inclusion or exclusion of additional models.
- Consider dual testing (IM93 and OBD-II) for 1996 to 1999 model year vehicles given the numbers of high-emitters for these models. California currently dual tests OBD-II models and will continue to dual test 1996-1999 models after legislation[1] to allow OBD-II only testing of 2000 and newer models becomes effective in 2014. The legislation also allows for dual-testing of 2000 and newer models with emission problems that may not be adequately detected by the vehicle's OBD-II system.
- Consider raising the GVWR limit on vehicles tested from 9,000lbs to 10,000lbs or 14,000lbs. These heavier trucks have higher mass emissions and delivery trucks and shuttles have high vehicle miles traveled (VMT).
- Consider emissions testing for light- and medium-duty diesel powered vehicles. Light- and medium-duty diesel vehicles, although few in number today are increasingly popular. Older diesel models have particulate and NO_X emissions that are many times higher than gasoline vehicle emissions and smoking diesel vehicles cause the public to question whether I/M programs are targeting the right vehicles. Some newer European manufacturer diesel model passenger cars have high NO_x[2,3].

2 EQUIPMENT AND SITES

2.1 Equipment Description

The remote sensing device (RSD) survey used the Envirotest RSD4600 testing system. The RSD4600 detects vehicle emissions when a vehicle drives through an invisible light beam the system projects across a roadway. Figure 2-1 illustrates the remote sensing equipment set-up. The process of measuring emissions remotely begins when the RSD4600 Source & Detector Module (SDM) sends an infrared (IR) and ultraviolet (UV) light beam across a single lane of road to a Corner Cube Mirror (CCM). The mirror reflects the beam back across the street (creating a dual beam path) into a series of detectors in the SDM.

Figure 2-1: On-Road Remote Sensing Set-Up



Fuel specific concentrations of HC, CO, CO_2, NO, and smoke are measured in vehicle exhaust plumes based on their absorption of IR/UV light in the dual beam path. During this process, the data-recording device captures an image of the rear of the vehicle, while the Speed & Acceleration Detector measures the speed of each vehicle.

The RSD units are housed in fully outfitted cargo-style vans. These vans are equipped with heating/cooling, a generator, and adequate storage for all components. The vans carry a full complement of road safety equipment and tools for making small repairs. The vans are equipped with additional lighting for testing during pre-dawn and post-dusk hours. The RSD4600 includes the following features:

1) A long beam range for safer, more versatile deployment;
2) Simple and easy setup with laser alignment aids;
3) Continuous automatic background compensation minimizes the need for field calibration. (Only one or two calibrations are generally required during a full day of data collection);
4) Fourth generation real-time measurement validation;
5) Signal sensitivity and accuracy that significantly exceed 2002 California BAR certification standards;
6) Limited degrees of freedom in alignment resulting in improved optical stability and low noise for increased productivity, yielding more valid records;
7) A Windows operating system for ease of operation and multi-tasking;
8) A fuel specific smoke measurement using a UV wavelength that senses the fine particles invisible to traditional visible light opacity meters; and,
9) Rugged assemblies requiring low maintenance.

2.2 Equipment QA/QC Audits

2.2.1 Factory Testing and Certification

When an RSD system is built at the Tucson Technology Center, it undergoes several steps to ensure accuracy. First, the source detector module is bench calibrated. It is then audited using several blends of gas. When the system is fully calibrated and assembled, it is tested again in the parking lot using an audit truck. The unit tests are based on the BAR OREMS specification.

An audit truck is a modified vehicle that uses a long exhaust stack to redirect the vehicle engine exhaust upwards and away from the roadway. Audit gases of known concentrations are dispensed through a simulated tailpipe routed to the rear of the audit truck. When the truck is driven past a roadside remote sensing SDM/CCM set of modules, the system measures the pollutant concentrations in the dispensed test gas instead of the vehicle engine exhaust.

The remote sensing unit is setup in a parking lot to avoid interference from other traffic. The auditor drives the audit truck through the remote sensing system 40 times for each gas blend during acceptance testing. Envirotest detector accuracy, including speed and acceleration, will meet the detector accuracy tolerances shown below for at least 97.5% (39/40) runs for each gas. Six different audit gas blends are used to verify the unit accuracy over a range of pollutant concentrations.

2.2.2 Detector Accuracy

The carbon monoxide (CO%) reading will be within $\pm$ 10% of the Certified Gas Sample, or an absolute value of $\pm$ 0.25% CO (whichever is greater), for a gas range less than or equal to 3.00% CO. Negative values shall be included and will not be rounded to zero. The CO% reading will be within $\pm$ 15% of the Certified Gas Sample for a gas range greater than 3.00% CO.

The hydrocarbon reading (recorded in ppm propane) will be within $\pm$ 15% of the Certified Gas Sample, or an absolute value of $\pm$ 250 ppm HC, (whichever is greater). Negative values will be included and will not be rounded to zero.

The nitric oxide (NO) reading (ppm) will be within ± 15% of the Certified Gas Sample, or an absolute value of ± 250 ppm NO, (whichever is greater). Negative values shall be included and will not be rounded to zero.

2.2.3 Speed and Acceleration Accuracy

The vehicle speed measurement will be accurately recorded within ± 1.0 mile per hour.

The vehicle acceleration measurement will be accurately recorded within ± 0.5 mile per hour / second.

2.2.4 Daily Set-Up and Calibration

Every scheduled work day, the operator drives to an existing or new test site. The operator's first duty is to provide a safe work area for themselves and passing motorists. The next step is to set up the source detector module and allow the electronic components within to warm up for a minimum of 30 minutes. Following the set up and alignment of the other components, the SDM is aligned and ready for calibration.

An automated calibration utilizing a mechanized gas cell within the SDM is a method of testing the equipment without the need to drive an audit truck past the unit. During a gap in the passing traffic, a test gas within a sealed cell, with a known blend of HC, CO, CO_2, and NO, is maneuvered into the optical path of the remote sensing beam. If necessary, the instrument set-up is adjusted so that the pollutant values measured by the unit, match the known concentrations of pollutants in the test gas blend.

Calibration for the RSD4600 occurs once at the beginning of the day and at mid-day if conditions warrant.

2.2.5 Equipment Audits

After each daily calibration, the operator is required to perform an audit to verify an optimal calibration. A puff audit is a method of testing the equipment without the need to drive an audit truck past the unit. During a gap in the passing traffic, a test gas with a known blend of HC, CO, CO_2 and NO, is puffed into the optical path of the remote sensing beam. If the audit passes a predetermined pass/fail tolerance, the operator is allowed to begin testing vehicles. If not, the operator is required to realign and recalibrate the system until it passes the audit process.

Audits for the RSD4600 occur every hour (2 hour maximum before system lockout occurs), twice when a calibration is performed (once before to earmark data and once after to begin testing) and once at the end of the test collection period to earmark the data.

2.3 Overview of 0.5% Sample

2.3.1 Sample Design Criteria

The objective is to obtain the 1.0% sample from sites that will be generally representative of vehicles operating in the I/M program areas.

As shown in Figure 2-2: Site Locations, thirteen sites were used to collect RSD data. The intent was to collect tests on a random sample that is representative of all the on-road vehicle traffic.

Measurements are distributed geographically with no one area receiving an undue amount of testing.

2.3.2 Description of Sample Site Characteristics

Site selection is critical to obtaining RSD measurements that are representative of vehicle operation. Recommended site attributes include:

- Absence of cold start vehicle operating conditions;
- Sites where vehicles will generally be accelerating or driving at a steady speed uphill to avoid the highly variable tailpipe emissions that can occur under deceleration;
- Absence of enrichment due to high load conditions;
- Single lane operation;
- High volume traffic;
- Unobtrusive citing of the remote sensing equipment;
- Stability in the traffic mix from one year to the next; and,
- Adequate median space for safe operation of the RSD equipment

2.4 Sites selected for studies

Table 2-1 lists the site locations selected for the 1.0% sample. All the sites selected are on-ramps or exit loops that provide the required physical characteristics of an appropriate RSD site. Sites were pre-qualified for:

- Single lane operation with space for the RSD equipment to be deployed without disrupting traffic flow;
- Geographically dispersed throughout the I/M area;
- A satisfactory percentage of valid readings; and,
- An adequate traffic volume.

2.4.1 Sites Used

Table 2-1 shows the survey sites used and the number of valid measurements obtained.

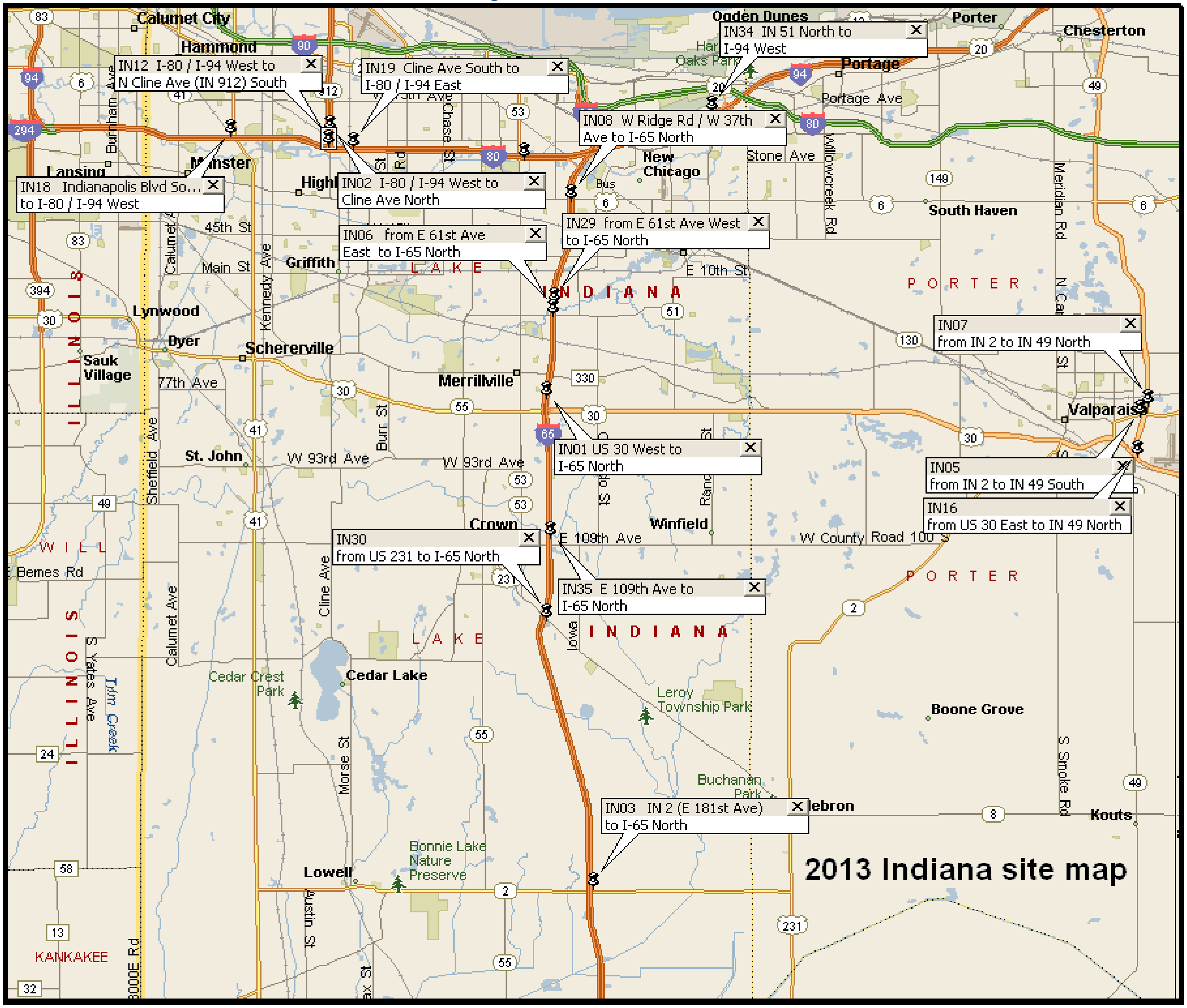
Figure 2-2 displays the distribution of the sites.

Detailed descriptions of the sites with pictures and layouts are in Appendix A

Table 2-1: Sites Used

Site Code	Location	City	County	Degrees of Grade	Valid RSD in Desired VSP Range
IN01	US 30 to I-65 North	Merrillville	Lake	3.32	5,707
IN02	WB 80 94 to NB Cline	Gary	Lake	2.17	6,970
IN03	61st Ave West to I-65 North	Merrillville	Lake	0.80	3,558
IN05	IN 2 to IN 49 South	Valparaiso	Porter	0.50	5,990
IN06	EB 61st to NB I65	Merrillville	Lake	-0.98	7,112
IN07	IN 2 to IN 49 North	Valparaiso	Porter	1.30	6,618
IN08	Ridge Road to NB I65	Hobart	Lake	2.20	448
IN16	US 30 to IN 49 North	Valparaiso	Porter	0.20	3,308
IN19	SB Cline to EB 80 94	Gary	Lake	0.20	2,673
IN29	WB 61st to NB I 65	Merrillville	Lake	0.55	1,053
IN30	US 231 to I-65 North	Crown Point	Lake	1.43	5,405
IN34	IN 51 North to I-94 West	Lake Station	Lake	0.80	1,408
IN35	109th to I-65 North	Crown Point	Lake	0.41	8,670
Total					58,920

Figure 2-2: Site Locations



2.5 Data Screening

The RSD system applies checks to determine the validity of emissions measurements. These include determining if a sufficient exhaust plume was measured. The general criteria for an RSD system 'valid' measurement include:

- The system was active and calibrated;
- A valid exhaust gas measurement was recorded;
- A valid speed and acceleration was recorded; and,
- A readable plate was recorded and transcribed.

Particular applications can require further screening. Envirotest applied the following additional screening checks to the RSD measurements to ensure the data used were representative of the vehicle emissions:

- Screening for Vehicle Specific Power (VSP) range; and,
- Screening of hourly observations to check for cold starts.

The exhaust plume validations and the additional screening procedures are described in the following paragraphs.

2.5.1 Valid Exhaust Plumes

The RSD4600 unit takes many measurements of each exhaust plume in the one half second after each vehicle passes the equipment.

The basic gas record validity criteria applied are:

- A gas record is valid if there are at least 5 plume measurements where the sum of the amount of CO_2 and CO gas exceed 10%-cm[i]; or
- A gas record is valid if there are at least 5 plume measurements where the sum of the amount of CO_2 and CO gas exceed 5%-cm and the background gas values are very stable (not changing faster than a specified rate) at the time the front of the vehicle breaks the measurement beam.

2.5.2 Vehicle Specific Power (VSP)

VSP provides an estimate of the relative power output of the vehicle based upon speed, acceleration and slope at the site and for light-duty vehicles is defined by the following equation:

VSP = 4.364*sin(Grade in Deg/57.3)*Speed + 0.22*Speed*Accel + 0.0657*Speed + 0.000027*Speed*Speed*Speed

[i] The unit of measurement 10%-cm is a measurement of the amount of a gas in the optical path. In this case, if all the molecules of the gas in the path were collected together into just one centimeter of the path then the concentration of the gas in the one-centimeter would be 10%.

Engine load is a function of the vehicle speed and acceleration, the slope of the site, vehicle mass, aerodynamic drag, rolling resistance, and transmission losses. The effects of these forces can be aggregated into a single parameter called VSP, which was the topic of a presentation at the Ninth Coordinating Research Council (CRC) On-road Vehicle Emissions Workshop[4.] The CRC E-23 Project[5,6] further developed the concept of vehicle specific power. In 2002, EPA adopted the use of VSP as a parameter for predicting vehicle emissions in the recently adopted Motor Vehicle Emissions Simulator (MOVES) emissions inventory model that replaces Mobile6[7].

Studies have found vehicle emissions to be more stable and more representative of the average in-use emissions of a vehicle when the engine is under a light to moderate load such as occurs when cruising above 30 mph, during non-aggressive acceleration, or driving up inclines. In day-to-day use, a majority of fuel is consumed in light to moderate engine load. Therefore Envirotest requires that vehicle emission observations be made when VSP is positive and sites are selected to measure vehicles when they are typically operating with moderate engine load. For CO high-emitter identification, upper limits are placed on VSP depending on the model year.

2.5.3 Screening of Hourly Observations

Envirotest is concerned about vehicles operating in cold start mode or under conditions when exhaust plumes condense to steam. Vehicles measured under these conditions could appear to have high HC emissions without any emission system problems. To investigate this possibility, Envirotest tabulated for each site and hour the percentage of vehicles up to 5 years old that exceeded 150 ppm HC (Table 2.3). The percent of vehicles up to 5 years old that exceed 150 ppm HC tend to be higher during periods of cold temperatures. Table 2-4 shows there were many hours in April and on May 10th when temperatures were below 50F. During some of these periods the percent of vehicles up to 5 years old exceeding 150 ppm HC was higher than 5%. Measurements made during these periods were flagged as invalid and excluded from further consideration when the temperature was less than 50^{o}F (10^{o}C).

2.5.1 Screening of Day-to-Day Variations in Emission Values

Each day's emission measurements of 2008 and newer model year vehicles were ordered by value and divided into ten groups or deciles each containing an equal number of the ordered measurements. Day-to-day decile emission values were compared for 2008 and newer vehicles. Only a small percentage of these newer vehicles are expected to have high emissions and, therefore, the decile emission values for the lower nine deciles should not vary significantly from day-to-day, from site-to-site, or between RSD units. In Figure 2-3, the lower nine daily HC decile values of measurements are plotted side-by-side. The right hand legend indicates the color of each decile number. This comparison revealed median values for 2008 and newer model year vehicles that ranged day-to-day from –3 ppm to +23 ppm. Although these variations are well within the HC specification of the RSD units they are significant compared to average fleet emissions for newer vehicles.

Table 2-3: Percentage of New Model Measurements Exceeding 150 ppm HC

Day	Unit	Site	06 & earlier	07	08	09	10	11	12	13	14	15	16	17	18 & later
1-Apr-13	4645	IN35		7%	1%	0%	0%	2%	0%	0%	0%				
3-Apr-13	4605	IN05			4%	9%	3%	0%	0%	0%	0%				
4-Apr-13	4605	IN05		8%	13%	0%	0%	0%	0%	0%	0%				
4-Apr-13	4645	IN30	0%	2%	1%	0%	0%	0%	0%	0%	0%				
5-Apr-13	4605	IN05				0%	0%	2%	0%	0%	0%				
9-Apr-13	4605	IN05									0%				
15-Apr-13	4645	IN03			0%	0%	6%	0%							
19-Apr-13	4645	IN30		2%	1%	2%	0%	3%	2%	0%	0%				
22-Apr-13	4645	IN03		0%	0%	0%	0%	0%	0%	0%	0%				
24-Apr-13	4605	IN07		23%	15%		12%	8%	9%	5%	2%				
24-Apr-13	4645	IN03				6%		7%	8%	0%	0%	0%			
25-Apr-13	4605	IN07					0%	2%	0%	10%	1%	0%			
26-Apr-13	4605	IN07					0%	0%	0%	0%	0%	0%			
26-Apr-13	4645	IN29		0%	0%	0%	0%	0%	0%	0%	0%				
1-May-13	4605	IN16			0%	0%	0%	0%	0%	0%	0%	0%			
2-May-13	4605	IN16		0%	0%	0%	0%	0%	0%	0%	0%	0%			
2-May-13	4645	IN06		0%	0%	0%	0%	0%	0%	0%	0%				
3-May-13	4645	IN06		5%	6%	0%	9%	8%							
6-May-13	4645	IN06		0%	0%	0%	0%	0%	0%	0%	0%				
8-May-13	4645	IN08		0%					0%	0%					
10-May-13	4605	IN19			0%	0%	0%	0%	9%	0%	0%	2%	0%	0%	
10-May-13	4645	IN02		0%	0%	0%	0%	0%	0%	6%	0%	6%	0%	0%	0%
11-May-13	4605	IN01				0%	0%	0%	0%	2%	0%	0%	0%		
11-May-13	4645	IN35			0%	0%									
12-May-13	4605	IN01				0%	0%	0%	0%	0%	0%	0%			
12-May-13	4645	IN35			0%	2%	0%	0%	0%	0%	2%	0%			
13-May-13	4645	IN06					0%	0%	0%	0%	0%	0%	0%		
14-May-13	4605	IN01			0%	0%	0%	0%	0%	0%	0%	0%			
14-May-13	4645	IN35		0%	1%	0%	0%	0%	0%	0%	0%	0%			
15-May-13	4645	IN02		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
16-May-13	4645	IN02		0%	0%	0%	0%	0%	0%	4%	3%	5%	0%	0%	0%
17-May-13	4605	IN34		0%	0%	0%		0%	0%	0%	0%				
18-May-13	4605	IN07			0%	0%	0%	0%	0%	0%	0%	0%			
19-May-13	4605	IN16			0%	0%	0%								
20-May-13	4645	IN06		0%	0%	0%	0%	0%	0%	0%	0%				
24-May-13	4645	IN35		1%	1%	0%	0%	0%	0%	0%	0%	0%			
29-May-13	4605	IN34			0%	0%	0%	0%	0%	0%	0%				
30-May-13	4645	IN30		1%	1%	0%	0%		2%	0%	0%				
6-Jun-13	4605	IN05		0%	0%	0%	0%	0%	0%						

The most likely explanation is that this represents the limits of accuracy in the daily instrument set-up although it is unusual that the median would be negative on all days. For HC, an adjusted set of values was created by direct addition or subtraction of a daily offset that would set the daily median values to zero. We believe this is appropriate since the median I/M test result for new models is normally zero or very close to zero. The results of the correction are shown in Figure 2-4 and analyses shown later in this report used the adjusted HC values.

Day-to-day decile CO, NO, and UV smoke values for 2008 and newer model year vehicles are shown in Figures 2-5 to 2-7. Median values for CO, NO, and smoke were 0.01% to +0.05%, -1 to +16 ppm and -.00 to +0.02 respectively. These negative and positive values were relatively small and adjustments were not applied to these pollutants.

Table 2-4: Average Hourly Temperature Fahrenheit

Day	Unit	Site	06 & earlier	07	08	09	10	11	12	13	14	15	16	17	18 & later
01-Apr-13	4645	IN35		32	35	36	42	44	49	53	56				
03-Apr-13	4605	IN05			38	41	44	47	49	48	46	45			
04-Apr-13	4605	IN05		39	38	47	53	58	62	65	64				
04-Apr-13	4645	IN30	29	38	46	58	65	69	71	69	68				
05-Apr-13	4605	IN05				46	48	47	47	47	46	47			
09-Apr-13	4605	IN05								73	73	73			
15-Apr-13	4645	IN03		57	58	60	62	63	62	67	69				
19-Apr-13	4645	IN30		38	38	38	40	42	41	41	40	40			
22-Apr-13	4645	IN03		45	48	54	59	65	71	76	79				
24-Apr-13	4605	IN07	36	36	36	37	38	38	42	46	50				
24-Apr-13	4645	IN03			40	41	41	41	46	53	58	59			
25-Apr-13	4605	IN07				51	47	47	44	47	50	51			
26-Apr-13	4605	IN07					59	61	63	65	66	68			
26-Apr-13	4645	IN29		44	48	54	60	63	67	69	71				
01-May-13	4605	IN16			74	78	80	82	84	87	87	87	88		
01-May-13	4645	IN29		67	68	77	81	85	88	92	92	93			
02-May-13	4605	IN16		52	54	58	61	63	63	57	55	55			
02-May-13	4645	IN06		50	51	53	56	58	61	60	63	63			
03-May-13	4645	IN06		45	46	50	52	52							
06-May-13	4645	IN06		57	60	65	70	74	74	75	82	83			
08-May-13	4645	IN08		59	66	78	85	91	94	97	96				
10-May-13	4605	IN19			48	48	48	47	44	43	43	42	42	42	42
10-May-13	4645	IN02		50	50	50	51	50	48	47	46	45	45	45	45
11-May-13	4605	IN01			53	55	55	56	56	64	59	57	54		
11-May-13	4645	IN35		50	51	53									
12-May-13	4605	IN01				49	50	52	55	57	58	61			
12-May-13	4645	IN35			45	49	51	53	56	60	60	62			
13-May-13	4645	IN06				58	59	62	68	72	82	84	85		
14-May-13	4605	IN01			65	70	75	79	84	88	91	92			
14-May-13	4645	IN35		60	64	69	73	78	83	89	94	98			
15-May-13	4645	IN02		73	76	81	82	86	88	91	93	91	93	84	83
16-May-13	4645	IN02		66	71	74	81	86	89	95	98	100	102	95	88
17-May-13	4605	IN34		68	71	76	78	76	76	77	68				
18-May-13	4605	IN07			64	67	74	76	80	83	82	78	79		
19-May-13	4605	IN16		72	75	79	81								
20-May-13	4645	IN06		76	78	80	81	83	88	92	94	94			
24-May-13	4645	IN35		46	50	53	56	57	60	64	67	69			
29-May-13	4605	IN34			75	78	79	79	78	78	84	88	88		
30-May-13	4645	IN30		77	85	92	94	92	92	92	90				
06-Jun-13	4605	IN05		63	64	69	72	71	66						
27-Jun-13	4645	TEST								95	97				

Figure 2-3: Daily HC Deciles

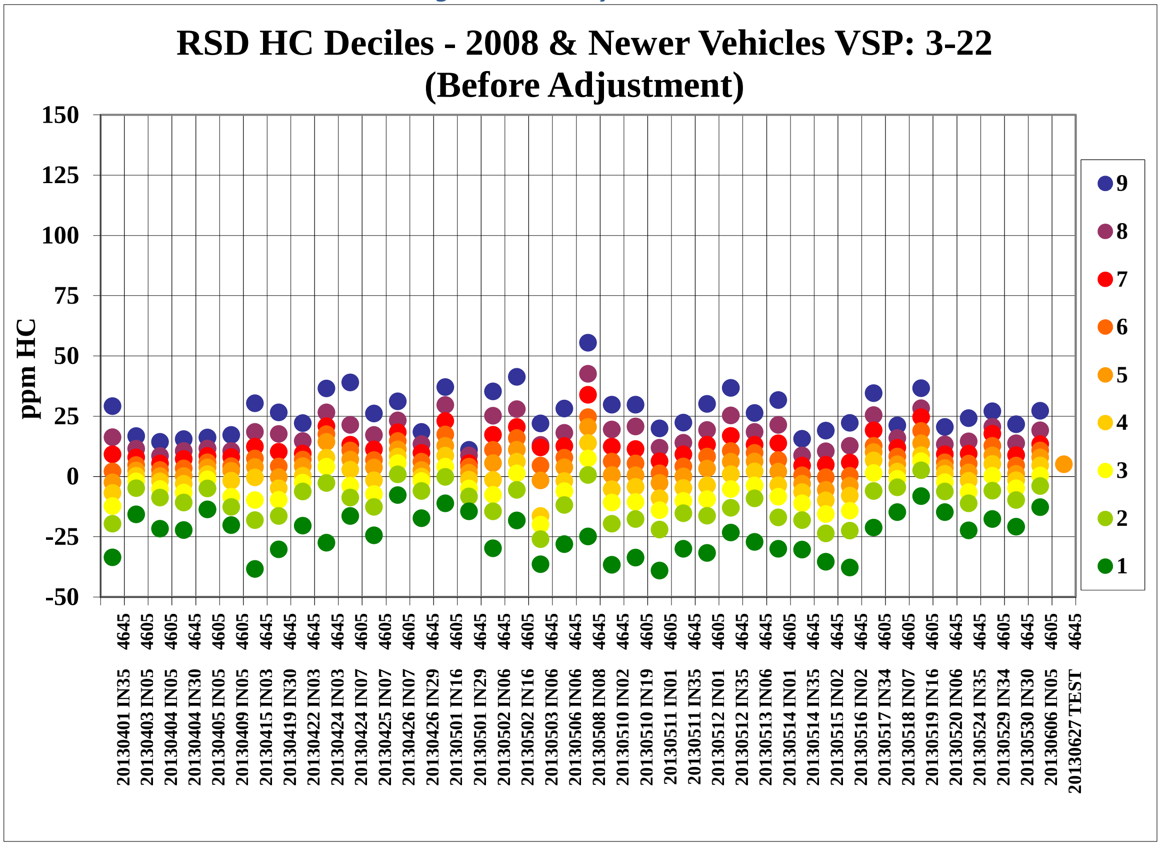


Figure 2-4: Daily HC Deciles – After Adjustment

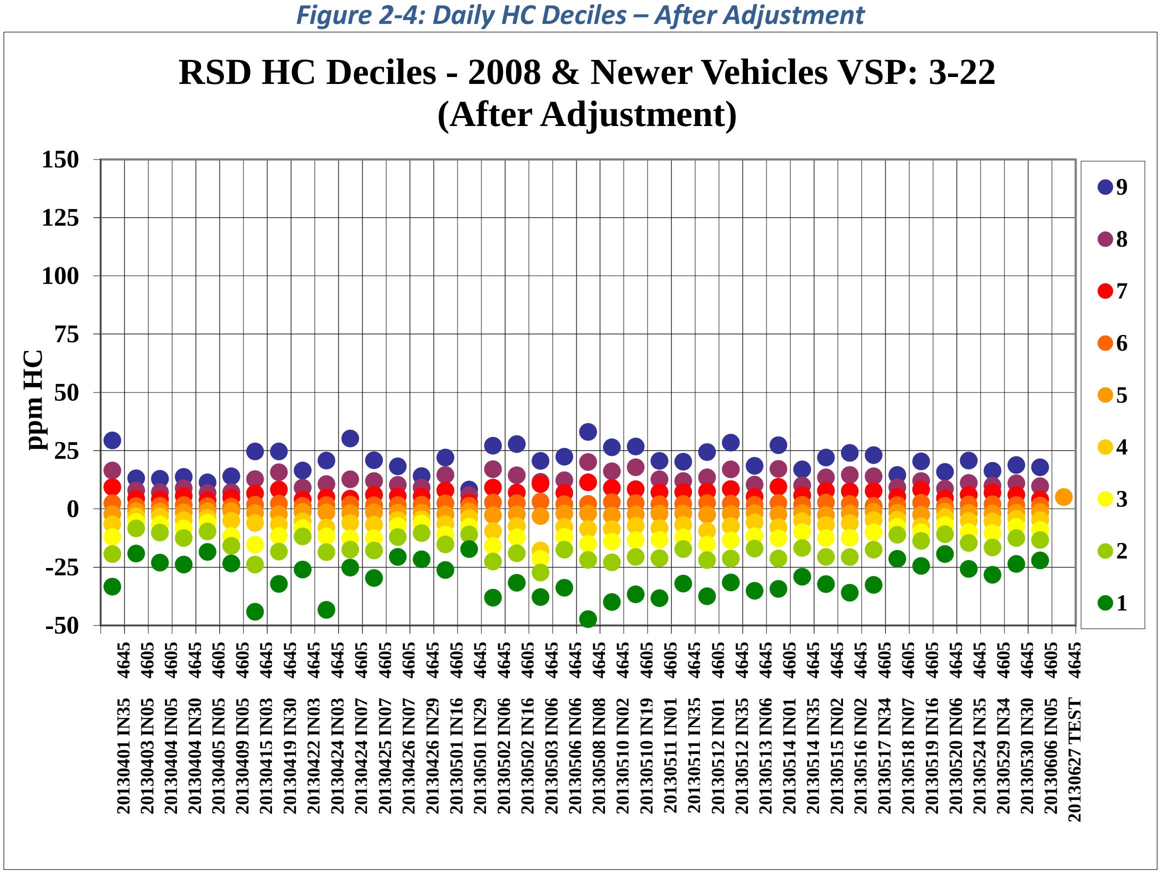


Figure 2-5: Daily CO Deciles

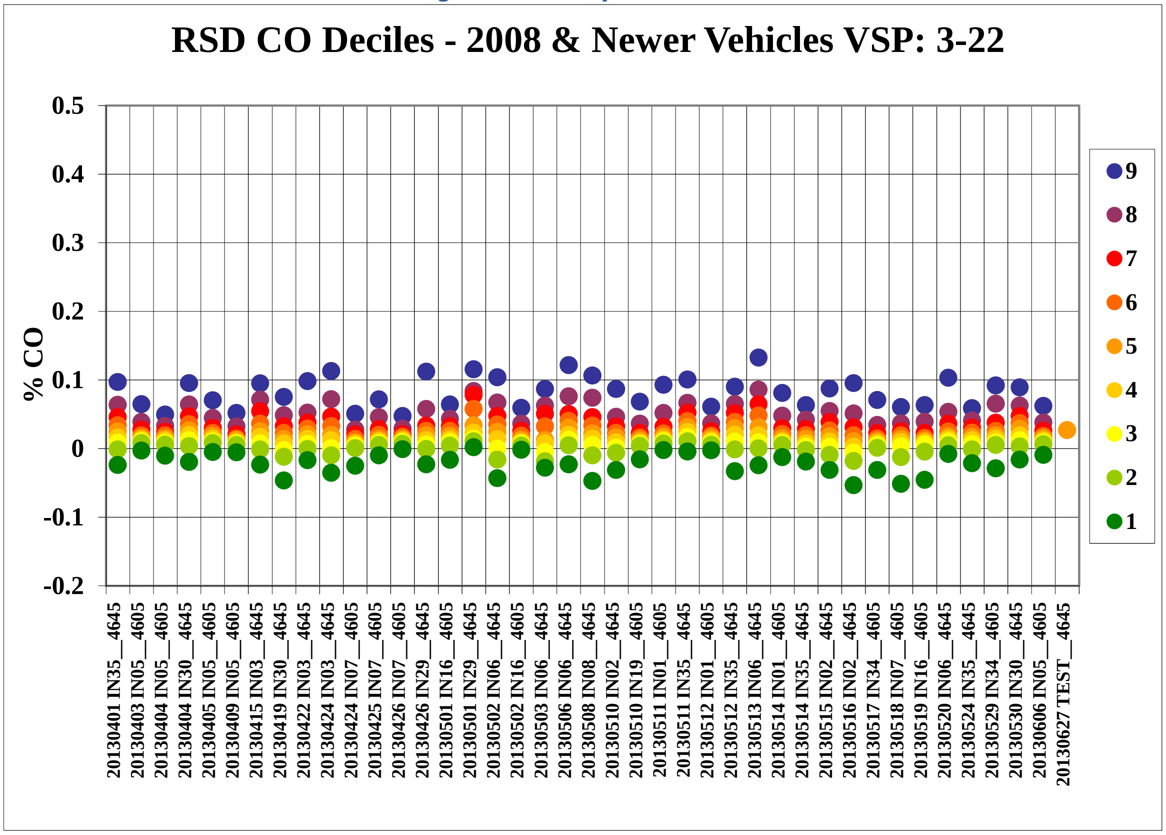


Figure 2-6: Daily NO Deciles

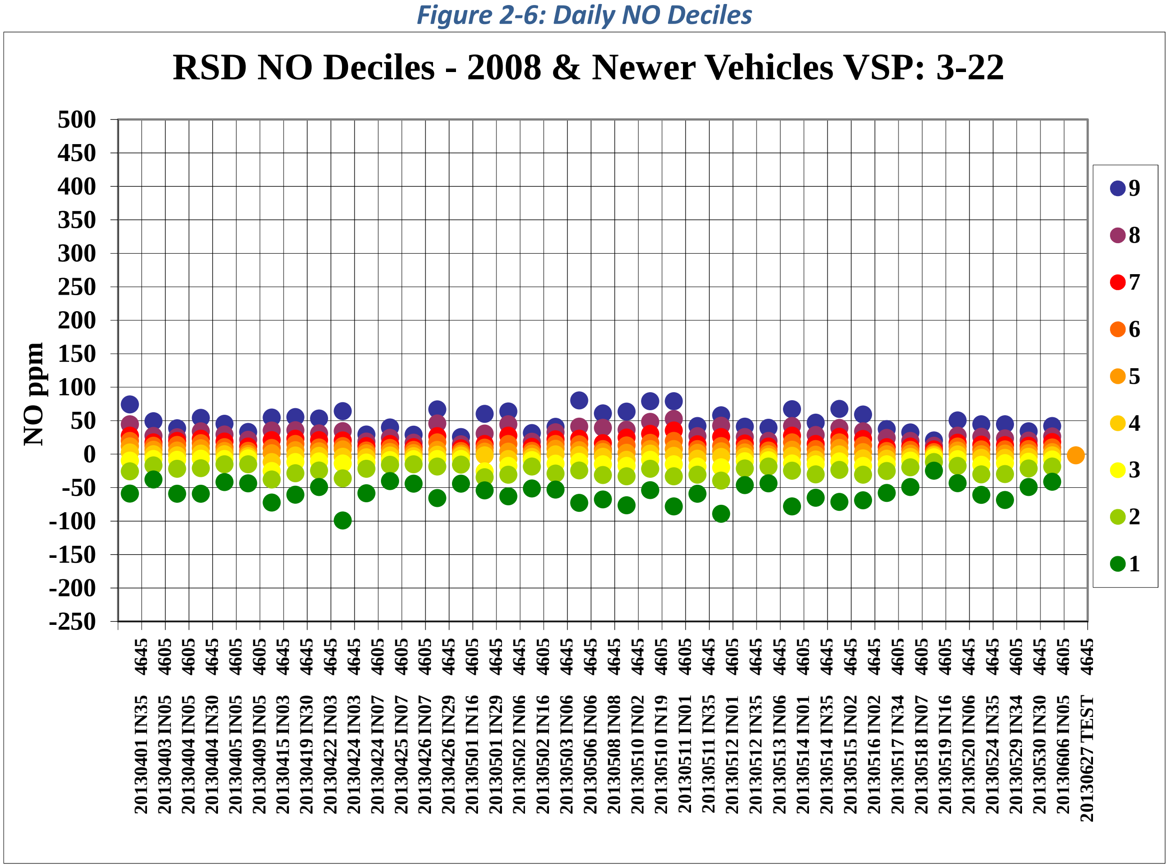
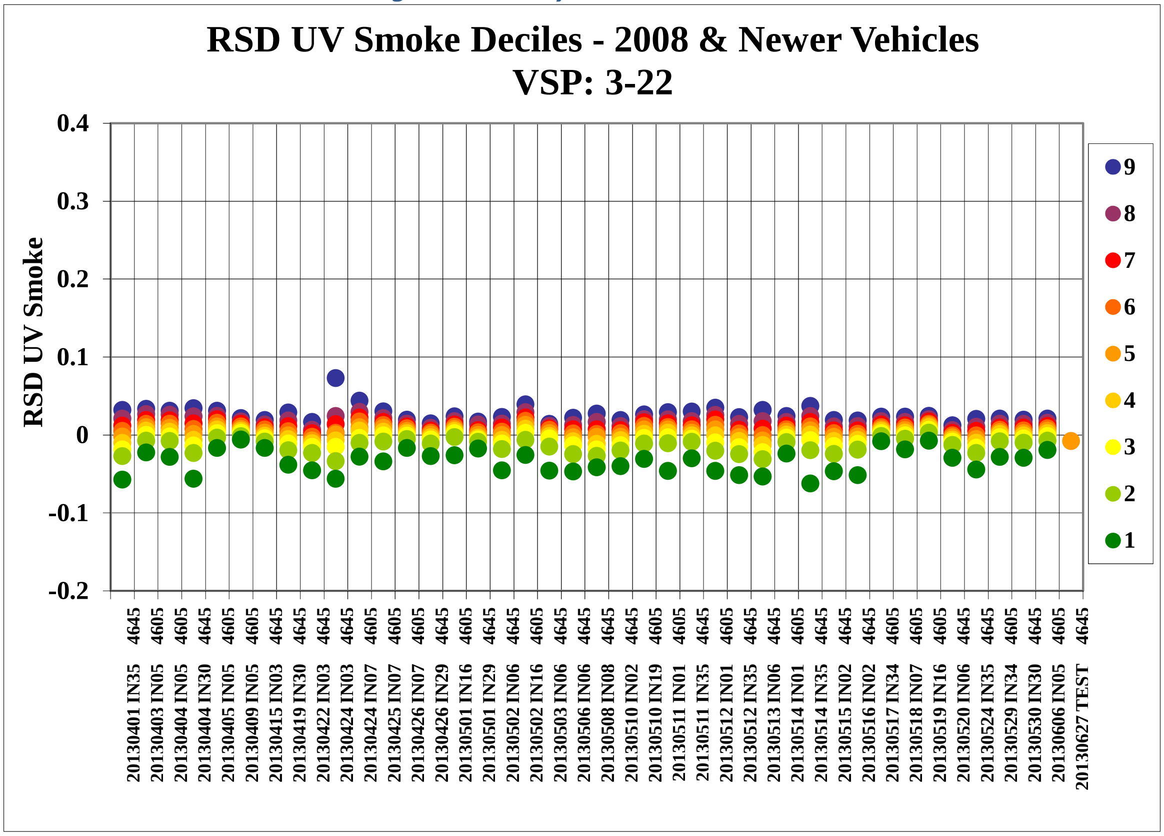


Figure 2-7: Daily UV Smoke Deciles



2.6 Sources of Data and Description of Elements

Data used in the analyses in this report come from two primary sources, the RSD on-road measurements and the Bureau of Motor Vehicles (BMV) registrations database.

In the following description of data elements, key fields that are used to access other tables are shown in **bold**.

2.6.1 RSD Measurements

For each vehicle the following information is collected:

- **Vehicle Plate or tag;**
- Date and Time;
- **Site Reference;**
- HC, CO, CO_2, NO, and UV Smoke emissions; and,
- Speed and acceleration.

2.6.2 RSD Sites

For each site the following information is collected:

- **Site Reference;**
- Description of location; and,
- Slope of site in degrees.

2.6.3 Vehicle Registration Data

Data from the RSD is matched to the vehicle registrations data provided by BMV. Using the vehicle plate identified by RSD, the registration file is accessed to determine the vehicle identification number (VIN) and additional information about the vehicle such as model year and county in which it is registered. In order to obtain an accurate match, the plate number, a two-letter plate type and the registration year are required. BMV uses a series of plate types and in the past the same plate number was sometimes be issued to more than one plate type. This practice is being phased out and only a handful of instances were observed among approximately 450,000 2011 BMV records. For this survey, plates were initially matched to BMV 2011 and 2010 records for Lake and Porter counties and a small balance of unmatched vehicles were matched to plates in I/M test records. A balance of 5,500 unmatched plates were then sent to BMV for matching to the statewide registration database.

Another limitation is that vehicle plates do not always remain with the same vehicle. Upon purchase of a new or used vehicle, an owner may transfer the same plate from the old vehicle to the new vehicle. In this situation, data processing delays can result in incorrect identification of some vehicles measured by RSD unless BMV transaction dates are included in the data, which was not the case for this survey.

2.6.4 NO vs. NO_X

The vast majority of nitric oxides emitted from gasoline vehicle tailpipes are in the form of NO. The NO is later oxidized to NO_2 and other oxides of nitrogen, which are collectively referred to as NO_X.

To convert from NO to NO_X, a factor of 1.03 is applied. Subsequent sections in the report show NO_X values. In Section 5, where individual vehicles are compared to standards for determination of high emitters, the NO values are converted to NO_X and also adjusted for humidity as described below.

2.6.5 NO_X and Humidity

Higher humidity reduces vehicle NO_X emissions. When vehicles are inspected in the I/M program, humidity correction factors are applied to adjust NO_X measurements to values that would have been achieved when the water vapor content is 75 grains per lb. For temperatures above 75 degrees Fahrenheit (ºF):

Correction factor = e^(.004977*(H-75) - .004447*(T-75))

For temperatures below 75 ºF:

Correction factor = 1/(1.0 - .0047*(H - 75.0))

Where:

H = absolute humidity in grains of water/lb dry air
T = Temperature (ºF)

Both of the correction factors are capped at a value of 2.19.

Correction factors were calculated using weather information recorded by the weather station attached to the RSD van. Water vapor grains per lb were determined using the temperature, relative humidity and barometric pressure:

Saturated Vapor Pressure = $(-4.14438 \times 10^{-3} + 5.76645 \times 10^{-3} \times [\text{Temp ºF}] - 6.32788 \times 10^{-5} \times [\text{Temp ºF}]^2 + 2.12294 \times 10^{-6} \times [\text{Temp ºF}]^3 - 7.85415 \times 10^{-9} \times [\text{Temp ºF}]^4 + 6.55263*10^{-11} \times [\text{Temp ºF}]^5)*25.4$

Grains per lb = (43.478 x [Relative Humidity] x [Saturated Vapor Pressure]) / (([Barometric pressure Hg mm])-([Saturated Vapor Pressure]*[Relative Humidity]/100))

The vehicle NO_X emissions reported in Section 5 have been adjusted for humidity.

3 VEHICLE EMISSION DATA COLLECTED

3.1 RSD Sample Quantity

3.1.1 Data Collection Summary

The number of light-duty vehicles registered in the Northern I/M area (Lake and Porter counties) is approximately 450,000. The requirement of a 1% sample of subject vehicles therefore requires 4,500 measurements.

In total, 58,973 RSD measurements were made from April 1st through June 26th 2013. These statistics include duplicate instances of the same vehicle where the vehicle has been measured by RSD more than once. Data were collected from thirteen sites.

Table 3-1: Remote Sensing Measurements Summary

Item	Quantity	%
RSD valid HC, CO, NOx, Speed & Acceleration		
and in desired operating mode (VSP)	58,973	
Additional screening:		
Cold temperature	3440	
NOx values less than -250 ppm	3	0.0%
UVSmoke values less than -0.05 SF	3	0.0%
Valid and in desired VSP range after screening	55,527	
Valid with readable plate or state	49,860	89.8%
Of which:		
Indiana plate read	42,848	85.9%
Out of State License Plate	7,012	14.1%
Indiana plates read:		
Matched to BMV Lake/Porter Registrations	27,392	63.9%
Matched to BMV Other Counties	-	0.0%
Unmatched	15,456	36.1%

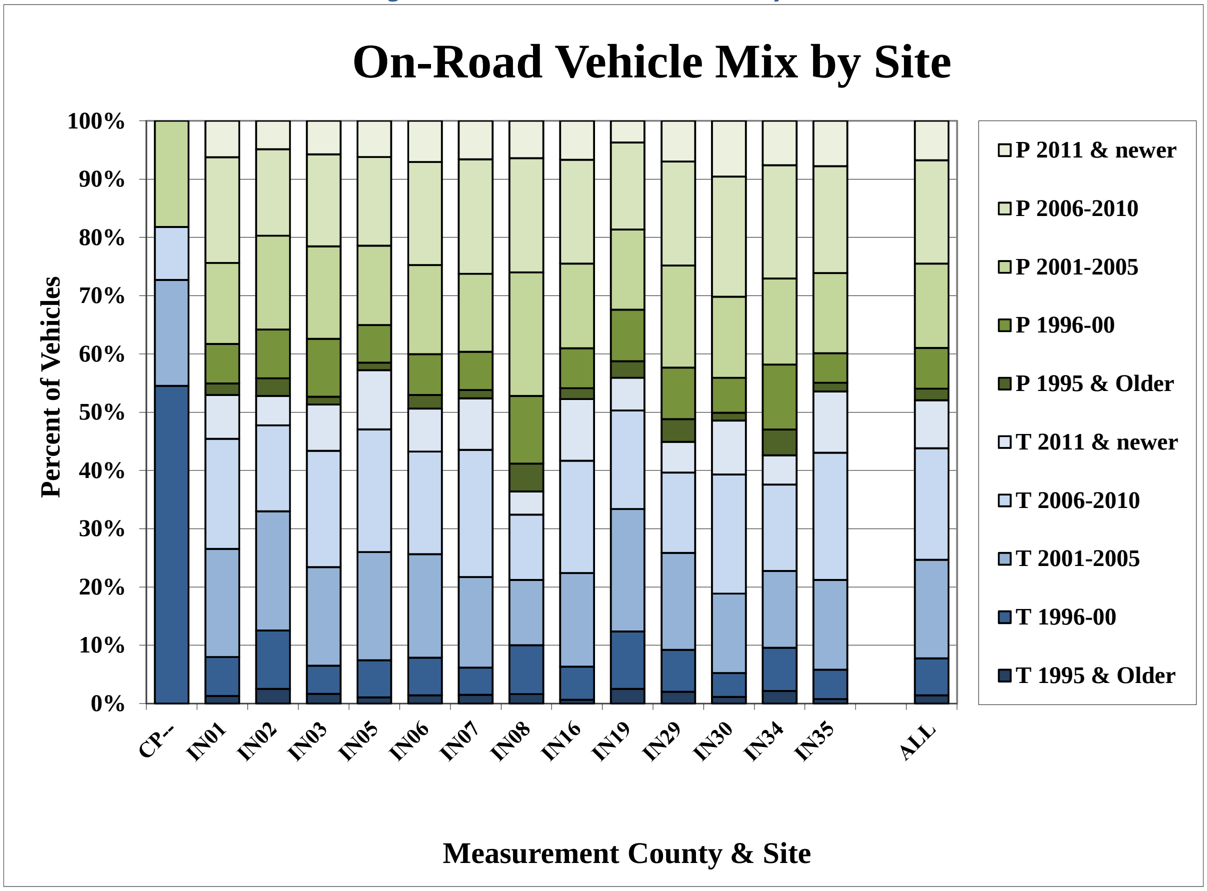
3.1.2 Vehicle Composition

Vehicle type was identified from the VIN for matched plates. For vehicles registered in Lake and Porter counties these were determined to be:

- Passenger vehicles 48%
- Trucks 52%

Vehicles were then divided into five model year ranges to determine if the mix of vehicles by type and model year was consistent among sites. Figure 3-1: On-road Vehicle Mix by Site shows differences in the proportion of passenger vehicles and the age of vehicles.

Figure 3-1: On-road Vehicle Mix by Site



3.2 On-road Fleet Emission Distribution

The following four charts show the emission percentiles for HC, CO, NO_X, and UV Smoke for all Indiana plate vehicles measured in the 3 to 22 kilowatts per metric ton (kW/t) range. Pollutant values are shown on the left y-axis.

Upper black lines indicate the % of the pollutant (right y-axis) produced by a given % of vehicles (x-axis) when rank ordered from highest to lowest. This indicates 20% of vehicles account for 80% of CO, 82% of HC, 88% of NO_X, and 71% of PM (UV Smoke) emissions.

The vast majority of vehicles had low emissions and contribute little to regional pollution. Ten-to-twenty percent of vehicles had much higher emissions and emit over 70-90% of the on-road light-duty vehicle emissions.

Figure 3-2: CO Emissions Distribution

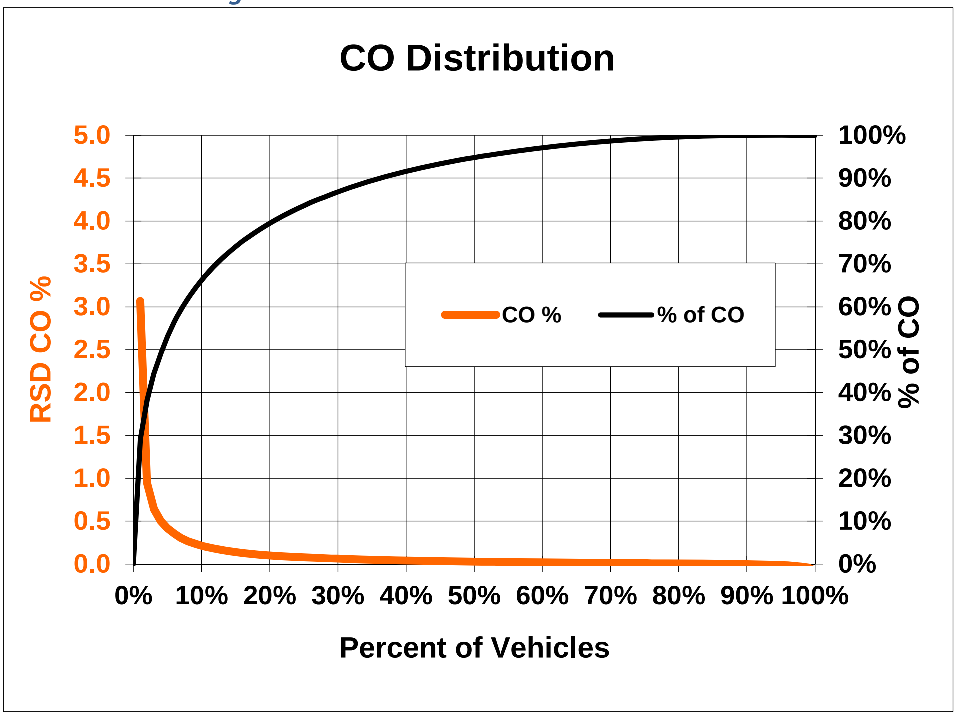


Figure 3-3: HC Emissions Distribution

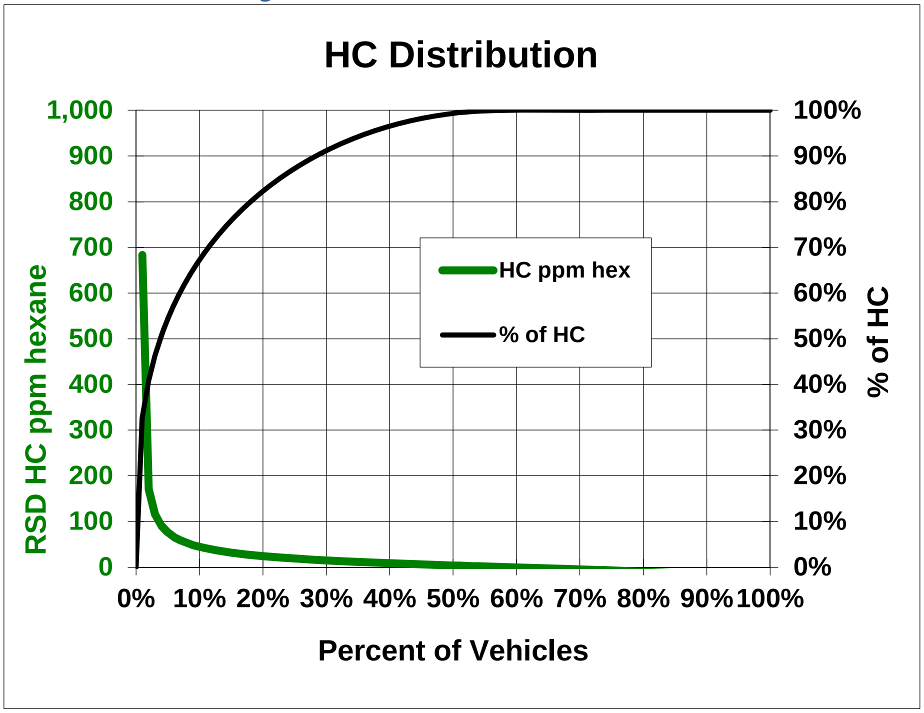


Figure 3-4: NO_X Emissions Distribution

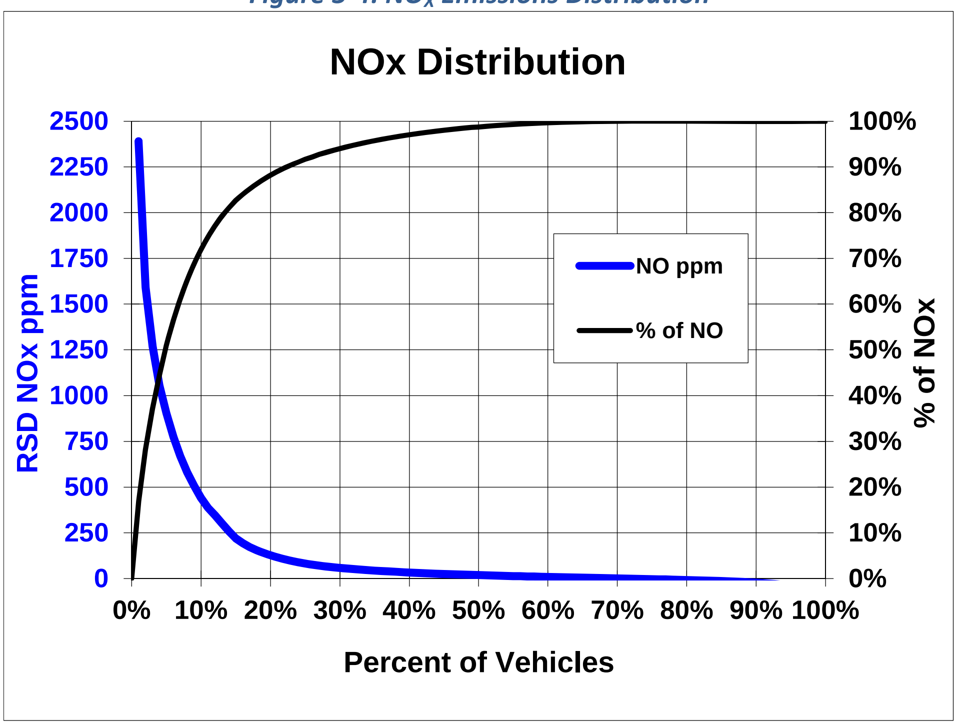
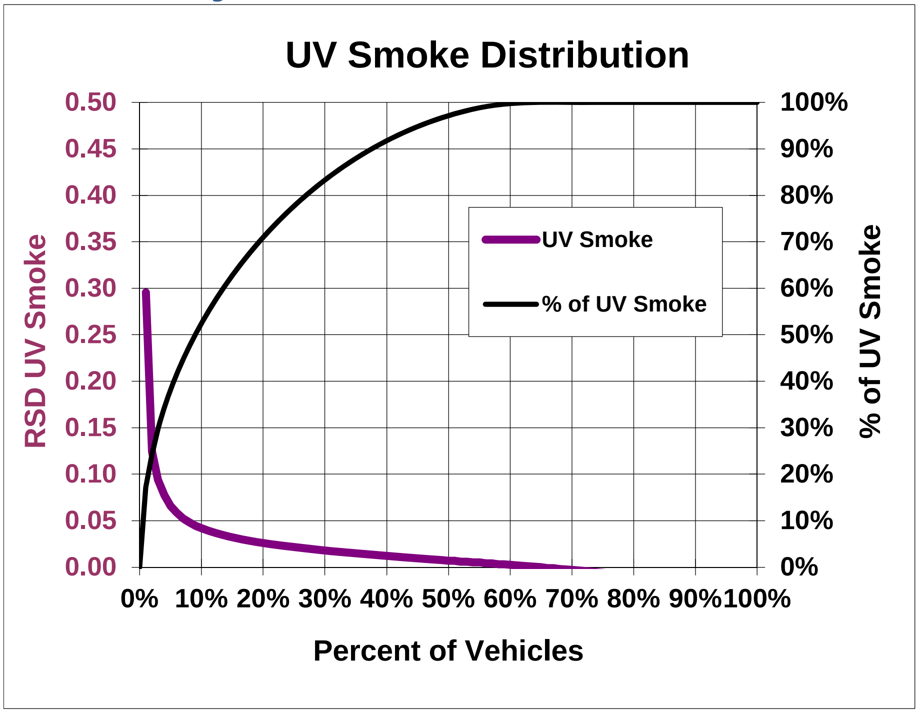


Figure 3-5: UV Smoke Emissions Distribution



3.3 Emissions by Registered Jurisdiction

In this section, emissions of vehicles registered in the different areas are compared (independent of where they were seen driving). Table 3-2 and Figures 3-7 to 3-10 show mean HC, CO, NO_X, and Smoke measurements by jurisdiction. Data about the vehicles such as their type and model were only available for vehicles registered in Lake and Porter counties. Therefore, the results shown are for all vehicles from a jurisdiction and it is not known whether the vehicles from the different jurisdictions have a similar mix of vehicles by age and type. Thus one should cautious of drawing conclusions from these charts.

In addition, matching registration data were not available for vehicles newly registered within the last year and new Lake and Porter County vehicles were included in the 'Unmatched Indiana' category. Vehicles registered after October 1, 2012 were missing at the time the report was compiled. These new low emitting vehicles initially registered from October 2012 through the survey period of April-June 2013 were by default included in the 'Unmatched Indiana' vehicles. Their absence from the Lake and Porter matched vehicles meant the reported average emissions for vehicles registered in Lake and Porter were higher than they would have been had all the registration records been available. An estimated correction has been made by assuming the newest vehicles were similar in number and emissions to model year 2011, which were 7% of measurements. Vehicles and emissions equivalent to seven months of 2011 model vehicles, 1,117 records, were deducted from the 'Unmatched' category and added to Lake and Porter counties.

Using the adjusted Table 3-2c, vehicles registered in Indiana counties outside the I/M area had average HC, CO, and NOx emissions of 14%, 39% and 35% higher respectively than the average emissions of vehicles registered in Lake and Porter counties.

Compared to Lake and Porter registered vehicles, vehicles from Illinois and Michigan also had higher emissions of HC, CO and NO_X. Vehicles from other more distant states had emissions similar or lower than Lake and Porter registered vehicles.

Table 3-2a: Emissions by Jurisdiction

Jurisdiction	Records	% CO	HC ppm	NOx ppm	RSD Smoke	VSP kW/t
Lake County	17,512	0.11	17	148	0.009	8.2
Porter County	9,880	0.09	10	118	0.013	8.4
Unmatched Indiana	15,456	0.11	18	167	0.012	8.3
Illinois	4,142	0.11	15	140	0.010	8.9
Michigan	377	0.09	15	143	0.007	8.5
Ohio	155	0.10	8	103	0.006	8.2
Wisconsin	240	0.09	14	124	0.010	9.6
Other States	2,098	0.10	11	120	0.010	9.1
Total	49,860	0.10	15	146	0.011	8.4
Lake & Porter combined	**27,392**	**0.10**	**14**	**137**	**0.010**	**8.3**

Table 3-2b: 2011 Models by County

Jurisdiction	Records	% CO	HC ppm	NOx ppm	RSD Smoke	VSP kW/t
Lake County	1,156	0.04	3	18	0.005	8.5
Porter County	759	0.03	2	12	0.009	8.4
Lake & Porter MY 2011	**1,915**	**0.04**	**3**	**16**	**0.007**	**8.5**

Table 3-2c: Adjusted Emissions by Jurisdiction

Jurisdiction	Records	% CO	HC ppm	NOx ppm	RSD Smoke	VSP kW/t
Lake County	18,186	0.11	16	143	0.009	8.2
Porter County	10,323	0.08	10	114	0.013	8.4
Unmatched Indiana	14,339	0.11	19	179	0.013	8.2
Illinois	4,142	0.11	15	140	0.010	8.9
Michigan	377	0.09	15	143	0.007	8.5
Ohio	155	0.10	8	103	0.006	8.2
Wisconsin	240	0.09	14	124	0.010	9.6
Other States	2,098	0.10	11	120	0.010	9.1
Total	**49,860**	**0.10**	**15**	**146**	**0.011**	**8.4**
Lake & Porter combined	**28,509**	**0.10**	**14**	**133**	**0.010**	**8.3**

To assess whether the comparison of emission values from different jurisdictions were affected by different vehicle operating conditions, the average vehicle specific power for each group was plotted in Figure 3-11. Average VSP was similar for all jurisdictions.

Figure 3-6: Jurisdiction of Vehicles Measured

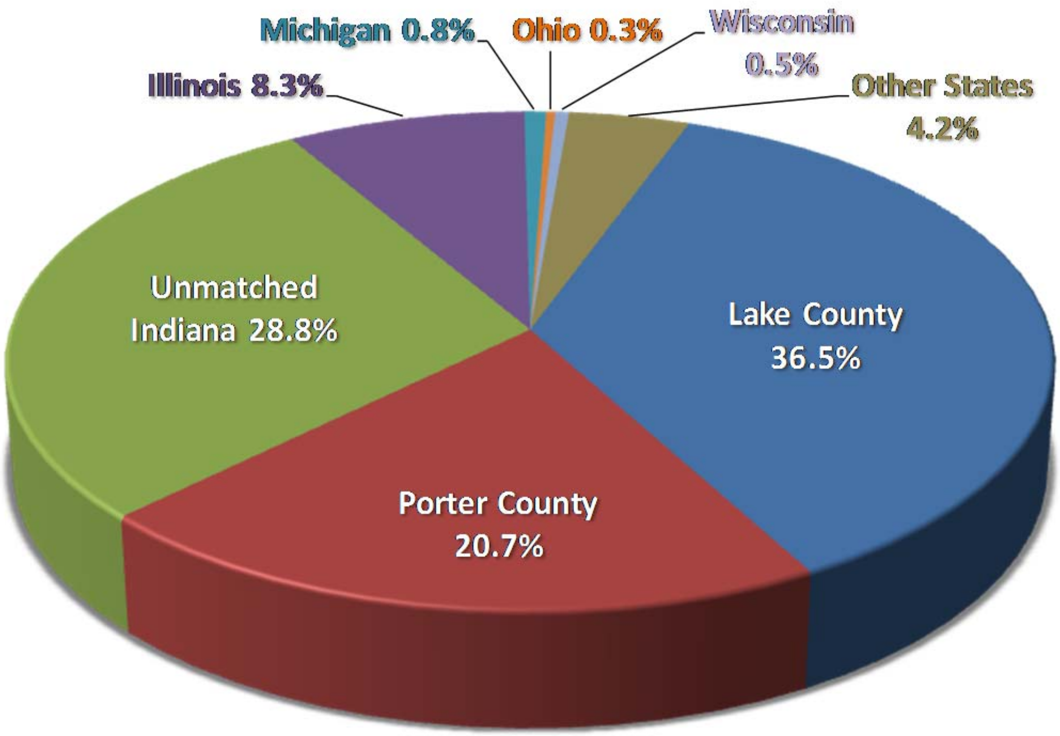


Figure 3-7: RSD HC Emissions by Jurisdiction

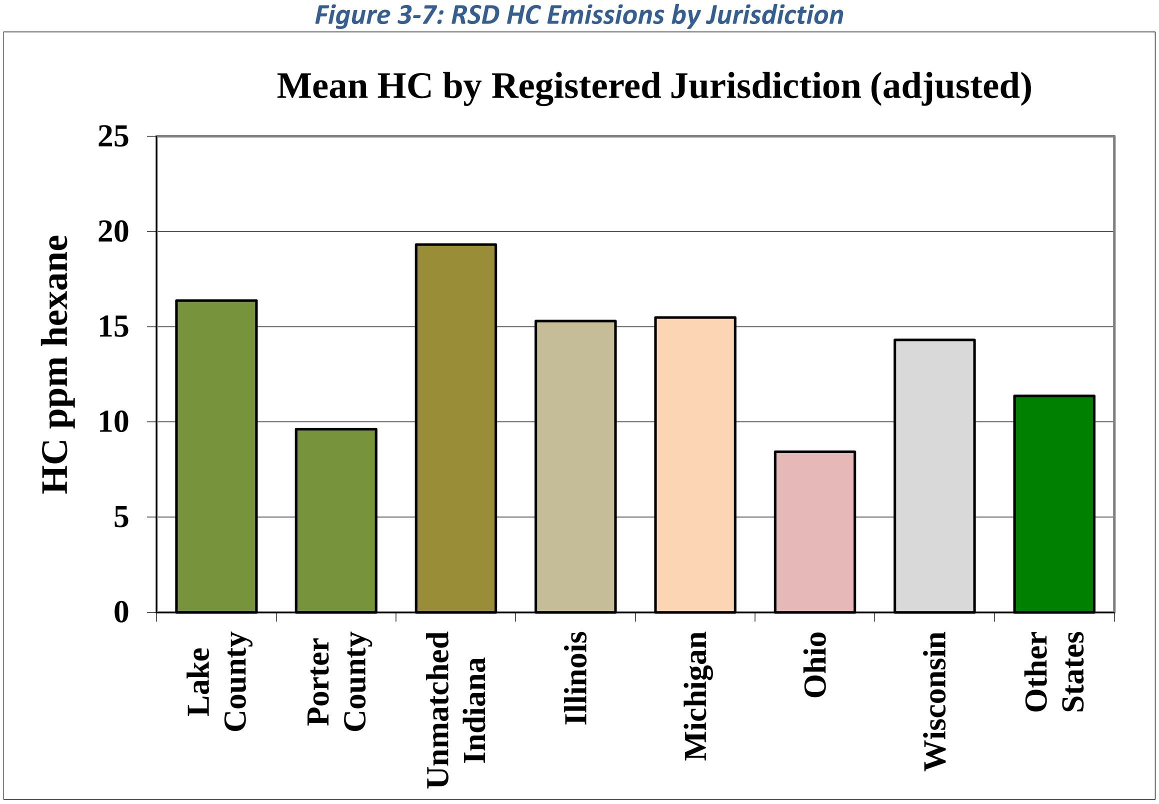


Figure 3-8: RSD CO Emissions by Jurisdiction

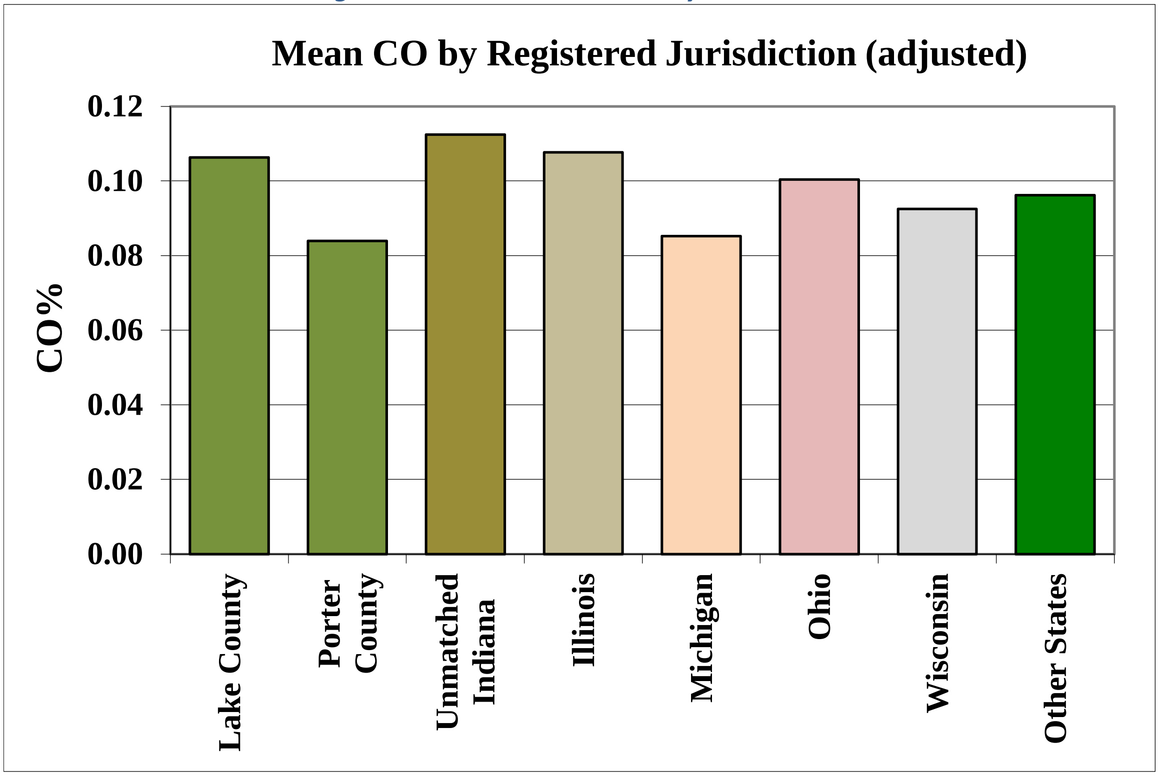


Figure 3-9: RSD NO_X Emissions by Jurisdiction

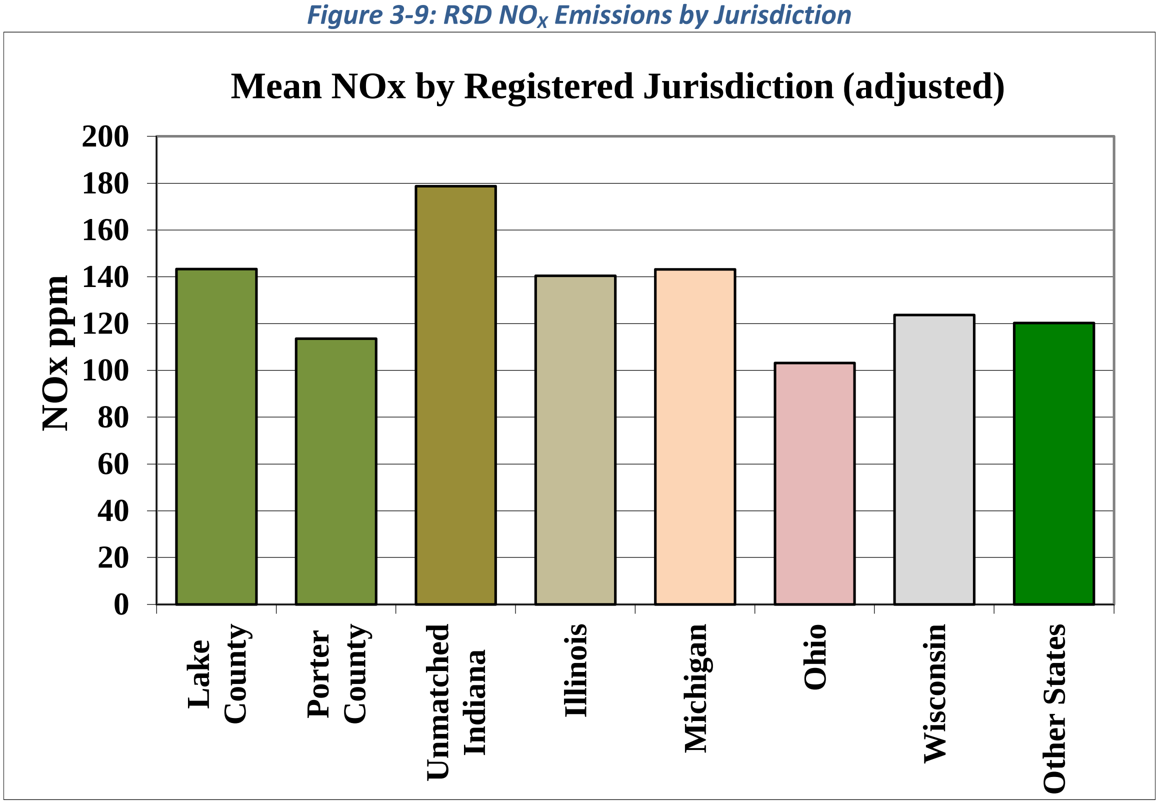


Figure 3-10: RSD UV Smoke Emissions by Jurisdiction

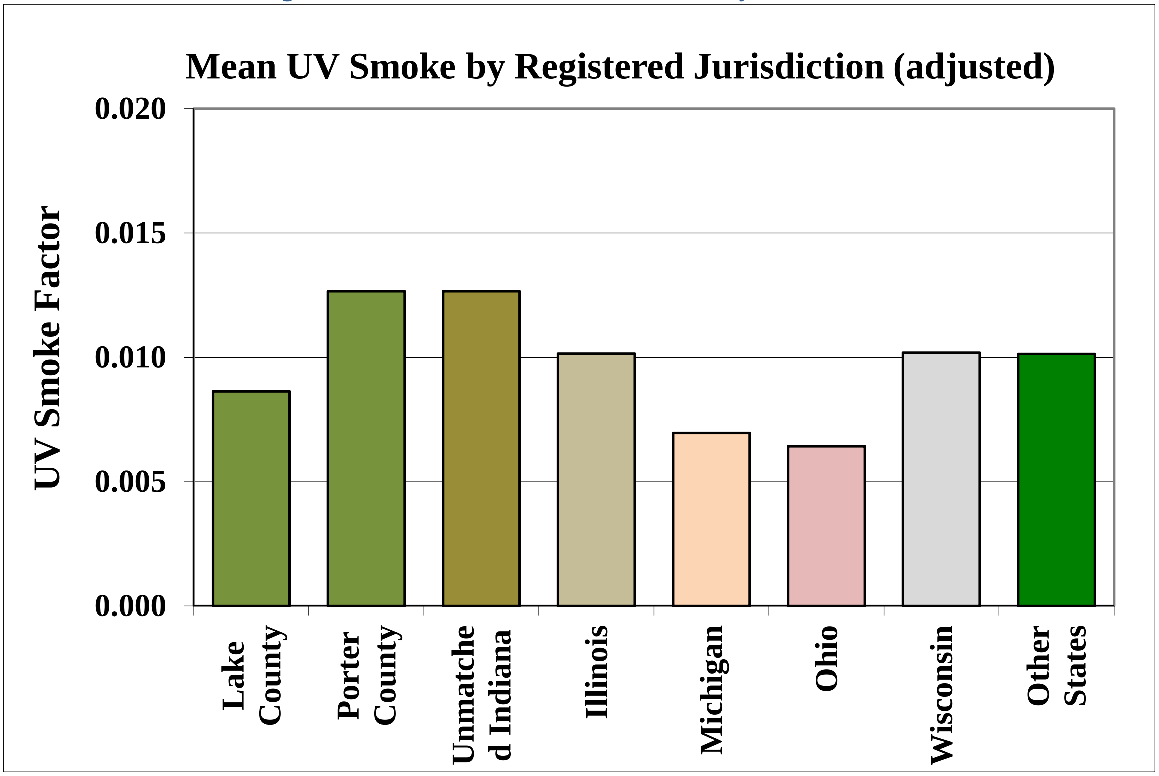
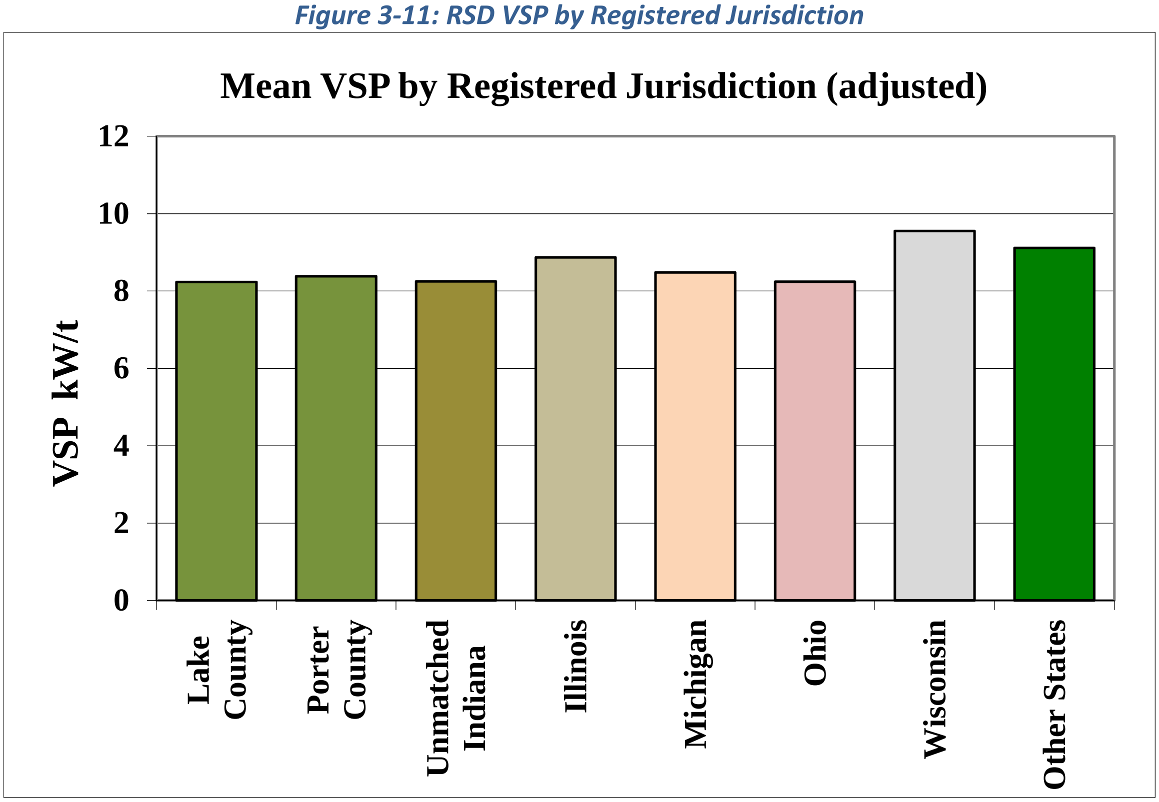


Figure 3-11: RSD VSP by Registered Jurisdiction



3.4 Emissions by Type and Model Year

Emissions for different models by 5-year bins are shown in Figure 3-12 for Lake and Porter counties passenger vehicles and light-duty trucks.

The difference in average emissions between the oldest and newest models is extreme. Only 90 passenger vehicles and 50 trucks model year 1990 and older were measured. Other bins contained at least 300 measurements. 1995 and older models were many times dirtier than newer models. Even 1996-2000 models had emissions several those of 2006-2010 models. 1991-1995 model trucks had higher emissions than passenger vehicles and 1996-2000 model trucks had higher HC, NO_X and PM.

Figure 3-12: Emissions by Vehicle Type and Model Year

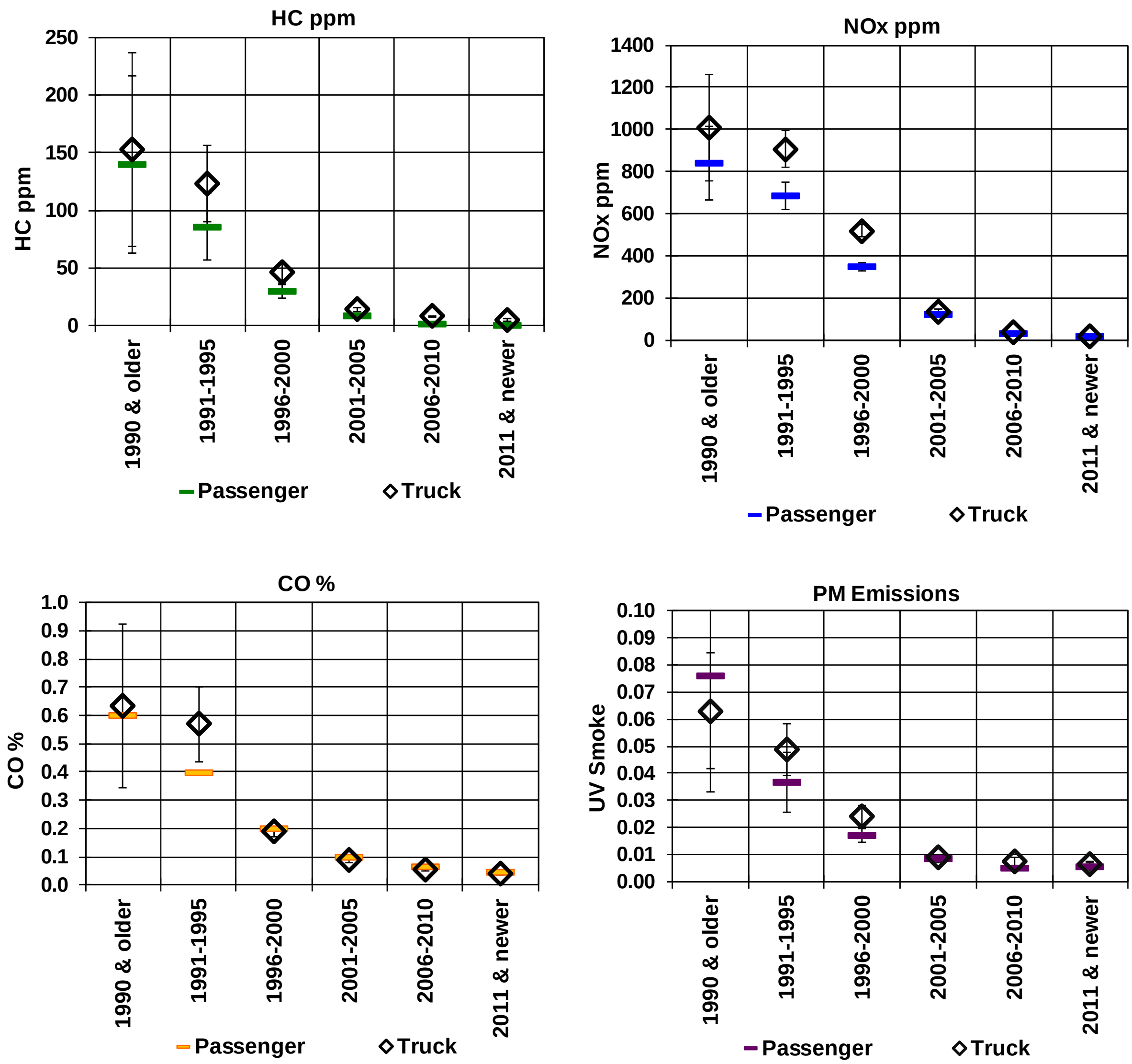


Figure 3-13 compares average emissions of passenger vehicles in Lake and Porter counties. Older model Lake county vehicles tended to have higher average HC and CO emissions but differences were not statistically significant.

Figure 3-13: Lake and Porter Counties Passenger Vehicle Emissions

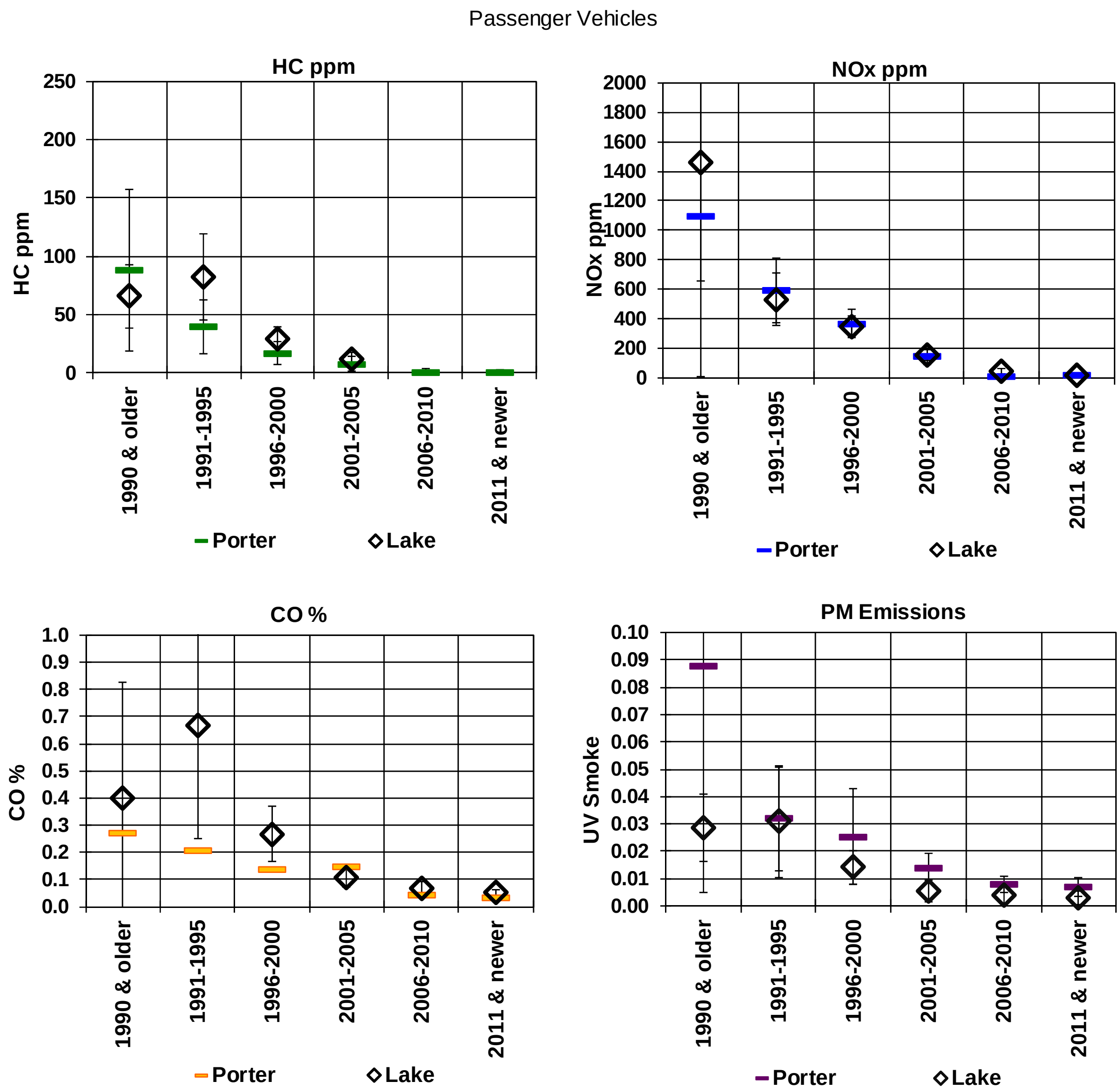
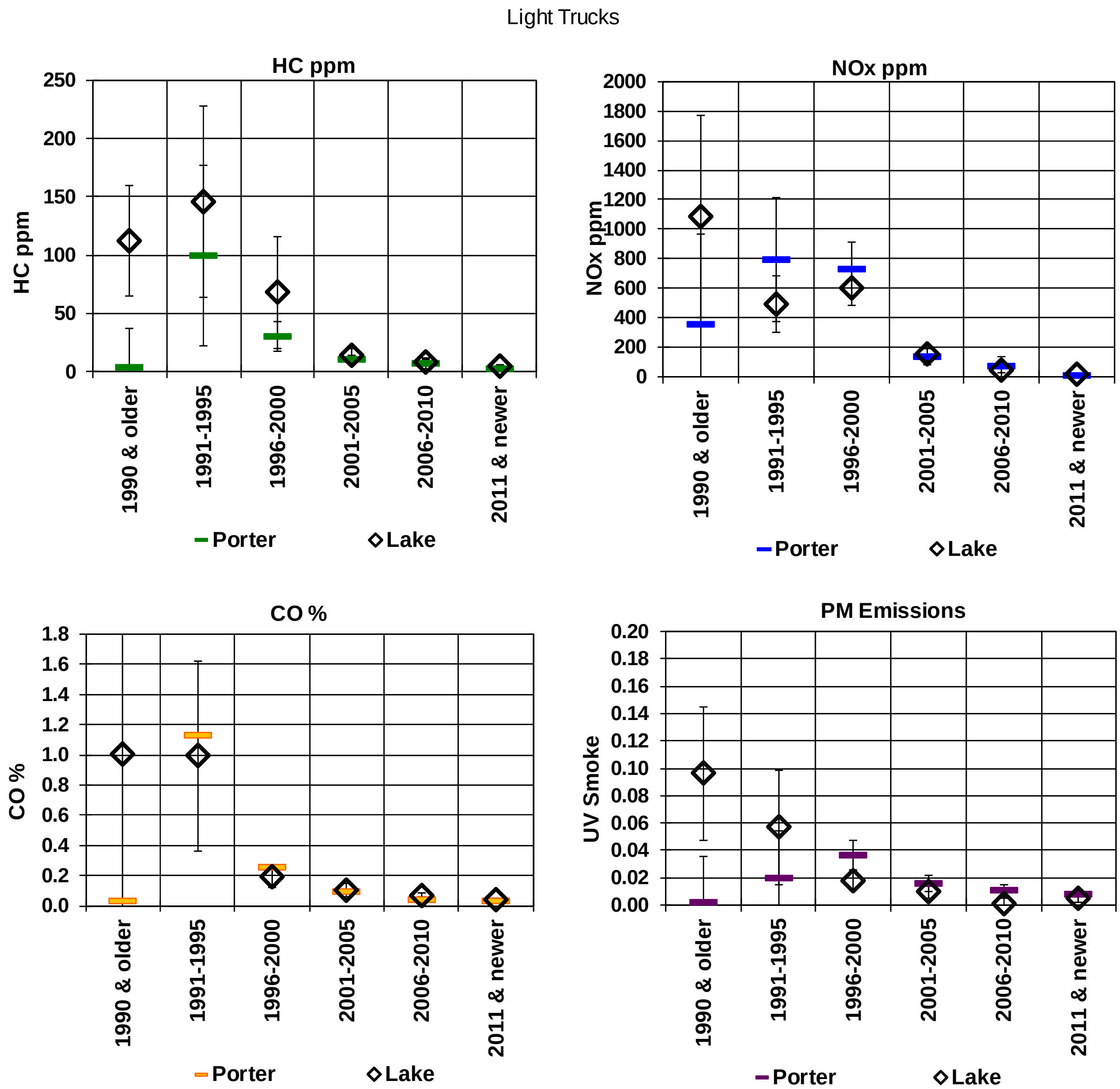


Figure 3-14 compares average emissions of light-duty trucks in Lake and Porter counties. Older model Lake County vehicles tended to have higher HC emissions but differences were not statistically significant.

Figure 3-14: Lake and Porter Counties Light-Duty Truck Emissions



The relationship between UV Smoke Factor and mass for gasoline PM estimates is approximate. Gasoline particulates have different characteristics than diesel particulates and, as noted earlier, an accurate characterization of typical gasoline vehicle particulates and their mass correlation to RSD UV Smoke Factor is the subject of continuing research.

3.5 Emission Contributions by Type and Age

Table 3-3 and Figure 3-17 show the split between Lake and Porter registered passenger vehicles and light-duty trucks in numbers and their estimated emissions contributions. As in the section 3.3 Emissions by Jurisdiction, an adjustment was made for missing new vehicles by adding the equivalent 7 months of 2011 models.

Light-duty trucks were 52.4% of vehicles observed compared to 47.6% passenger vehicles.

Relative emission contributions in Table 3-3 and Figure 3-17 were calculated using a simplified approach: emission contribution is proportional to the number of measurements times the emission levels. The number of RSD measurements of a class of vehicles has been demonstrated in studies[8] to be proportional to the VMT of the class, i.e. the greater the miles driven by a class of vehicle the more often its members are observed on-road. The mass of exhaust per mile is inversely proportional to fuel economy, i.e. better fuel economy equated to a smaller mass of exhaust emissions per mile. Mass emissions are consequently proportional to the average emission concentrations times the number of observations divided by fuel economy. This allows the relative share or contribution of emissions produced by different classes of vehicles to be calculated.

Average fuel economies of 23 mpg for passenger vehicles and 17 mpg for light-duty trucks were used in the calculations. This is reasonable if fuel economy is similar across all age groups (fuel economy has changed little since the early 1980's). More accurate estimates could be obtained by determining and applying the individual fuel economy for each vehicle.

Using the simple approach described above, light-duty trucks were estimated to contribute 56.1%, 69.7%, 62.8%, and 63.6% of the light-duty vehicle sector CO, HC, NO_X, and PM (UV Smoke) emissions. It is assumed that UV Smoke is a reasonable measure of total particulate emissions.

Table 3-3: Vehicles and Emission Contributions by Type and Age

		Emission Contributions			
Type	**Vehicles**	**CO**	**HC**	**NOx**	**PM**
Passenger	47.6%	43.9%	30.3%	37.2%	36.4%
Truck	52.4%	56.1%	69.7%	62.8%	63.6%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Within passenger vehicles, Table 3-4 shows that 1995 and older models were 4.1% of measurements contributing 35.7% of HC and 22.7% of NO_X. In contrast, 2006-2012 models were 52.2% of measurements contributing 3.3% HC and 10.5% of NO_X.

The lower section of Table 3-4 shows the light-duty trucks measured were predominantly 2001 and newer models (86%). Older models, 2000 & older, were 14% of vehicles and emitted 51.9% of light-duty truck HC and 58.8% of light-duty truck NO_X.

Figures 3-18 and 3-19 further illustrate the split of vehicles and contributions within the passenger vehicle and light-duty truck sectors.

Figure 3-17: Passenger and Light-Duty Truck Emission Contributions

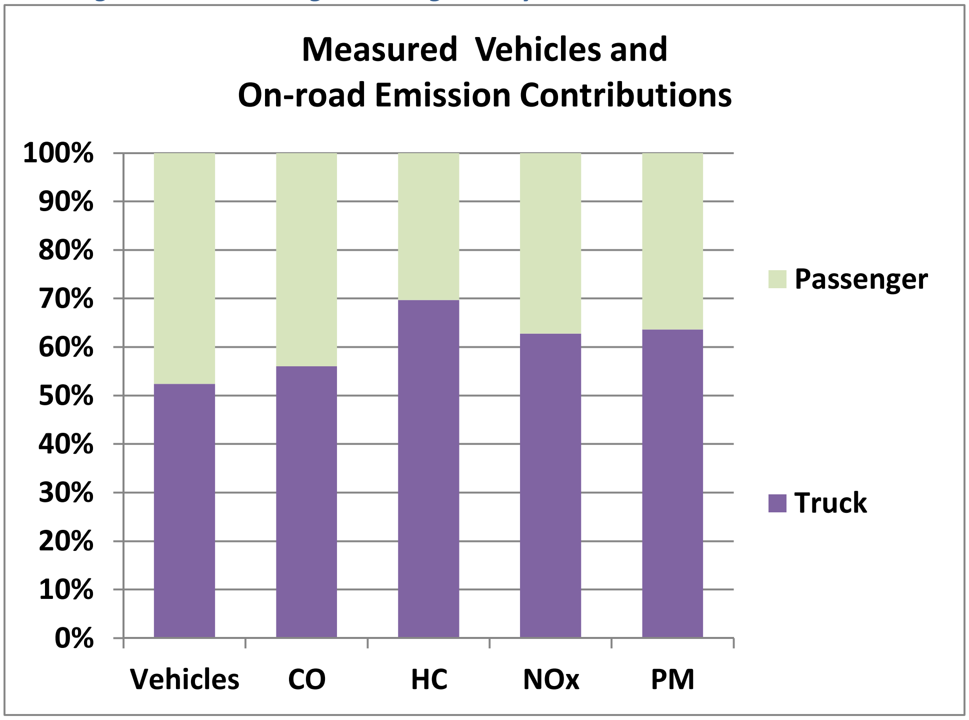


Table 3-4: Vehicles and Emission Contributions by Age

		Passenger Vehicle Emission Contributions			
Model Years	**Vehicles**	**CO**	**HC**	**NOx**	**PM**
1990 & older	0.7%	3.9%	8.8%	4.5%	5.6%
1991-1995	3.4%	12.8%	26.9%	18.2%	13.5%
1996-2000	14.2%	27.0%	38.5%	38.8%	26.6%
2001-2005	29.1%	26.6%	22.4%	28.0%	26.2%
2006-2010	35.7%	22.2%	3.3%	8.2%	18.3%
2011 & newer	16.9%	7.5%	0.0%	2.3%	9.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

		Light Truck Emission Contributions			
Model Years	**Vehicles**	**CO**	**HC**	**NOx**	**PM**
1990 & older	0.3%	2.4%	3.1%	2.3%	2.0%
1991-1995	2.3%	14.3%	16.7%	14.2%	10.3%
1996-2000	11.7%	24.4%	32.1%	42.3%	26.1%
2001-2005	31.0%	29.5%	26.1%	29.4%	26.3%
2006-2010	35.0%	21.1%	16.3%	9.7%	24.0%
2011 & newer	19.6%	8.2%	5.7%	2.1%	11.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 3-18: Passenger Vehicle Emission Contributions by Age

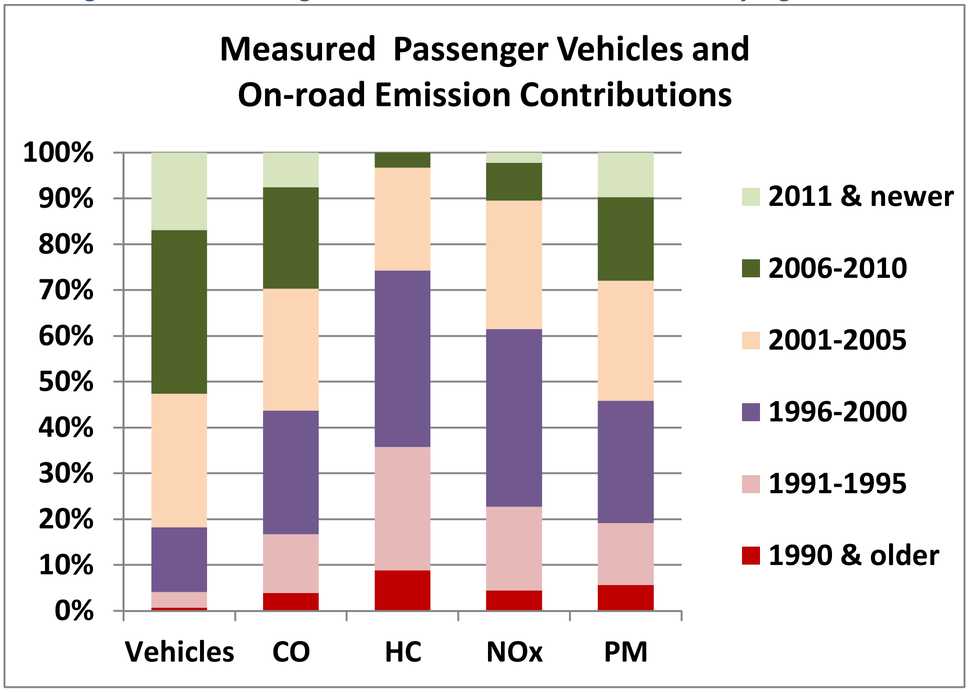
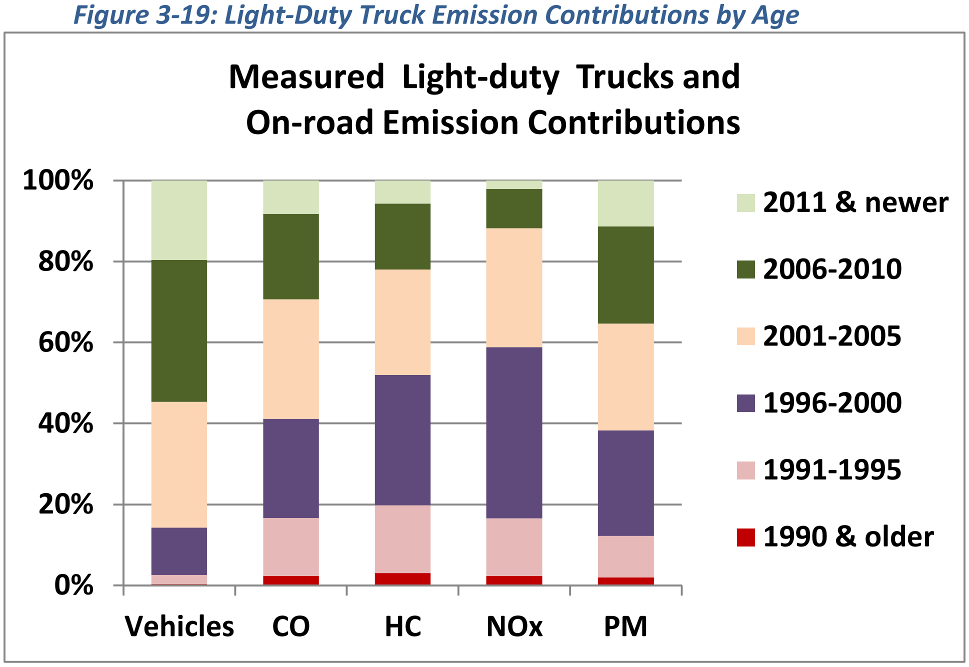


Figure 3-19: Light-Duty Truck Emission Contributions by Age



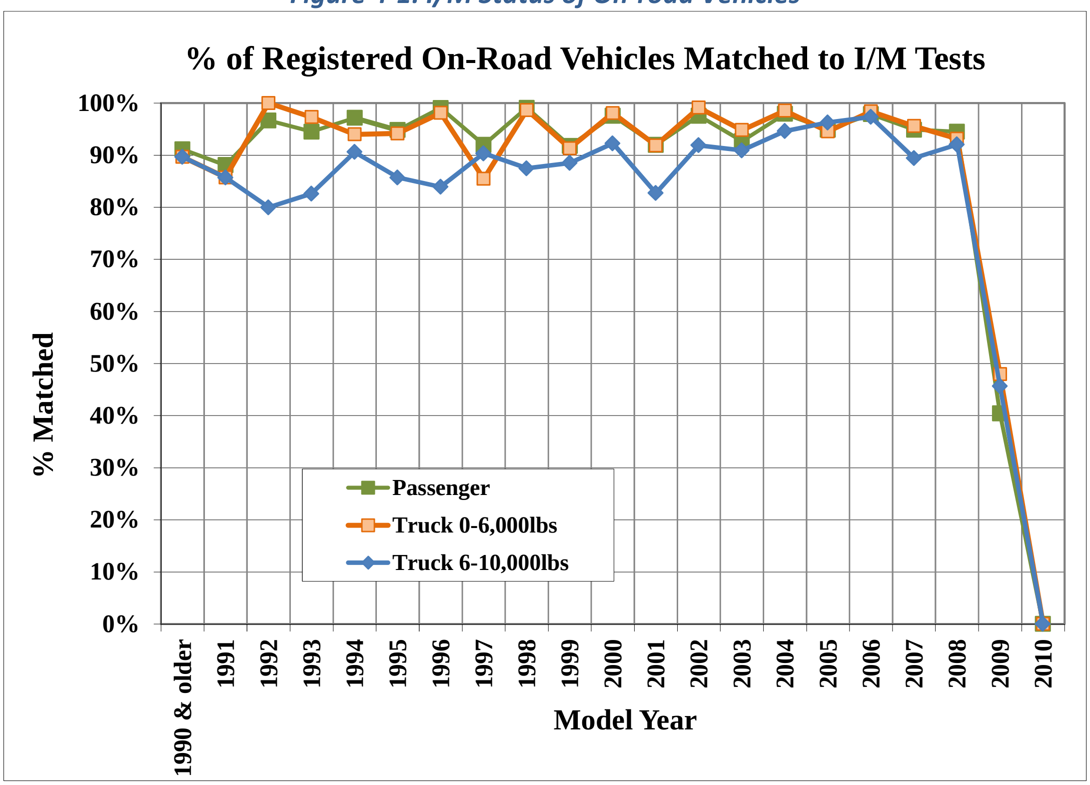
4 I/M STATUS OF ON-ROAD VEHICLES

Envirotest compared on-road emissions to the previous I/M inspection result for gasoline and diesel powered vehicles registered within the two counties. I/M records from 10/1/2010 through the date of the on-road survey were analyzed to extract the date and the result of the last I/M test. That allowed 30 months (October 2010 - March 2013) in which a vehicle could have received a biennial test.

Figure 4-1, 'I/M Status of On-road Vehicles', summarizes the status of vehicles observed on-road by model year. Vehicles as old as 1976 models were subject to inspection. Because of the four-year new model exemption, 2009 and newer models were not required to have obtained an emissions inspection at the time of the survey.

The upper orange and green lines show that 95.4% of 1976-2008 passenger models and 95.7% of trucks 6,000lbs GVWR or less had obtained at least one inspection between 10/1/2010 and the date they were observed on-road. The equivalent rate for trucks between 6,000 and 10,000lbs GVWR and greater was 91.5%. Some of the latter were exempt from testing as the upper weight limit on the inspection requirement is 9,000lbs GVWR. Diesel fueled vehicles were excluded.

Figure 4-1: I/M Status of On-road Vehicles



Among 1996 and newer models there is a biennial pattern in the results showing the rate of matched tests was higher for even model year vehicles. We are not sure why that should be so. The pattern was reversed in the 2011 survey with higher percentages of odd model year vehicles tested.

Figure 4-2: I/M Status of On-road Vehicles by County shows on-road vehicles with test matched records by county for the 1976-2008 models by fuel, type (P-passenger, T-truck) and truck weight class (1 or 2). Figure 4-3 confirms that inspection rates were similar in the two counties.

Figure 4-2: I/M Status of On-road Vehicles by County

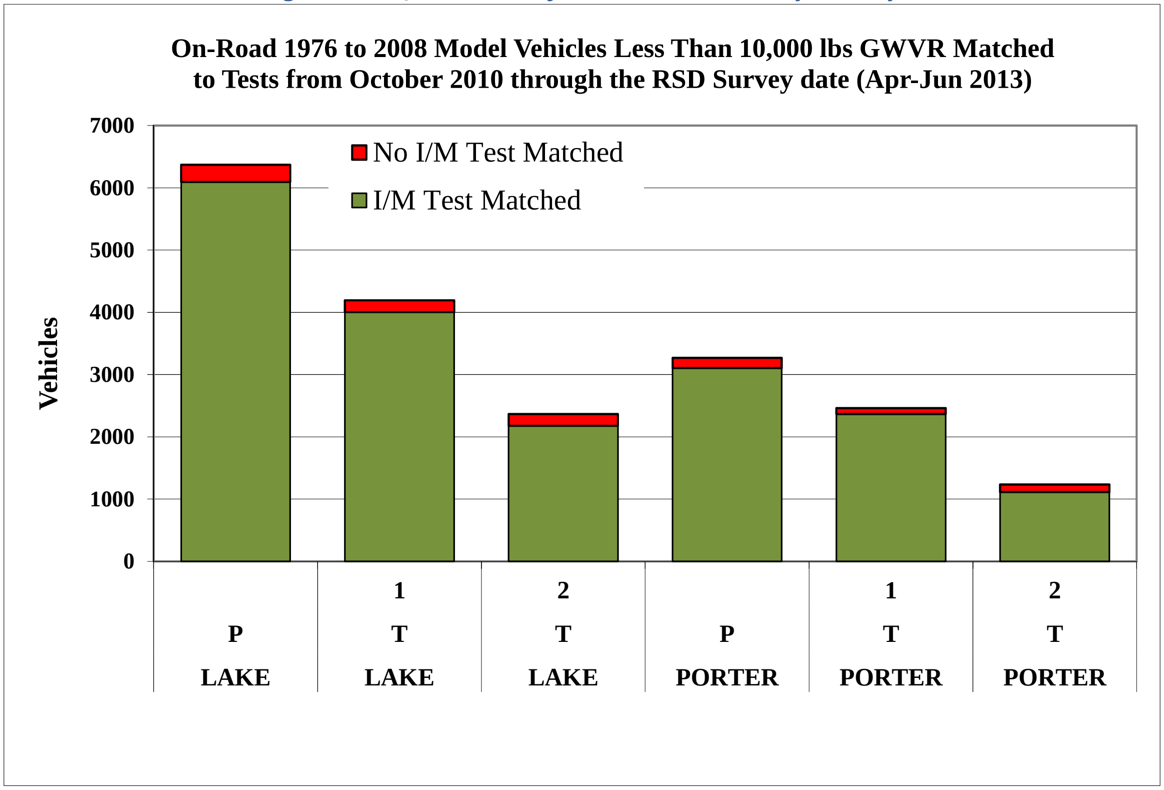
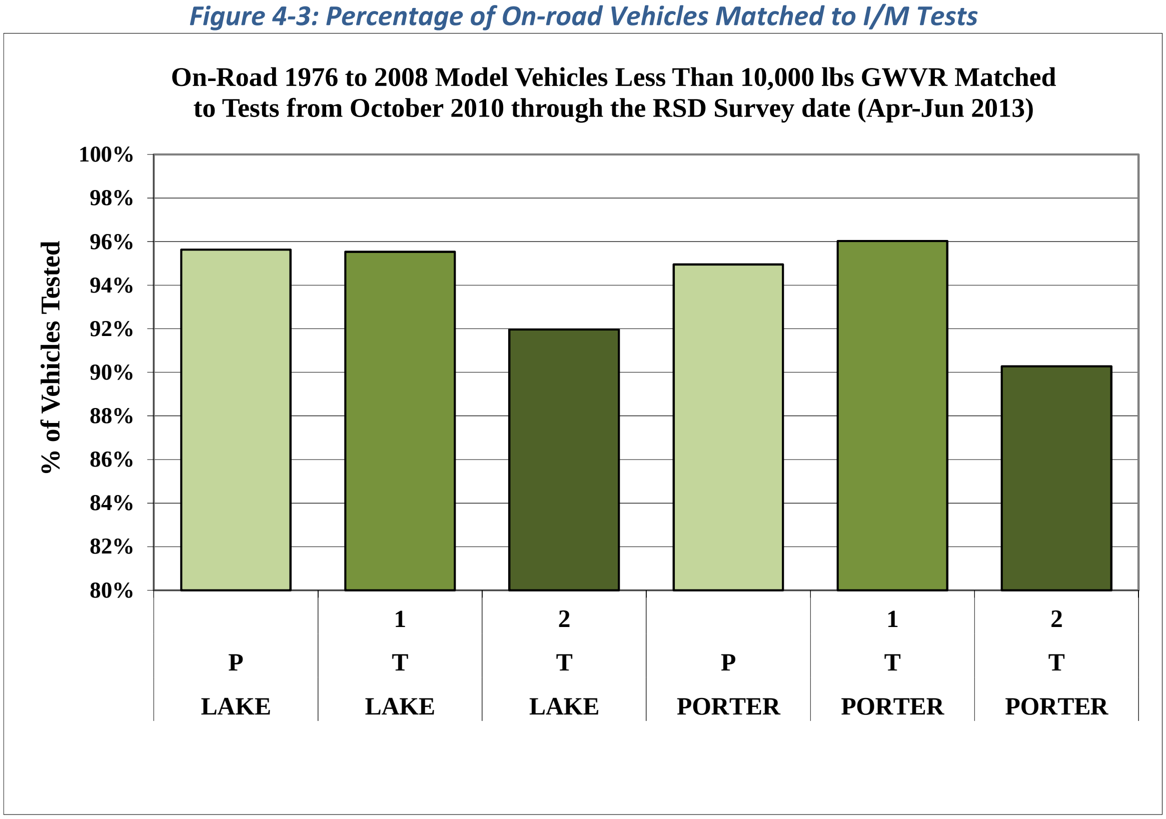


Figure 4-3: Percentage of On-road Vehicles Matched to I/M Tests



5 High Emitters

For this survey, high emitters were identified using cutpoints listed in Table 5-1, which have been used to identify high emitters in Maryland surveys. Vehicles were divided into three GVWR classes: 1) 0 to 6,000 lbs, 2) 6,001 to 10,000 lbs, and 3) over 10,000 lbs. The cutpoints for HC in this table are specified in ppm HC hexane, which is consistent with most I/M inspection equipment used to measure tailpipe concentrations. Remote sensing NO_X emissions were corrected for humidity as described in Section 2 before being compared to the high emitter standards.

In order to be considered a high emitter a vehicle was required to have 2 or more readings that exceeded the standards for the same pollutant on different days. If the standard was exceeded by less than the tolerance of the RSD unit, a third measurement was required for confirmation.

Table 5-1: On-road High Emitter Cutpoints

	GVWR <= 6,000 lbs			GVWR 6,001-10,000 lbs			GVWR 10,001+ lbs		
Year	HC (ppm)	CO (%)	NOx (ppm)	HC (ppm)	CO (%)	NOx (ppm)	HC (ppm)	CO (%)	NOx (ppm)
1977	700	7	2,718	700	7	2,557	700	7	5,000
1978	645	7	2,718	700	7	2,557	700	7	5,000
1979	600	6	2,718	700	7	2,045	700	7	5,000
1980	330	2.6	2,718	525	7	2,045	700	7	5,000
1981	330	1.8	2,718	375	4.5	2,045	700	7	5,000
1982	330	1.8	2,718	330	3.8	2,045	700	7	5,000
1983	330	1.8	2,718	330	2.3	2,045	700	5.3	5,000
1984	264	1.8	2,252	311	1.8	1,969	660	4.5	4,500
1985	264	1.8	2,252	292	1.8	1,969	660	4.5	4,500
1986	264	1.8	2,252	292	1.8	1,969	420	3.8	4,500
1987	264	1.8	2,252	187	1.8	1,969	330	1.8	4,500
1988	264	1.8	1,243	180	1.8	1,917	330	1.8	4,500
1989	264	1.8	1,243	180	1.8	1,917	330	1.8	4,500
1990	264	1.8	1,243	180	1.8	1,917	330	1.8	4,500
1991	208	1.8	1,087	168	1.8	1,457	330	1.8	4,000
1992	208	1.8	1,087	168	1.8	1,457	330	1.8	4,000
1993	208	1.8	1,087	168	1.8	1,457	330	1.8	4,000
1994	208	1.8	1,087	168	1.8	1,457	330	1.8	4,000
1995	208	1.8	1,087	168	1.8	1,457	330	1.8	4,000
1996+	100	1.0	893	168	1.0	1,457	330	1.8	3,600

Some 3,690 vehicles had two or more valid remote sensing measurements on different days within the normal VSP operating range of 3 to 22 kW/t. Sixty-nine (1.9%) of these exceeded the cutpoints on both of their last two measurements for the same pollutant having average emissions of 310 ppm HC, 0.77% CO, and 1,353 ppm NO_X.

Twenty-five percent of high emitters were 1995 and older models and 45% were 1996-1999 models.

In the 2011 survey, 19% of high emitters identified were registered outside the I/M counties. Additional registration information is required from BMV in order to identify similar vehicles measured in the 2013 survey.

Vehicles with out-of-state registrations were not considered in the high emitter analysis because their type and model year was unknown. Correct high emitter cutpoints cannot be selected without this information.

As summarized in Table 5-2, under the Maryland rules, 26 of the 69 suspected high emitters required additional confirmation by a third measurement. Those not requiring a third measurement are listed in Table 5-3. Those requiring a third measurement are listed in Table 5-4.

Table 5-2: High Emitter Summary

Pollutant Exceeded	High Emitter	Suspected	Total
HC only	3	9	12
CO only	2	2	4
NO only	25	15	40
HC & CO	5	0	5
HC & NOx	8	0	8
CO & NOx	0	0	0
All	0	0	0
Total	43	26	69

Third measurements were available on 14 of the high emitters and these are listed in Table 5-5.

The 1.9% high emitters and suspected high emitters accounted for 33%, 16% and 23% of HC, CO and NOx respectively emitted by the 3,690 vehicles with two or more measurements. Eliminating this small percentage of vehicles from the entire fleet would yield benefits roughly equivalent in size to the emission reductions of the I/M program (as modeled by the USEPA mobile source emissions model MOVES).

Table 5-3: High Emitters

				GVW		Registration	Date		HC Values			CO Values			NOx Values		
Year	Type	Make	Model	Code	Fuel	County	Last	Prev	Std	Last	Prev	Std	Last	Prev	Std	Last	Prev
High Emitters (Last two measurements both exceed the emissions standards for at least one pollutant by more than the RSD tolerance).																	
1988	P	VOLVO	740 GLE	0	G	LAKE	24-May-13	14-May-13	264	53	65	1.8	0.0	(0.0)	1,243	3,399	2,212
1991	P	MAZDA	323/SE	0	G	LAKE	20-May-13	13-May-13	208	410	822	1.8	0.1	0.2	1,087	233	788
1992	T	DODGE	DAKOTA	1	G	LAKE	16-May-13	15-May-13	208	95	91	1.8	0.1	0.1	1,087	2,451	2,453
1992	T	GMC	VANDURA G3500	2	G	PORTER	26-Apr-13	25-Apr-13	168	2,765	2,917	1.8	3.1	2.9	1,457	1,130	1,669
1994	T	CHEVROLET	ASTRO	1	G	LAKE	15-May-13	10-May-13	208	1,057	1,604	1.8	0.1	0.7	1,087	1,009	82
1994	T	CHEVROLET	S10	1	G	PORTER	26-Apr-13	25-Apr-13	208	155	136	1.8	0.5	0.5	1,087	1,393	1,425
1994	T	DODGE	DAKOTA	1	G	LAKE	22-Apr-13	01-Apr-13	208	232	188	1.8	0.7	0.8	1,087	2,058	1,905
1994	P	CADILLAC	DEVILLE CONCOURS	0	G	LAKE	16-May-13	10-May-13	208	(20)	(42)	1.8	0.0	0.0	1,087	2,177	2,454
1995	T	DODGE	DAKOTA	1	G	LAKE	24-May-13	14-May-13	208	292	226	1.8	1.3	0.5	1,087	1,926	1,931
1995	T	DODGE	DAKOTA	1	G	LAKE	26-Apr-13	24-Apr-13	208	215	74	1.8	1.7	0.2	1,087	1,640	2,418
1995	T	NISSAN	PATHFINDER	1	G	LAKE	16-May-13	10-May-13	208	110	16	1.8	0.1	(0.0)	1,087	1,390	3,886
1995	P	PONTIAC	GRAND PRIX SE	0	G	PORTER	05-Apr-13	04-Apr-13	208	48	7	1.8	0.3	0.1	1,087	1,735	1,436
1995	P	PONTIAC	GRAND AM SE	0	G	LAKE	15-May-13	10-May-13	208	58	(12)	1.8	0.0	0.1	1,087	1,850	2,026
1996	T	PLYMOUTH	VOYAGER	1	G	PORTER	01-May-13	26-Apr-13	100	274	300	1.0	0.4	0.5	893	1,305	1,258
1996	P	MERCURY	GRAND MARQUIS LS	0	G	LAKE	20-May-13	06-May-13	100	151	274	1.0	0.7	0.8	893	1,341	1,404
1997	T	CHEVROLET	ASTRO	1	G	PORTER	03-May-13	02-May-13	100	44	50	1.0	0.4	0.5	893	1,391	1,252
1997	T	GMC	JIMMY -JMY	1	G	LAKE	20-May-13	06-May-13	100	66	28	1.0	0.1	(0.0)	893	1,505	2,004
1997	T	JEEP	Z78	1	G	PORTER	04-Apr-13	03-Apr-13	100	129	51	1.0	0.4	0.2	893	1,743	1,199
1997	T	JEEP	Z78	1	G	PORTER	04-Apr-13	03-Apr-13	100	129	51	1.0	0.4	0.2	893	1,743	1,199
1997	T	FORD	EXPEDITION	2	G	LAKE	16-May-13	15-May-13	168	2,603	3,080	1.0	0.4	0.2	1,457	1,934	2,102
1998	T	CHEVROLET	S10	1	G	LAKE	24-Apr-13	15-Apr-13	100	(37)	44	1.0	0.4	0.5	893	1,961	1,632
1998	T	DODGE	DAKOTA	1	G	PORTER	26-Apr-13	25-Apr-13	100	27	32	1.0	0.3	0.4	893	1,183	1,407
1998	P	VOLKSWAGEN	JETTA GLS -JGS	0	G	PORTER	26-Apr-13	25-Apr-13	100	180	305	1.0	1.5	3.3	893	38	7
1999	T	CHEVROLET	S10	1	G	LAKE	27-Jun-13	26-Jun-13	100	2,493	3,270	1.0	1.4	1.0	893	1,891	1,182
1999	T	DODGE	RAM VAN B2500	2	G	LAKE	01-May-13	05-Apr-13	168	99	132	1.0	0.6	0.9	1,457	2,773	2,361
1999	P	DODGE	STRATUS	0	G	LAKE	16-May-13	15-May-13	100	51	127	1.0	0.5	0.6	893	2,677	2,269
1999	P	OLDSMOBILE	CUTLASS GL	0	G	LAKE	20-May-13	06-May-13	100	179	217	1.0	0.3	0.6	893	2,669	2,369
1999	P	SATURN	SC1	0	G	LAKE	19-Apr-13	04-Apr-13	100	3	648	1.0	0.3	0.4	893	1,211	1,773
2000	P	BUICK	LESABRE LIMITED-LLF	0	G	LAKE	16-May-13	08-May-13	100	2,314	957	1.0	0.0	0.1	893	114	134
2000	P	BUICK	LESABRE LIMITED-LLF	0	G	LAKE	24-May-13	12-May-13	100	64	72	1.0	2.3	3.0	893	(1)	36
2000	P	CHEVROLET	CAVALIER	0	G	LAKE	24-Apr-13	22-Apr-13	100	10	-	1.0	0.1	0.1	893	1,250	1,523
2000	P	HYUNDAI	SONATA GLS - SGL	0	G	LAKE	15-May-13	10-May-13	100	10	-	1.0	0.0	0.0	893	1,412	1,815
2000	P	PONTIAC	GRAND AM SE1	0	G	LAKE	16-May-13	10-May-13	100	123	107	1.0	0.8	1.1	893	2,322	1,494
2001	T	DODGE	RAM 2500 QUAD	2	D	LAKE	06-May-13	01-Apr-13	168	78	25	1.0	0.1	0.1	1,457	1,924	1,810
2001	P	FORD	FOCUS SE/SE COMFORT	0	G	LAKE	06-Jun-13	03-Apr-13	100	125	456	1.0	7.3	11.8	893	269	25
2002	T	KIA	SEDONA	1	G	LAKE	15-May-13	01-Apr-13	100	46	66	1.0	0.4	0.2	893	1,576	2,227
2002	P	CADILLAC	DEVILLE -DFW	0	G	LAKE	15-May-13	11-May-13	100	279	305	1.0	1.1	1.2	893	1,166	795
2002	P	SATURN	SL1	0	G	LAKE	22-Apr-13	15-Apr-13	100	33	36	1.0	0.1	0.0	893	1,589	1,548
2003	T	DODGE	CARAVAN/GRAND	1	G	LAKE	16-May-13	10-May-13	100	91	161	1.0	1.4	5.5	893	188	46
2003	P	HYUNDAI	TIBURON GT	0	G	LAKE	19-Apr-13	04-Apr-13	100	134	158	1.0	0.4	0.8	893	2,294	2,384
2004	T	DODGE	RAM 1500 ST/SLT	2	G	PORTER	02-May-13	05-Apr-13	168	161	88	1.0	0.8	0.7	1,457	3,141	2,319
2005	T	DODGE	RAM 1500 ST	2	G	LAKE	01-May-13	25-Apr-13	168	1,853	1,078	1.0	1.4	1.2	1,457	1,346	1,256
2007	T	JEEP	LIBERTY LIMITED	1	G	LAKE	16-May-13	15-May-13	100	17	9	1.0	(0.1)	0.0	893	2,713	1,560

Table 5-4: High Emitters Requiring a Third Measurement

						Registration	Date		HC Values			CO Values			NOx Values		
Year		Make	Body Style			County	Last	Prev	Std	Last	Prev	Std	Last	Prev	Std	Last	Prev
A third reading is needed to verify high emitter status (The last two measurements exceed standard by less than the RSD tolerance).																	
1994	T	GMC	SONOMA	1	G	PORTER	30-May-13	04-Apr-13	208	112	84	1.8	0.1	0.1	1,087	1,671	1,274
1995	T	DODGE	DAKOTA	1	G	LAKE	11-May-13	10-May-13	208	83	73	1.8	2.1	0.0	1,087	1,106	2,051
1996	P	CADILLAC	DEVILLE -DFW	0	G	LAKE	06-May-13	01-Apr-13	100	103	140	1.0	0.2	0.1	893	1,186	397
1996	P	CHEVROLET	CAVALIER	0	G	LAKE	16-May-13	10-May-13	100	76	29	1.0	0.3	0.4	893	1,368	987
1997	P	CHRYSLER	SEBRING JX	0	G	LAKE	22-Apr-13	15-Apr-13	100	145	117	1.0	0.3	0.5	893	11	62
1997	P	FORD	TAURUS GL	0	G	PORTER	16-May-13	15-May-13	100	33	35	1.0	0.4	0.2	893	1,065	962
1997	P	NISSAN	MAXIMA GLE/GXE/SE	0	G	LAKE	30-May-13	01-Apr-13	100	166	68	1.0	1.0	0.6	893	1,055	958
1997	P	TOYOTA	CAMRY CE/LE/XLE	0	G	PORTER	09-Apr-13	04-Apr-13	100	36	73	1.0	0.2	0.5	893	941	945
1998	P	HONDA	CIVIC	0	G	PORTER	26-Apr-13	05-Apr-13	100	141	126	1.0	3.2	0.5	893	250	1,913
1998	P	OLDSMOBILE	REGENCY	0	G	LAKE	06-May-13	02-May-13	100	154	118	1.0	5.0	0.4	893	92	92
1999	T	PONTIAC	MONTANA/TRANS SPORT	1	G	LAKE	10-May-13	06-May-13	100	42	49	1.0	0.2	0.3	893	1,121	1,466
1999	T	CHEVROLET	C1500 SILVERADO	2	G	LAKE	24-May-13	20-May-13	168	279	2,376	1.0	0.3	0.4	1,457	677	577
1999	T	DODGE	RAM 1500	2	G	PORTER	05-Apr-13	04-Apr-13	168	114	59	1.0	0.5	0.3	1,457	1,857	1,588
1999	P	CHRYSLER	SEBRING LXI	0	G	LAKE	24-May-13	12-May-13	100	143	229	1.0	0.3	0.1	893	66	1,775
2000	T	CHEVROLET	ASTRO VAN	1	G	LAKE	16-May-13	10-May-13	100	26	51	1.0	(0.0)	(0.0)	893	1,063	1,352
2000	T	JEEP	CHEROKEE	1	G	PORTER	20-May-13	06-May-13	100	35	38	1.0	0.3	0.5	893	968	1,413
2000	T	CHEVROLET	TAHOE	2	G	LAKE	13-May-13	02-May-13	168	43	35	1.0	0.1	0.2	1,457	2,705	1,493
2000	P	HONDA	ACCORD EX - UEX	0	G	PORTER	02-May-13	04-Apr-13	100	(5)	(4)	1.0	0.2	0.1	893	997	1,051
2000	P	PLYMOUTH	NEON/LX	0	G	PORTER	02-May-13	01-May-13	100	72	73	1.0	0.4	0.4	893	1,603	994
2002	P	MITSUBISHI	LANCER ES	0	G	LAKE	02-May-13	25-Apr-13	100	(18)	(10)	1.0	0.1	0.1	893	947	1,399
2002	P	OLDSMOBILE	AURORA	0	G	LAKE	20-May-13	13-May-13	100	341	119	1.0	0.4	0.5	893	772	1,106
2003	T	DODGE	DURANGO	2	G	LAKE	30-May-13	19-Apr-13	168	28	56	1.0	1.0	1.0	1,457	463	601
2003	T	FORD	ECONOLINE CUTAWAY	2	D	LAKE	13-May-13	11-May-13	168	101	10	1.0	0.1	(0.0)	1,457	1,632	1,617
2003	P	LINCOLN	LS	0	G	LAKE	24-May-13	14-May-13	100	283	106	1.0	2.9	0.7	893	1,751	233
2004	P	CADILLAC	CTS	0	G	LAKE	16-May-13	10-May-13	100	107	110	1.0	0.9	1.8	893	644	356
2005	P	SUBARU	IMPREZA WX/VDT	0	G	LAKE	20-May-13	06-May-13	100	133	31	1.0	1.1	1.2	893	254	182

Table 5-5: High Emitters and Suspected High Emitters with a Third Measurement

Year	Make	Body Style	Registration County	Date			HC Values				CO Values				NOx Values			
				Last	Prev	2nd Prev	Std	Last	Prev	2nd Prev	Std	Last	Prev	2nd Prev	Std	Last	Prev	2nd Prev
1988	VOLVO	740 GLE	LAKE	24-May-13	14-May-13	01-Apr-13	264	53	65	59	1.80	0.0	0.0	0.0	1243	3,399	2,212	3,756
1991	MAZDA	323/SE	LAKE	20-May-13	13-May-13	06-May-13	208	410	822	376	1.80	0.1	0.2	0.2	1087	233	788	268
1995	DODGE	DAKOTA	LAKE	26-Apr-13	24-Apr-13	01-Apr-13	208	215	74	87	1.80	1.7	0.2	0.6	1087	1,640	2,418	2,456
1995	DODGE	DAKOTA	LAKE	24-May-13	14-May-13	12-May-13	208	292	226	266	1.80	1.3	0.5	0.7	1087	1,926	1,931	2,317
2000	PLYMOUTH	NEON/LX	PORTER	02-May-13	01-May-13	09-Apr-13	100	72	73	46	1.00	0.4	0.4	0.4	893	1,603	994	933
2003	LINCOLN	LS	LAKE	24-May-13	14-May-13	11-May-13	100	283	106	215	1.00	2.9	0.7	5.4	893	1,751	233	259
2004	DODGE	RAM 1500 ST/SLT	PORTER	02-May-13	05-Apr-13	04-Apr-13	168	161	88	168	1.00	0.8	0.7	0.7	1457	3,141	2,319	2,525
1999	CHEVROLET	C1500 SILVERADO	LAKE	24-May-13	20-May-13	14-May-13	168	279	2376	156	1.00	0.3	0.4	0.4	1457	677	577	612
1997	GMC	JIMMY -JMY	LAKE	20-May-13	06-May-13	03-May-13	100	66	28	13	1.00	0.1	0.0	0.0	893	1,505	2,004	648
2000	JEEP	CHEROKEE	PORTER	20-May-13	06-May-13	02-May-13	100	35	38	19	1.00	0.3	0.5	0.4	893	968	1,413	636
1999	CHRYSLER	SEBRING LXI	LAKE	24-May-13	12-May-13	01-Apr-13	100	143	229	67	1.00	0.3	0.1	0.2	893	66	1,775	179
1997	FORD	TAURUS GL	PORTER	16-May-13	15-May-13	10-May-13	100	33	35	-40	1.00	0.4	0.2	0.1	893	1,065	962	383
1999	OLDSMOBILE	CUTLASS GL	LAKE	20-May-13	06-May-13	02-May-13	100	179	217	22	1.00	0.3	0.6	0.1	893	2,669	2,369	141
2003	DODGE	DURANGO	LAKE	30-May-13	19-Apr-13	04-Apr-13	168	28	56	16	1.00	1.0	1.0	0.1	1457	463	601	361

6 Clean Vehicles

The emissions distributions in Section 3 showed that the vast majority of vehicles are clean. For vehicles measured in 2013, Figures 6-1 and 6-2 show decile emissions of HC and NO_X within model year. In the charts, the 1995 and older models were compressed into two groups because few vehicles were measured for each individual model year of these older models. The charts further illustrate that most of the newer model vehicles have very low emissions. Since, 1996 and newer OBD-II equipped vehicles inform their owners if faults are detected in emission control system components, owners of these models are generally aware of whether their vehicle needs service. Exceptions are faults such as fuel leaks that are not detected by OBD-II but register as high RSD HC emissions on-road.

The on-road measurements, in addition to identifying high-emitters, provides a way of reducing the I/M burden for owners that keep their vehicles well maintained and are responsive to the OBD-II check engine warnings. A Clean Screen program uses RSD measurements to exempt these vehicle owners from a station inspection and allows the funds that would otherwise be spent on station visits to be directed toward the on-road measurements, thereby allowing comprehensive on-road monitoring, and toward support of other emission reduction activities such as repair and scrap programs. The wealth of on-road measurements can be used to focus on the residual high exhaust, high evaporative emitters and smoking vehicles through notifications and repair/scrap assistance programs. The net result is more convenience for owners of clean vehicles and a stronger focus on the small percentage of high emitting or smoking vehicles.

In 2011, surveyed recipients of a clean screen exemption notice together with an information sheet highlighting the importance of responding to the check engine light reported being less likely to ignore the check engine light (60%) and more likely to take the vehicle for service immediately (52%) or at the first opportunity (41%)[9]. A clean screen program provides an opportunity to educate vehicle owners when their attention is focused.

Envirotest has demonstrated modeling of a clean screen program using MOVES[10]. A combination of clean screening and high emitter identification programs linked to mandatory or incentivized scrap and programs can provide net positive emissions benefits.

Colorado has been running a successful clean screen program in the Denver Metro Area (DMA) since 2003. Current Clean Screen criteria require vehicles to have two RSD measurements with emissions below 200 ppm HC, 0.5% CO, and 1000 ppm NO_X. Vehicles may also pass with a single measurement if the historical fail rate for the model is low.

Ohio started low level clean screening in October 2012. The program uses RSD cutpoints based on ASM standards and a cap on the historical fail rate of vehicles in the same family.

In April 2012, Virginia passed legislation to phase in clean screening starting with 10% of testable vehicles in 2012/2013, 20% in 2013/2014, and up to 30% after July 2014[11]. Virginia intends to scale up its existing RSD high emitter program using the on-road data collected for clean screening and an RFP for the remote sensing program is expected in Q4 2013.

Figure 6-1: Decile HC Emissions

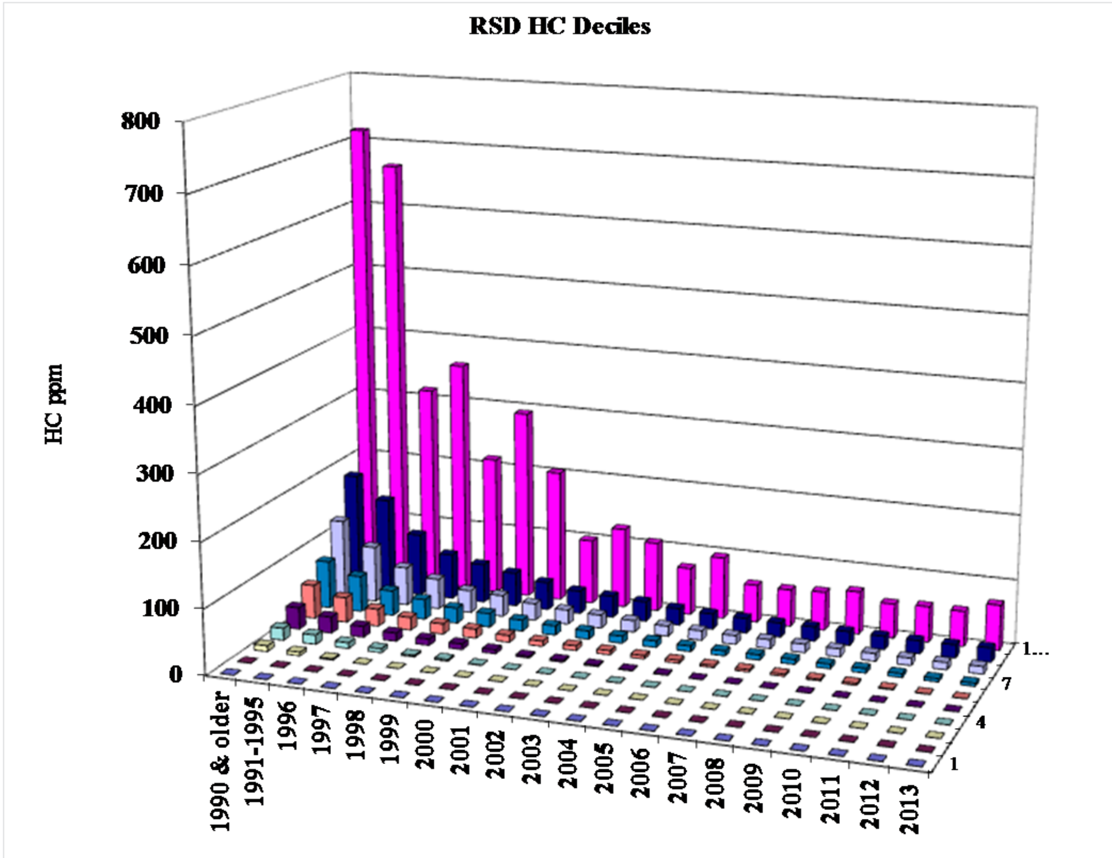
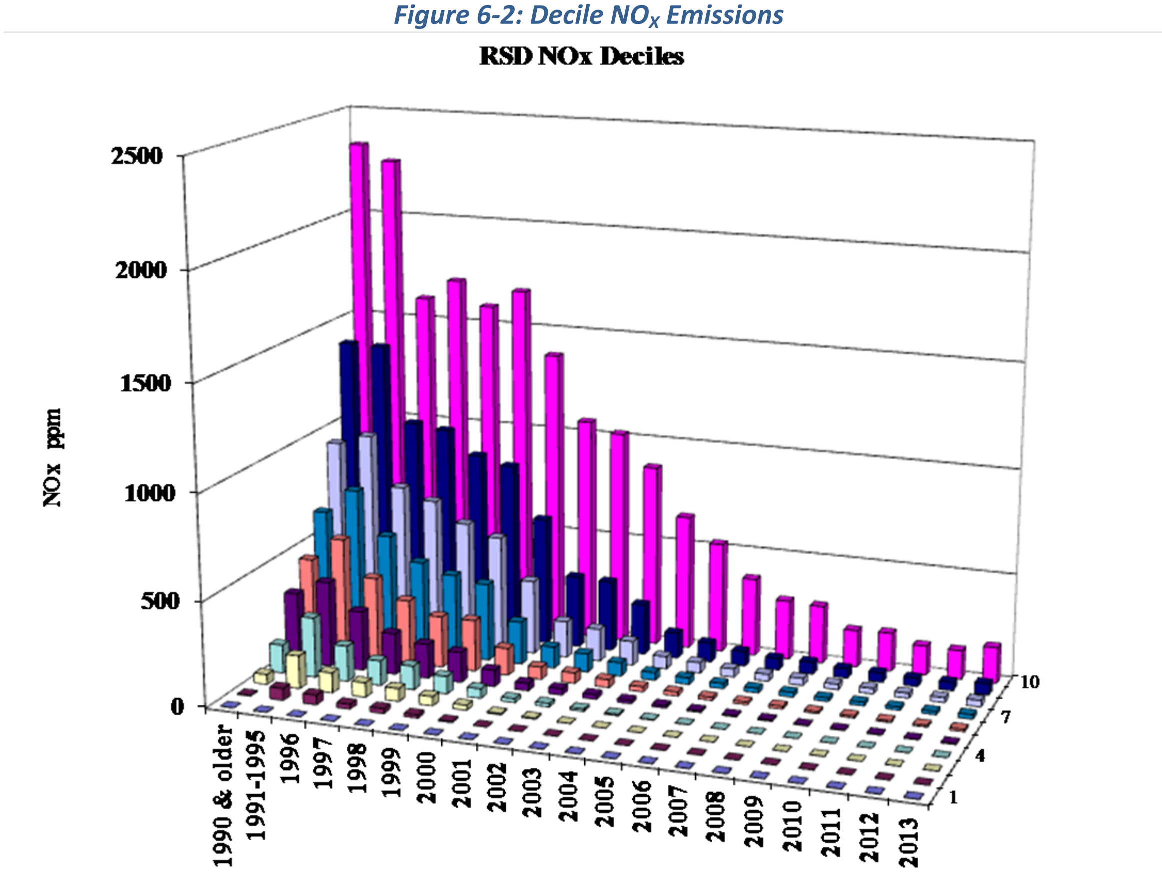


Figure 6-2: Decile NO_X Emissions



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