Environmental Systems Products Inc.
2002 North Forbes Blvd.
Tucson, AZ 84745

Enhanced Remote Sensing Performance Based Pilot Program

Prepared for:

North Central Texas Council of Governments

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Prepared by:

Peter M McClintock, Ph.D.
Applied Analysis
891 Tiburon Blvd.
Tiburon CA 94920
(415) 435-8301

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The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the views or policies of the Texas Department of Transportation, the U.S. Department of Transportation, the Texas Department of Public Safety, the Texas Commission on Environmental Quality; and Collin, Dallas, Denton, Ellis, Kaufman, Johnson, Parker, Rockwall, and Tarrant Counties.

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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
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
Enhanced I/M	A set of more rigorous vehicle I/M Program inspection requirements defined by the U.S. EPA usually involving IM240 testing
EPA	United States Environmental Protection Agency
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
GIT	Georgia Institute of Technology
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
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

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_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
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
Tag Edit	The transcription of vehicle license plates or tags from images to text
TSI	Two-Speed Idle test
VIN	Vehicle Identification Number
VDR	Vehicle On-road Record
VMT	Vehicle Miles Traveled
VSP	Vehicle Specific Power; estimated engine power divided by the mass of the vehicle
VTR	Vehicle Test Record

1 SUMMARY

In January 2010, the North Central Texas Council of Governments (NCTCOG) contracted with ESP to implement a six-month Enhanced Remote Sensing Performance Based Pilot Program to measure on-road vehicle emissions in the nine county nonattainment region comprising Collin, Dallas, Denton, Ellis, Johnson, Kaufman, Parker, Rockwall, and Tarrant counties.

Currently, the nine county nonattainment region is classified as serious nonattainment for the pollutant ozone. Ozone is formed when Nitrogen Oxide (NOx) mixes with Volatile Organic Compounds in the presence of sunlight. According to TCEQ, studies suggest on-road mobile emissions contribute 47% of the total NOx emissions in the region. EPA has stated it intends to lower the current standard for ozone, 85 ppb, to between 60 -70 ppb. The new standard will require the region to pursue every possible avenue for decreasing the amount of NOx emissions, including reductions in mobile NOx emissions.

The Texas Department of Public Safety (DPS), in coordination with the Texas Commission of Environmental Quality (TCEQ), operates a decentralized enhanced I/M Program in the nine counties. The emissions inspection is part of a combined safety and emissions inspection program and is visually enforced via vehicle certificates. Gasoline fueled vehicles 2 to 24 years old are required to pass an annual emissions test or receive a waiver. New vehicles are granted a two year emissions inspection exemption. Vehicles model year 1996 and newer receive an On-Board Diagnostic (OBD) inspection. Vehicle models 1986 to 1995 up to 8,500 lbs. GVWR are required to obtain a two-mode Acceleration Simulation Mode (ASM-2) test if they are able to be tested on a single axle dynamometer. Other vehicles obtain a Two-Speed Idle (TSI) test. All diesel powered vehicles and motorcycles are exempt from emissions testing, but are still required to have the annual safety inspection.

The goal of the pilot was to detect on-road smoking and/or high-emitting gas and light-duty diesel vehicles.

Pilot Program Objectives

- Collect 250,000 valid measurements of on-road vehicles in the nonattainment region;
- Identify high-emitting and/or smoking gasoline and diesel vehicles in the region;
- Identify vehicles operating in the region not in compliance with the I/M Program;
- Identify vehicles operating within the region and registered in attainment counties or out-of-state.

Pilot Program Results

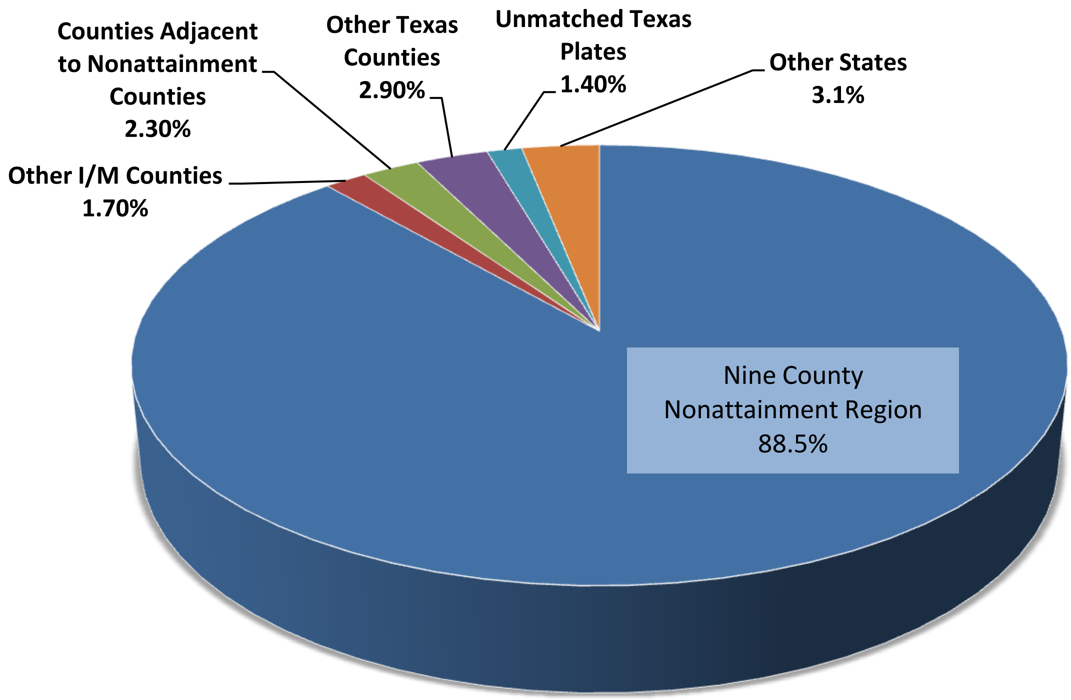
RSD units were deployed on 101 days from May 3rd through November 3rd 2010 to measure vehicle emissions at 37 on-road sites within the nine counties. Each site was used for two to five days. Of approximately 470,000 passing vehicles, 287,847 (61%) valid emissions measurements and speed and acceleration measurements were obtained.

Plate images were reviewed and in 8.5% of cases the plate image was not fully readable. After additional screening for positive power and emissions outliers, a net 248,850 on-road emissions measurements were used to identify high-emitters operating in the nine counties.

In aggregate, 4,719 vehicles were identified as high-emitters using criteria approved by NCTCOG. Light-duty diesel vehicles accounted for 3% of vehicles measured and 1.6% of high-emitters (74 vehicles). Within each fuel class, the rates of gasoline and diesel high-emitters were 2.7% and 1.5% respectively.

The chart below shows the registered jurisdiction of the vehicles measured in the nonattainment region. Of the 248,850 vehicles measured, 88.5% were registered in the nonattainment region, 8.4% were registered elsewhere in Texas and 3.1% were from other states.

Figure 1-1: Registration Jurisdictions of Vehicles Measured in the Nonattainment Region



Findings and Conclusions

Following are the key findings and conclusions drawn from the Pilot Program:

On-Road Vehicles and Emissions:

- Average emission rates of all vehicles measured on-road in the nine counties, regardless of where they were registered, were 28 ppm HC, 0.17 % CO and 205 ppm NO.
- Vehicles positively identified as being registered in the nine counties had lower average emissions of 23 ppm HC, 0.16% CO and 184 ppm NO – 27% lower HC, 5% lower CO and 10% lower NO.

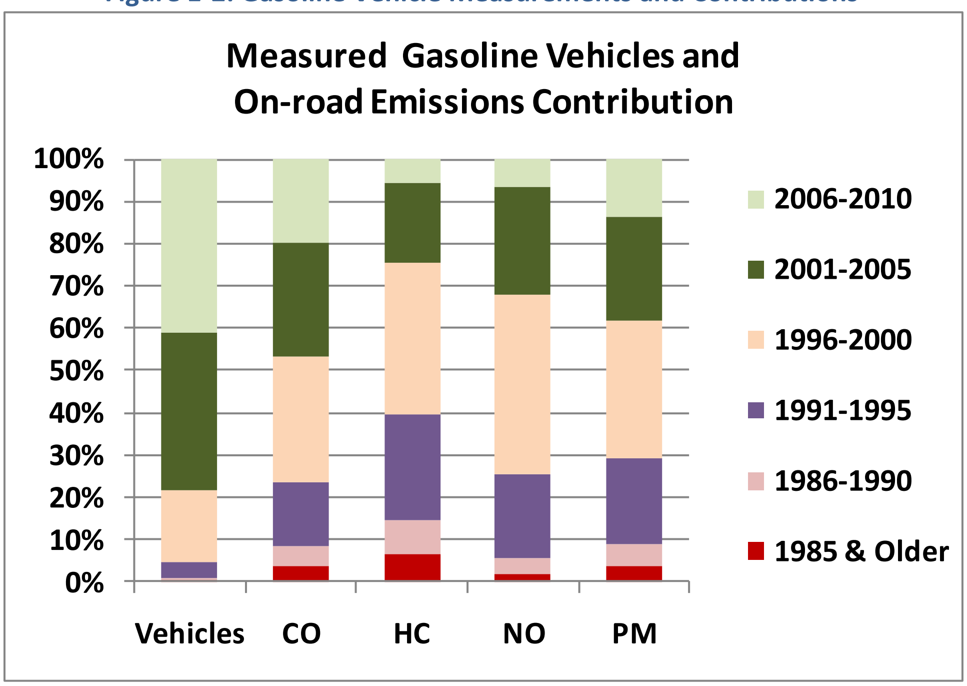
- Gasoline vehicles were 97% of observations. Because of their large numbers, aggregate emissions from gasoline vehicles were much greater than diesel vehicle emissions. As shown in Table 1-1, however, diesel vehicles had on average over four times higher NO and ten times higher smoke. These results do not include heavy-duty diesel vehicles with vertical exhausts that were not measured.

Table 1-1: Average On-road Emissions of Light Vehicles Registered in the Nine-County Nonattainment Region

Fuel	% of Measured Vehicles	CO %	HC ppm	NO ppm	Smoke Factor	Approx Age (Date observed - Model Year)
Gasoline	97.2%	0.170	23	170	0.012	6.9
Diesel	2.8%	0.059	43	740	0.109	6.0

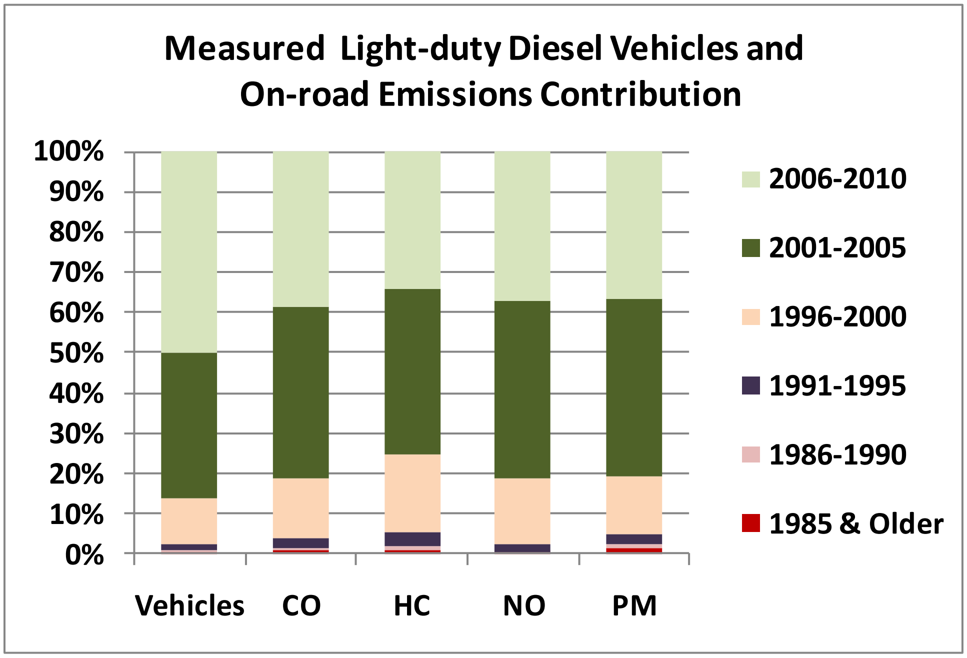
- Figure 1-2 shows the fractions of on-road gasoline vehicles and their contribution to emissions by age. 1986-1995 gasoline models were 4.6% of observations and contributed 33% of HC and 24% of NO. 2006-2010 models were 41% of vehicles but contributed only 6% of HC and 7% of NO.

Figure 1-2: Gasoline Vehicle Measurements and Contributions



- Figure 1-3 shows the fractions of on-road light-duty diesel vehicles and their contribution to emissions by age. Light-diesel vehicles measured were predominantly 2001 and newer models (86.1%) contributing 81.2% of light-duty diesel NO and 80.7% of light-duty diesel PM. 2006-2010 models were 50% of the light-duty diesel vehicles measured and contributed 37% of NOx and PM.

Figure 1-3: Light-duty Diesel Vehicle Measurements and Contributions



High-Emitters:

- Gasoline vehicles had a highly skewed emissions distribution with a small percentage of high-emitters contributing a substantial portion of total light vehicle emissions.
- Average RSD emissions of selected high-emitters were up to 18 times higher than the average emissions of the fleet.
- Among 1986 to 2008 gasoline models, 2.7% of vehicles were flagged as probable high-emitters.
- Gasoline high-emitters were estimated to contribute 50% of gasoline vehicle HC emissions and 20% of gasoline vehicle NO emissions.
- NCTCOG used lower emissions cutpoints for identifying high-emitting gasoline vehicles than those currently used in the DPS Remote Sensing high-emitter program. The lower emissions cutpoints doubled the percentage of vehicles identified as high-emitters from 1.3% of gasoline vehicles to 2.7%. By pollutant, the percentages of vehicles identified as high-emitters increased from 0.6% to 1.3% for HC, from 0.5% to 0.7% for CO and from 0.2% to 1.0% for NOx. Some vehicles were high-emitters of more than one pollutant.
- Among 1986 to 2008 diesel models, 1.5% of vehicles were flagged as probable high-emitters, the majority of which were smoking vehicles.
- Diesel high-emitters were estimated to contribute 9% of diesel PM emissions.
- Only two diesel vehicles were flagged as NO high-emitters. However, as noted above, average NO emissions of diesels were over four times those of gasoline vehicles.

Compliance with the I/M Program:

Inspection records from January 2006 through December 2010 were examined to determine the last inspection for the vehicles measured on-road. All light vehicles model year 1987-2007 and registered in the nine counties were expected to have current records. A net 96.5% of vehicles registered in the region were identified as complying with the I/M Program. Inspection records were not found for 0.5% of vehicles and the last inspection record identified was over 13 months old for 2.8% of vehicles. A further 0.2% of vehicles failed their last inspection more than three months prior to being measured on-road. Additional follow-up on the 3.5% suspected of being in non-compliance is required to confirm their status.

10.7% of high-emitters did not have a current valid emission inspection.

Registration Compliance:
ESP reviewed registration expiration dates of vehicles measured on-road in the nonattainment counties. Over 95% of vehicles registered in the nonattainment region had expiration dates of June 2010 or newer. For vehicles registered to other jurisdictions and high-emitters the corresponding percentages were 90% and 92%. Additional information is provided in section 5.

Recommendations

- Since on-road mobile emissions contribute almost half of the NOx in the region, expanding the remote sensing high-emitter program to:
  - include lower cut points, as illustrated in Table 5.6, providing a significant contribution to meeting attainment goals;
  - send notice letters to all high-emitters identified by the remote sensing equipment (currently a vehicle registered I a nonattainment county has to be identified three times before TXDPS will send a letter; and
  - include additional remote sensing vans to provide consistent coverage in all nonattainment regions.
- A more comprehensive on-road emissions measurement program could be a valuable supplement to the current I/M Program by:
  - Identifying on-road evaporative emitters, some of which will not be identified by OBD;
  - Identifying high-emitters not captured by the I/M Program, or failing between tests;
  - Monitoring on-road vehicles for compliance;
  - Providing feedback on the effectiveness of the Program and repairs;
  - Examining the impact of OBD readiness exemptions and other I/M Program design decisions and options, e.g. the inclusion or exclusion of additional models.
- Consider dual testing (ASM and OBDII) for 1996 to 2000 vehicles given the spike in high-emitters for these models. California currently dual tests OBDII models and will continue to dual test 1996-1999 models after legislation[1] to allow OBDII only testing of 2000 and newer models becomes effective in 2013. 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.

- Review the 25-year age exemption, especially for light trucks that are more likely to be work vehicles than collector vehicles. Compared to new models, vehicles over 25 years old have extremely high emissions and are currently exempt from the I/M Program.
- Consider emissions testing for light-duty diesel vehicles. Light-duty diesel vehicles, although fewer in number, had particulate and NOx emissions that were four to ten times higher than gasoline vehicle emissions.

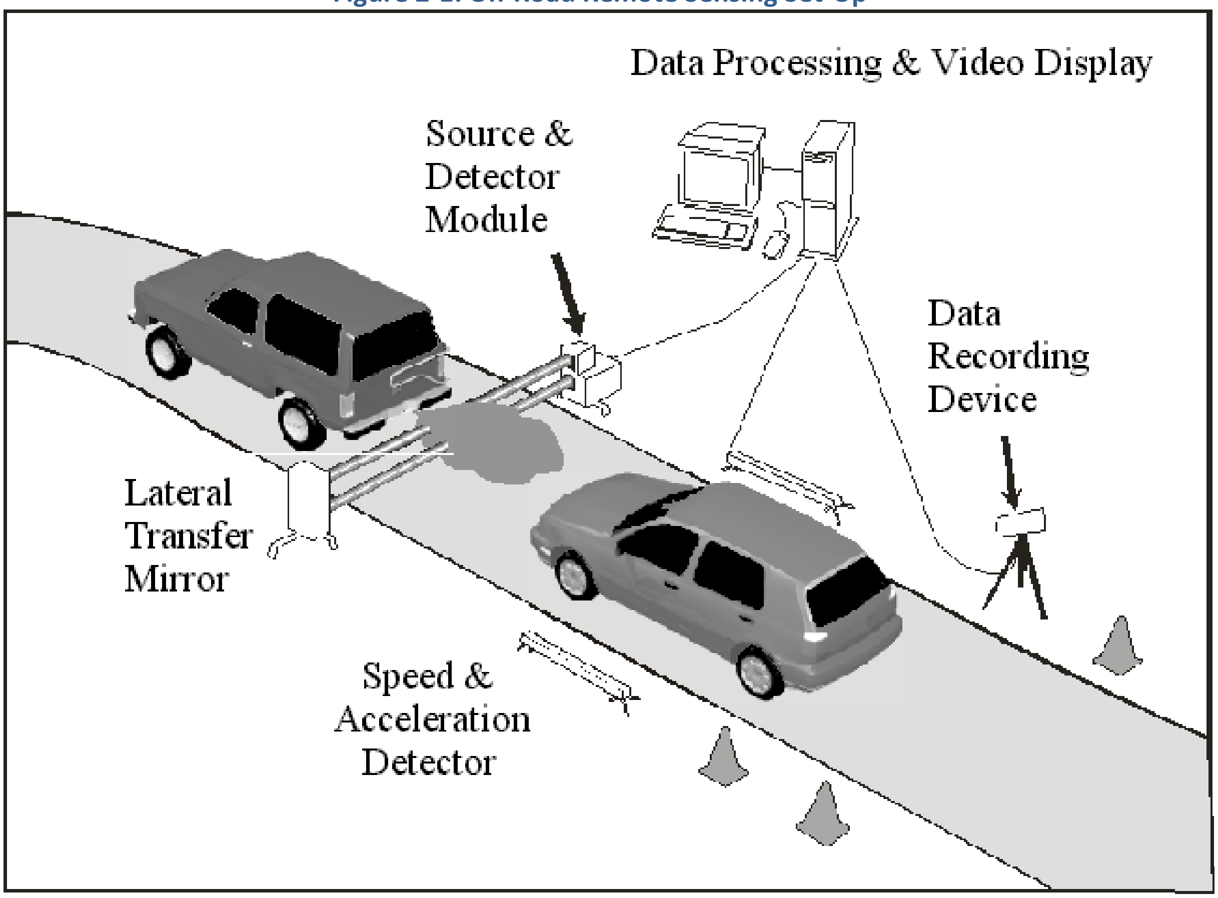
2 EQUIPMENT AND SITES

2.1 Equipment Description

The NCTCOG RSD program used the newest addition to ESP's line of products, the RSD4000. The RSD4000 is based on the same underlying technology as the predecessor RSD3000 but has completely re-engineered electronics to improve sensitivity. It is a more durable, easily operable, deployable and portable system that significantly improves operator and program effectiveness through greater capture rates of more accurate vehicle emissions readings.

The RSD4000 detects vehicle emissions when a car 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 RSD4000 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 RSD4000 includes the following features:

1) A longer beam range for safer, more versatile deployment
2) Simple and easy setup with laser alignment aids
3) Continuous automatic CO_2 for 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 less noise for increased productivity, yielding more valid records.
7) A Windows operating system for ease of operation and true multi-tasking
8) A fuel specific smoke measurement using a UV wavelength that senses the fine particles invisible to traditional visible light opacity meters
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. ESP 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. Negative values will be included and will not be rounded to zero.

The hydrocarbon reading (recorded in ppm propane) will be within ± 15% of the Certified Gas Sample, or an absolute value of ± 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 RSD4000 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 RSD4000 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.

2.2.6 Audits (drive-by audits)

Every month during the course of data collection, an Audit Truck was utilized to audit the RSD4000 systems.

The audit truck is outfitted with a gas cylinder rack that holds 4 compressed gas cylinders. Each gas cylinder is equipped with a high flow regulator, a high flow solenoid and a Tygon hose, which is adapted to a simulated tailpipe. Inside the truck cab, the audit truck operator has the ability to switch power from solenoid to solenoid to select the appropriate audit gas cylinder for drive-by audits. A traffic cone is placed 60-70 feet preceding the test site. This is used as a mark to begin the flow of gas to ensure there is an adequate plume of audit gas as the truck passes the RSD4000. The typical gas blends used in the audits are show below:

	HC (ppm)	**CO**	**CO_2**	**NO (ppm)**
Blend # 1	500	0.5%	14.70%	3000
Blend # 2	3000	1.00%	14.38%	2000
Blend #3	2000	2.75%	13.10%	500
Blend #4	6000	5.00%	11.55%	250

In addition to the equipment, the operator is also audited for following procedures: site setup, calibration, camera alignment, traffic safety and documentation.

2.3 Site Selection Criteria

An evaluation of sites to be used was performed during the work plan preparation. An experienced RSD operator evaluated and selected sites in the region. Site selection goals included developing a network of sites that would:

- Provide a representative sampling of the area fleet over the collection period.
- Provide a representative sampling of the out-of-area fleet observed in the region.
- Maximize valid records without compromising geographic coverage and data quality.
- Allow for multiple observations of vehicles when sites are repeated.
- Yield a measurement distribution roughly similar to the vehicle population.

The site visit strategy required data collection two to five times at each site. The strategy provides a good balance of general fleet coverage as well as a significant number of vehicles with multiple measurements[i].

[i] Data collection was planned for a site in Johnson County but rain prevented collection on the scheduled days. Over 2,800 Johnson County registered vehicles were measured at other sites.

2.3.1 Sites Used

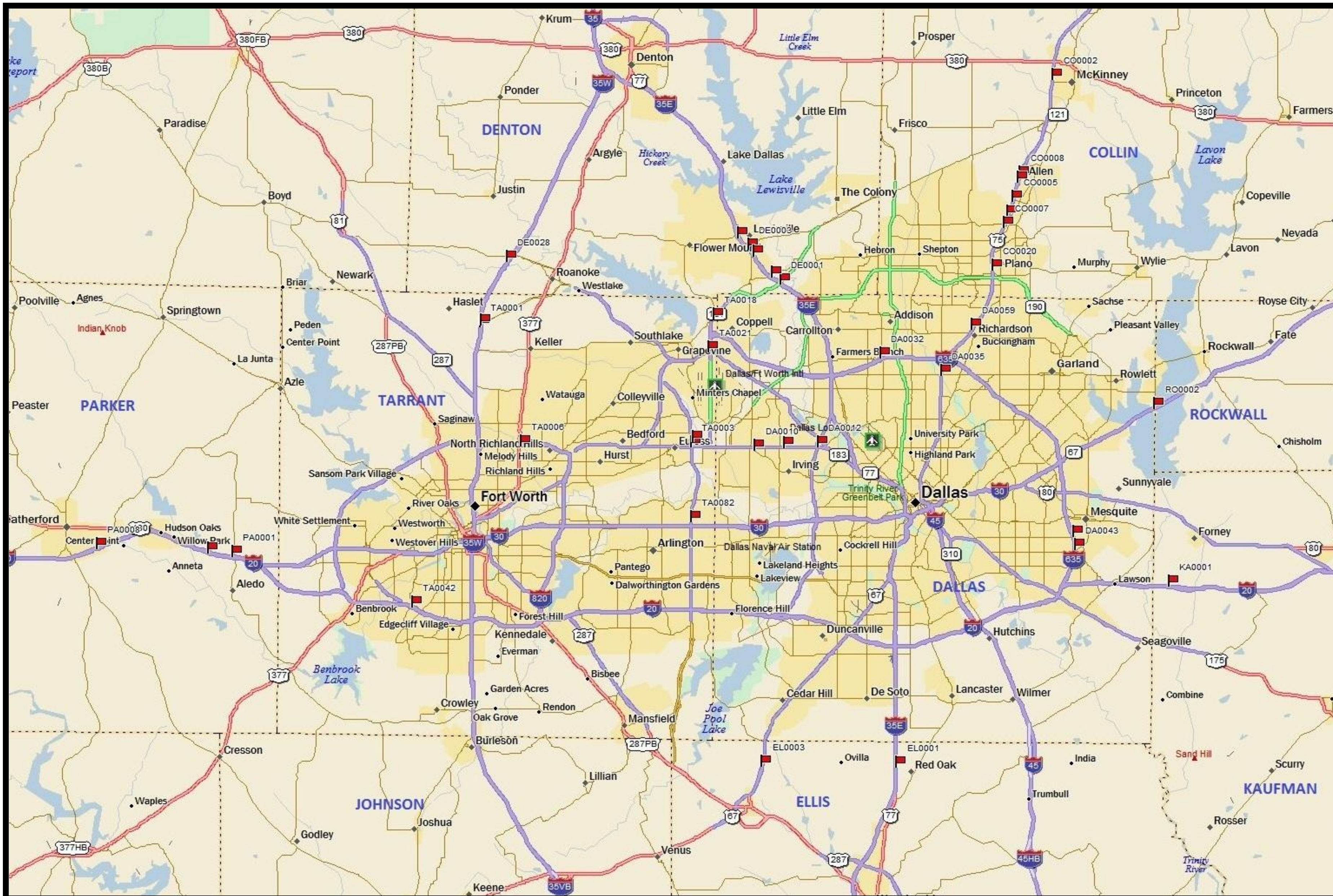
Table 2-1 shows the survey sites used and the number of days of on-road data collection.

Figures 2-2 displays the distribution of the sites.

Table 2-1: Sites Used

Site	Description	County	Slope	Days
CO0002	entrance ramp to NB US75/SH121 from Virginia Pkwy	Collin	1.25	2
CO0005	entrance ramp to SB US75 from Bethany Dr	Collin	0.30	4
CO0006	entrance ramp to SB US75 from Legacy Dr	Collin	0.90	4
CO0007	entrance ramp to SB US75 from W Spring Creek Pkwy	Collin	0.70	4
CO0008	ent ramp to NB US75 from FM2170 (McDermott Dr)	Collin	0.70	3
CO0020	entrance ramp to SB US75 from 15th St	Collin	0.68	4
CO0021	Ent Ramp McDermott Dr to US-75-S	Collin	0.40	2
DA0010	interchg ramp from WB SH356 to WB SH183 in DA Cnty	Dallas	2.50	2
DA0012	ent ramp LP12 to WB SH183 in DA cnty	Dallas	1.47	3
DA0032	entrance ramp to WB IH635 from Midway Rd	Dallas	3.28	4
DA0035	entrance ramp to SB US75 from Forest Ln	Dallas	0.95	4
DA0043	entrance ramp to NB IH635 from Lake June Rd	Dallas	1.50	2
DA0044	entrance ramp to NB IH635 from Burton Rd	Dallas	0.33	3
DA0059	entrance ramp to SB US75 from Arapahoe Rd	Dallas	0.25	2
DA0086	ramp - MacAuthor Blvd to SH-183-E	Dallas	0.65	2
DE0001	ent ramp SB IH35EE from SH121 (Vista Ridge Blvd)	Denton	0.28	4
DE0003	entrance ramp to NB Stemmons Frwy from SH121 Bus	Denton	2.05	4
DE0004	entarnce ramp to SB Stemmons Frwy from SH121 Bus	Denton	0.70	2
DE0019	entrance ramp to NB IH35E from SH121	Denton	0.53	3
DE0021	entrance ramp to NB IH35E from Main St	Denton	0.95	2
DE0028	int ramp SH-114 to I-35W-S	Denton	0.80	3
EL0001	entrance ramp to NB IH35E from Redoak Rd	Ellis	1.95	2
EL0003	exit ramp from SB SH67 to Dove Ln/Gifco Rd	Ellis	0.55	2
KA0001	entrance ramp to WB IH20 from SH740	Kaufman	0.40	2
PA0001	Entrance ramp to WB IH20 from FM1187	Parker	0.65	2
PA0003	Ent. Ramp Willow Park Ranch House Rd to IH 20 E.	Parker	0.55	2
PA0008	Ramp from FM 2552 to I 20 East	Parker	2.55	2
RO0002	entrance ramp to EB IH30 from Dalrock	Rockwall	0.10	2
TA0001	entrance ramp from SH170 to SB IH35W	Tarrant	1.30	2
TA0002	intchg ramp from NB IH35 WN to EB SH170 in TA cnty	Tarrant	0.70	2
TA0003	intchg ramp from SB SH360 to WB SH183	Tarrant	1.20	2
TA0006	entrance ramp from US377 to EB IH820	Tarrant	3.00	2
TA0012	intchg ramp from WB SH183 to NB SH360	Tarrant	1.20	2
TA0018	interchange ramp from NB SH26 to NB SH121	Tarrant	0.30	2
TA0021	interchange ramp from SB SH121 to EB SH114	Tarrant	0.50	2
TA0042	entrance ramp to EB IH20 from S Hulen St	Tarrant	0.78	5
TA0082	Ave H / Lamar blvd to SH-360-N	Tarrant	0.22	5
Total				101

Figure 2-2: Site Locations in the nine counties



2.4 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. ESP applied the following additional screening checks to the RSD measurements to ensure the data used for vehicle high-emitter evaluation were reasonable:

- 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.

2.4.1 Valid Exhaust Plumes

The RSD4000 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.

2.4.2 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 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 vehicle specific power (VSP), which was the topic of a presentation at the Ninth CRC On-road Vehicle Emissions Workshop[2.] The CRC E-23 Project[3,4] 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 MOVES emissions inventory model that replaces Mobile6[5].

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 ESP requires that vehicle emissions 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.

2.4.3 Screening of Hourly Observations

ESP 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, ESP tabulated for each site and hour the percentage of vehicles up to 5 years old that exceeded 150 ppm HC. The percent of vehicles up to 5 years old that exceed 150 ppm HC tend to be higher during periods of near freezing temperatures. With the exception of May 3rd, virtually all hours with measurements had less than 5% of new models with emission greater than 150ppm HC. Table 2-4 shows that temperatures were never close to freezing. Temperatures were high during some periods, which can lead to higher evaporative emissions. However, emissions measured during periods of high temperature reflect actual in-use emissions and may be symptoms of poor evaporative emissions control systems.

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

Day	Unit	Site	06:00 & earlier	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00 & later
3-May-10	__12074645	CO0002		1%	5%	0%	2%	4%	3%	6%					
4-May-10	__12074645	CO0002	0%	0%	2%	2%	0%	0%	1%	4%					
5-May-10	__12074645	CO0006	0%	0%	0%	1%	0%	0%	0%	0%					
6-May-10	__12074645	CO0006	0%	0%	0%	0%	0%	0%							
10-May-10	__12074645	CO0005		3%	0%	0%	0%	0%							
11-May-10	__12074645	CO0005	0%	0%	0%	0%	0%	0%	0%						
12-May-10	__12074645	CO0005	2%	0%	0%	0%	3%	0%	0%						
13-May-10	__12074645	CO0005	0%	1%	2%	0%	0%	0%	0%						
17-May-10	__12074645	CO0008	0%	1%	0%	0%	0%	0%	0%	0%					
18-May-10	__12074645	CO0008	0%	0%	0%			0%	0%	0%					
19-May-10	__12074645	CO0007	1%	0%	0%	0%	0%	1%	0%	0%					
20-May-10	__12074645	CO0007	0%	0%	1%	0%	0%		0%	0%					
24-May-10	__12074645	CO0021	0%	0%	0%	0%	0%	0%	0%	1%					
25-May-10	__12074645	CO0021				0%	0%	1%	2%	0%	0%	0%	0%		
26-May-10	__12074645	CO0020			0%	0%	0%	1%	0%	1%	0%	0%	0%		
27-May-10	__12074645	CO0020	0%	1%	0%	1%	0%	0%	0%	0%	0%				
1-Jun-10	__12074645	DA0012		3%	0%	0%	2%	0%	0%	0%	0%				
2-Jun-10	__12074645	DA0012				0%	0%	0%	0%	0%	0%	1%	2%	3%	
3-Jun-10	__12074645	DA0012	3%	0%	0%	0%	1%	2%	0%	0%					

Table 2-4: Average Hourly Temperature Fahrenheit

Day	Unit	Site	06:00 & earlier	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00 & later
3-May-10	__12074645	CO0002	55	57	65	73	79	84	87	89					
4-May-10	__12074645	CO0002	52	54	60	66	72	76	80	82					
5-May-10	__12074645	CO0006	66	75	85	93	96	98	97	97					
6-May-10	__12074645	CO0006	64	72	77	88	93	93							
10-May-10	__12074645	CO0005	66	68	70	75	80	82	86	85					
11-May-10	__12074645	CO0005	74	75	78	78	80	82	83	86					
12-May-10	__12074645	CO0005	74	77	82	88	90	90	88	90					
13-May-10	__12074645	CO0005	76	78	81	87	90	90	89	92					
17-May-10	__12074645	CO0008	70	72	74	79	83	88	91	93					
18-May-10	__12074645	CO0008	66	66	69	71	80	82	86	88					
19-May-10	__12074645	CO0007	72	73	75	79	88	89	88	90					
20-May-10	__12074645	CO0007	80	78	82	89	86		80	81					
24-May-10	__12074645	CO0021	74	77	78	84	89	93	95	94					
25-May-10	__12074645	CO0021				87	89	92	93	90	93	95	94		
26-May-10	__12074645	CO0020			83	88	97	100	102	100	99	99	101		
27-May-10	__12074645	CO0020	74	79	86	93	96	98	99	99	98				
1-Jun-10	__12074645	DA0012	80	91	98	103	106	105	106	105	106				
2-Jun-10	__12074645	DA0012			99	100	101	103	103	104	106	107	102	97	
3-Jun-10	__12074645	DA0012	74	81	85	91	94	94	91	88					

3 VEHICLE EMISSIONS DATA COLLECTED

3.1 Statistics and RSD Coverage

RSD units were deployed for 101 days and recorded 471,771 vehicles driving-by. In 41% of cases, either RSD system was not yet ready (1%), or a sufficiently good exhaust sample was not obtained (37%), or the speed and acceleration of the vehicle was not acquired (3%). This left a net 287,847 valid records.

Records with valid measurements were 'tag edited'. In 8.5% of cases a tag edit was attempted but the vehicle plate was not readable. Additional high-emitter application screening for positive vehicle specific power and removal of emissions outliers resulted in a net 53% of beam blocks and 248,850 measurements of vehicles with valid emissions measurements, recorded speed and acceleration and a visible, readable plate.

License tags were transcribed from the license plate images and Texas plates were processed against a database of registrations to obtain registered jurisdiction, make, model and other information about the vehicles measured. Table 3-1 summarizes the jurisdictions of the vehicles measured.

As shown in Figure 3-1 88.5% of vehicles measured were registered in the nonattainment region, 8.4% were registered elsewhere in Texas and 3.1% were from other states.

Figure 3-1: Registration Jurisdictions of Vehicles Measured in the Nonattainment Region

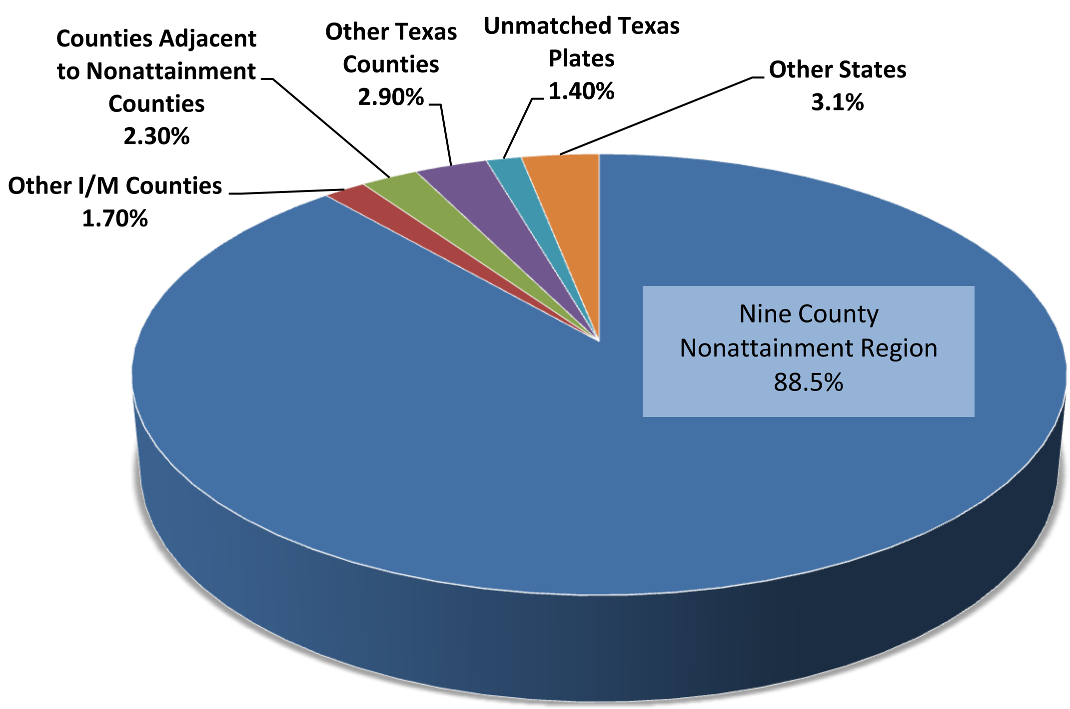


Table 3-1: Remote Sensing Records by Jurisdiction

Jurisdiction	Measurements	%
Collin	39,876	16%
Dallas	81,006	33%
Denton	25,182	10%
Ellis	3,356	1%
Johnson	2,852	1%
Kaufman	2,534	1%
Parker	7,207	3%
Rockwall	2,287	1%
Tarrant	55,928	22%
Subtotal nine counties	**220,228**	**88%**
Other I/M Counties	4,187	2%
Counties adjacent to nonattainment counties	5,818	2%
Other Texas counties	7,278	3%
Unmatched Texas plates	3,537	1%
Other States	7,802	3%
Total	**248,850**	**100%**

Table 3-2 reports the number of vehicles with one, two, three, four and five or more valid measurements.

Table 3-2: Multiple Measurements

Vehicles with Multiple Valid Measurements	
Unique VINS	203,977
VINS with 1 Measurement	176,537
VINS with 2 Measurements	22,607
VINS with 3 Measurements	3,861
VINS with 4 Measurements	727
VINS with 5 or more Measurements	245
Total Number of VINS with 2 or more Measurements	27,440
Percentage of Unique VINS with Multiple Measurements	13%

3.2 Nine County Area Vehicle Fleet Emission Rates

Average emission rates of all vehicles measured on-road in the nine counties, regardless of where they were registered, were 28 ppm HC, 0.17 % CO and 205 ppm NO. Vehicles positively identified as being registered in the nine counties had lower average emissions of 23 ppm HC, 0.16% CO and 184 ppm NO – 27% lower HC, 5% lower CO and 10% lower NO.

Figures 3-2 to 3.8 and Table 3-3 show the average age of on-road vehicles registered in the nine counties region, their average emissions and the average measured VSP. Age was calculated as the date of observation minus the model year. Thus, for example, if observations were made uniformly during 2010 then 2009 models would have a calculated average age of 1.5 years[i].

Average emissions are also shown for:

- I/M counties outside the nine nonattainment counties;
- Counties adjacent to I/M counties;
- Other Texas counties;
- Vehicles whose transcribed plate did not match a registration record;
- Plates that were not tag edited and the reason was not defined;
- Unreadable plates – often oversize vehicles; and
- Vehicles with plates from other states.

Among the nine counties, Dallas county vehicles had highest average HC emissions. As Figure 3-2 indicates, the Dallas County vehicles were also older on average. Vehicle age was not available for vehicles with unmatched or unreadable plates and vehicles with plates from other states.

Vehicles with unreadable plates had the highest average NO and PM emissions. In half the cases the plate was out of view, which is more often the case with trucks. Others included temporary plates (25%), vehicles flagged as trucks (12%), trailers (6%), trailer hitches obscuring the plate (3%) and others (4%).

[i] This is an overestimate of age of the on-road vehicles. More accurately, if the sales cycle of 2006 models was effectively Q4 2005-Q3, 2006 then the average age of a 2006 model observed in 2007 would be 1.25 years.

Table 3-3: Emissions by Jurisdiction

Jurisdiction	N	CO	HC	NO	Smoke	VSP	Age
Collin	39,876	0.14	14	144	0.01	17.2	6.6
Dallas	81,006	0.19	32	229	0.02	17.2	7.3
Denton	25,182	0.16	16	148	0.01	17.6	6.5
Ellis	3,356	0.2	17	190	0.02	18.9	6.3
Johnson	2,852	0.14	24	182	0.01	14.3	6.6
Kaufman	2,534	0.15	21	214	0.02	21.3	6.7
Parker	7,207	0.13	17	138	0.01	19.5	6.1
Rockwall	2,287	0.15	15	166	0.01	19.0	6.5
Tarrant	55,928	0.15	21	169	0.01	15.0	6.9
Other I/M	4,187	0.15	16	161	0.01	16.9	6.1
Other Adjacent	5,818	0.19	37	241	0.02	17.2	7.0
Other Texas	7,278	0.2	31	214	0.02	16.5	7.0
Reg Unmatched	3,537	0.21	34	204	0.02	17.2	
No Tag Edit	4,391	0.24	40	246	0.02	18.9	
Unreadable	24,504	0.21	63	391	0.05	16.3	
Out of State	7,802	0.2	30	188	0.02	16.4	
Total	**277,745**	**0.17**	**28**	**205**	**0.02**	**16.8**	5.9

Figure 3-2: Mean Observed Age by Jurisdiction

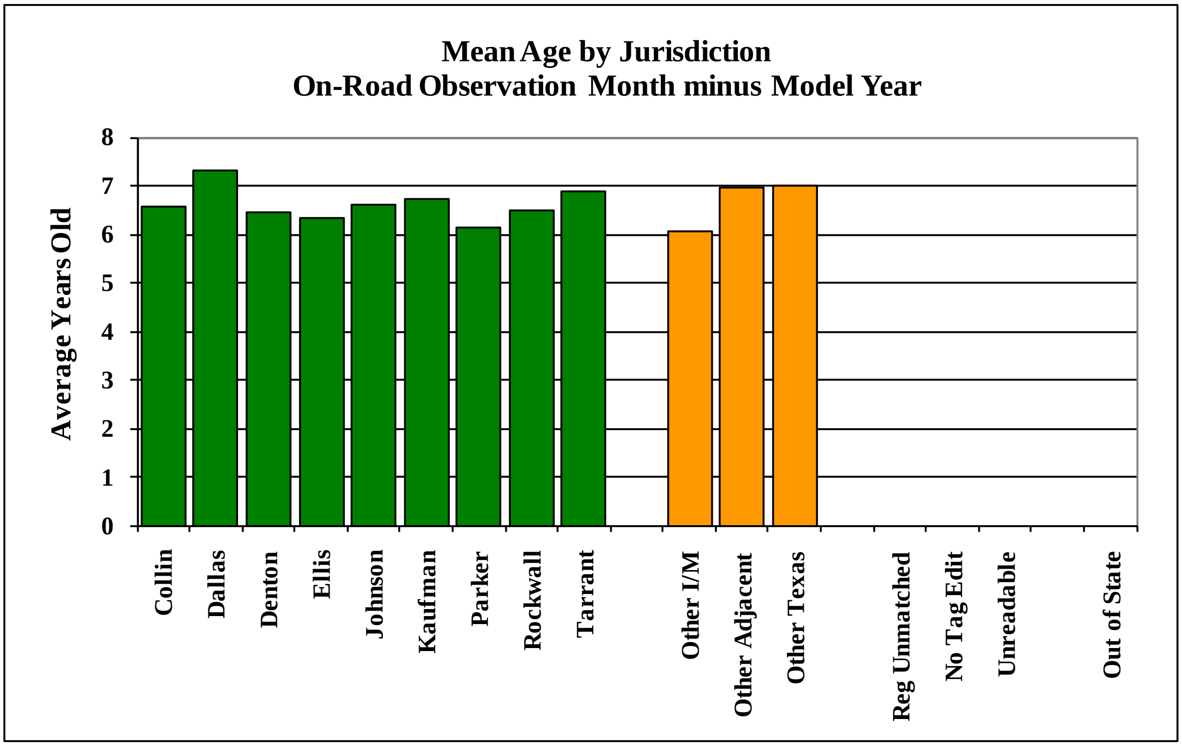


Figure 3-3: Mean HC Emissions by Jurisdiction

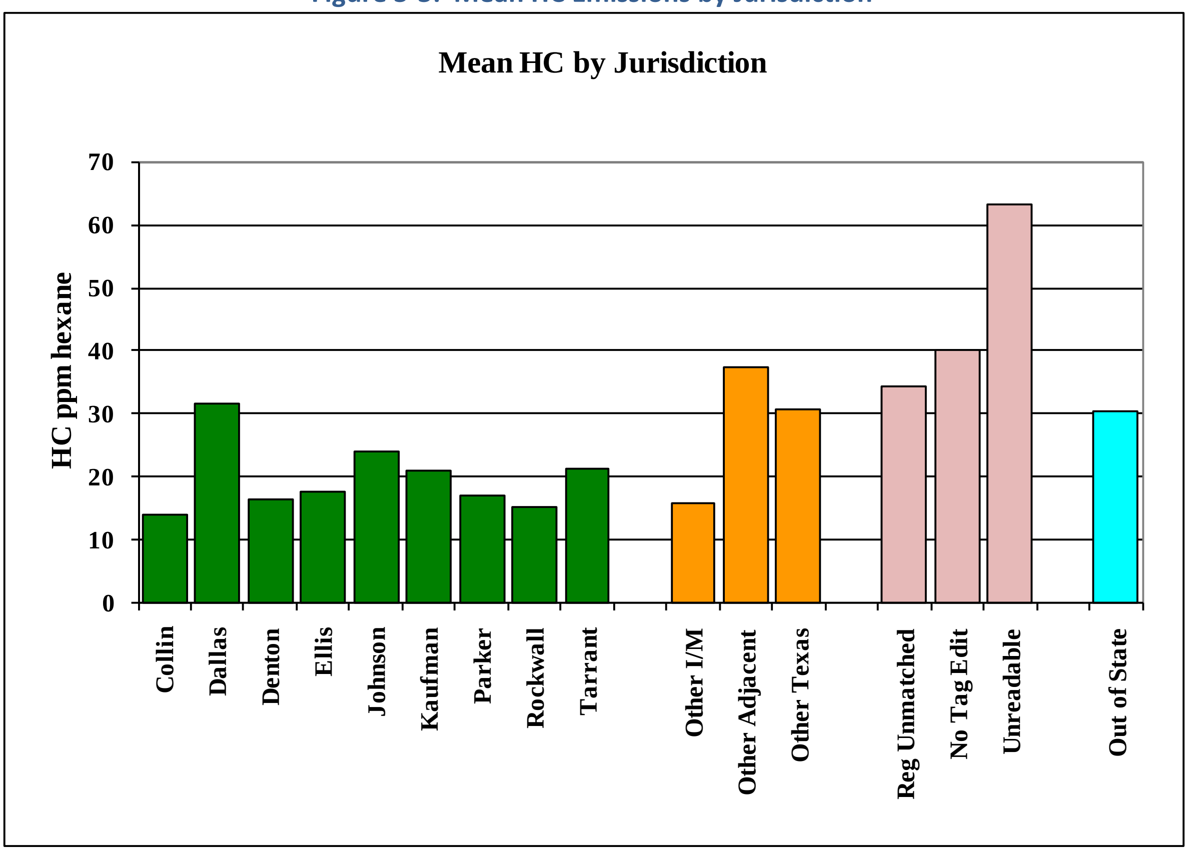


Figure 3-4: Mean CO by Jurisdiction

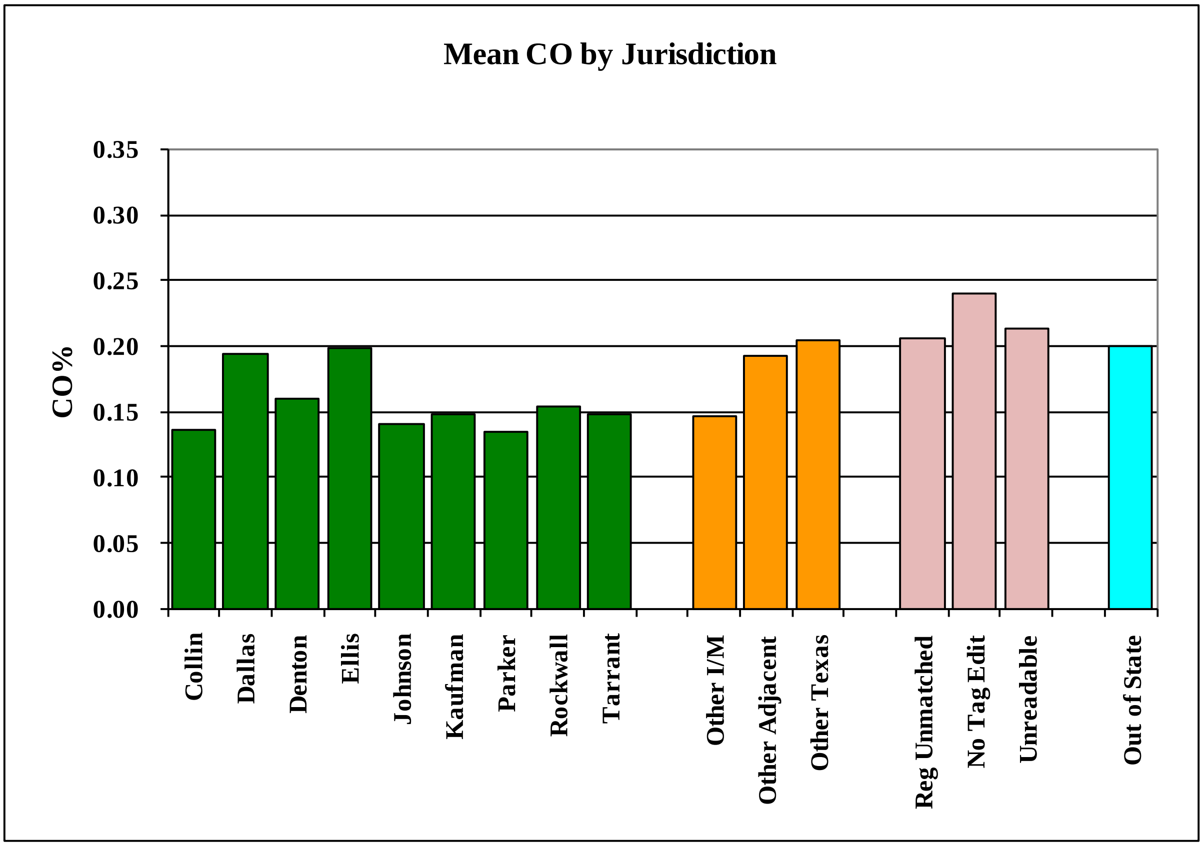


Figure 3-5: Mean NO by Jurisdiction

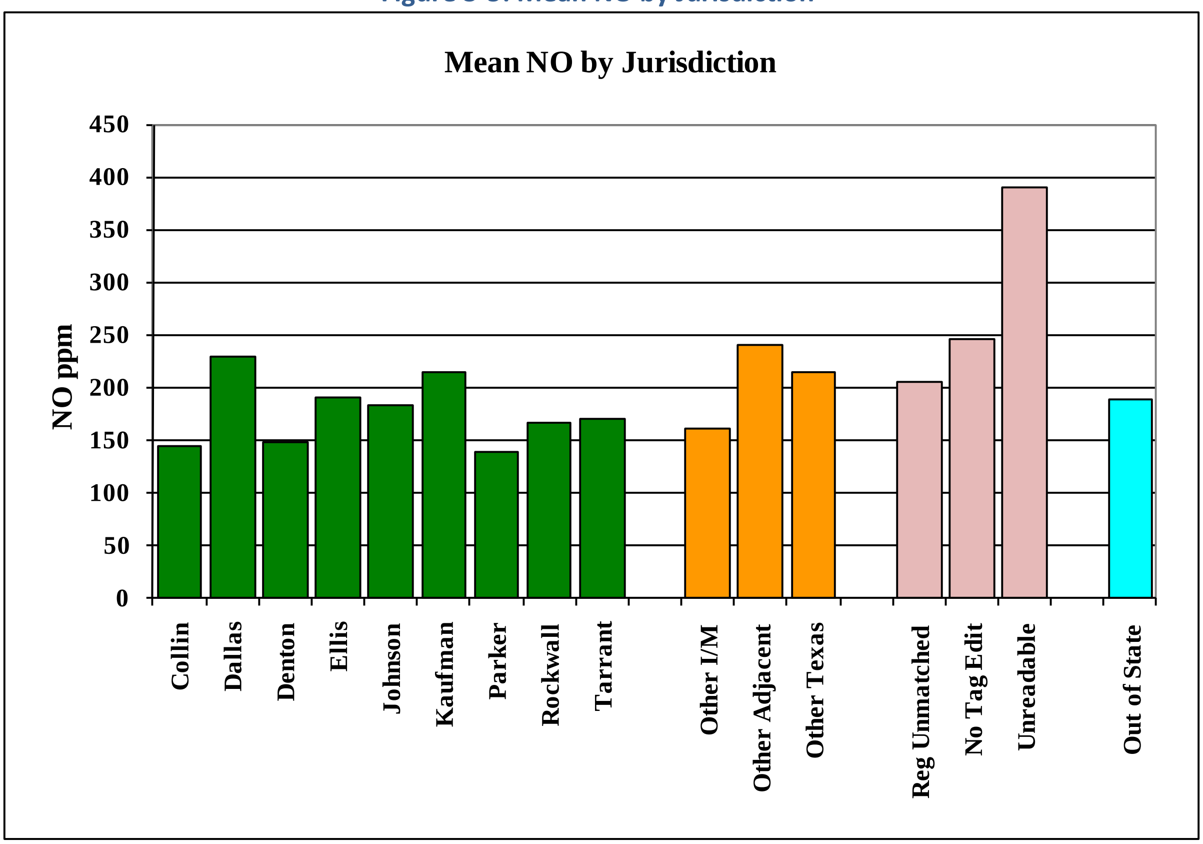


Figure 3-6: Mean Smoke by Jurisdiction

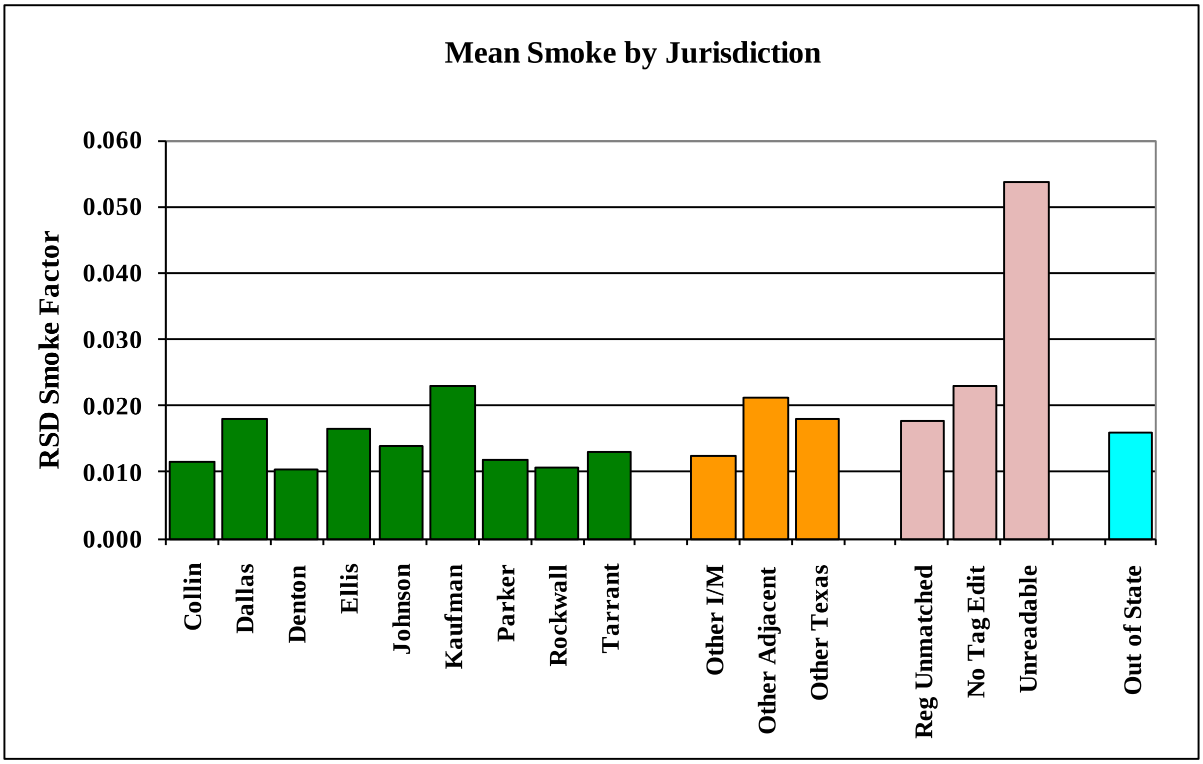


Figure 3-7: Average Observed Specific Power by Jurisdiction

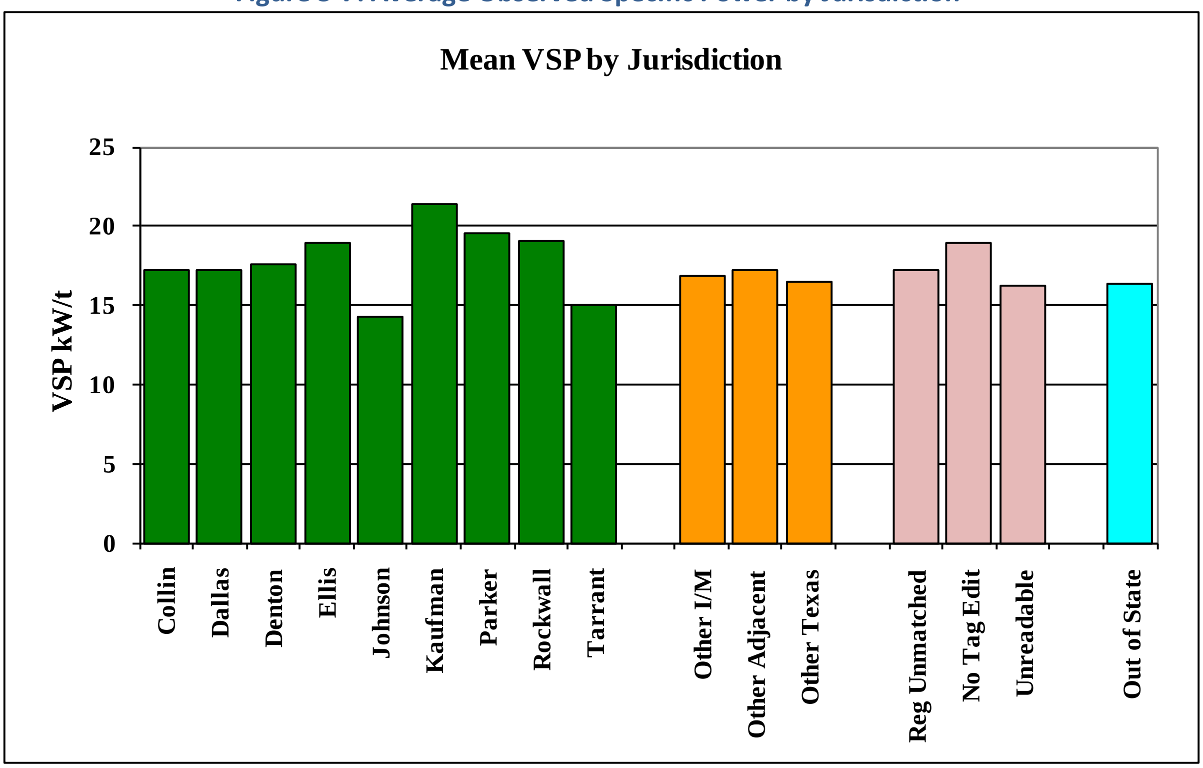
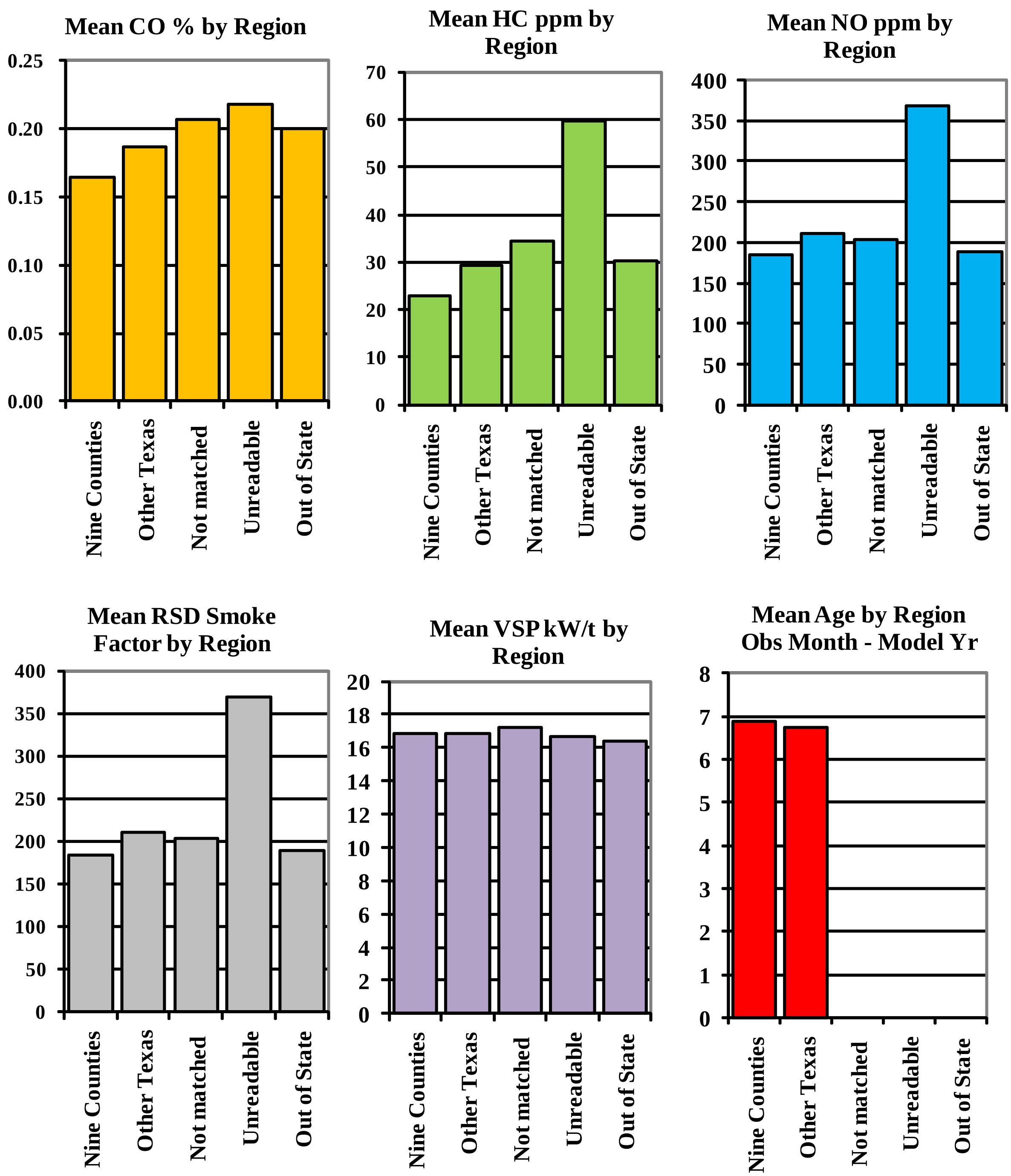


Figure 3-8: Mean Emissions, VSP and Age by Region



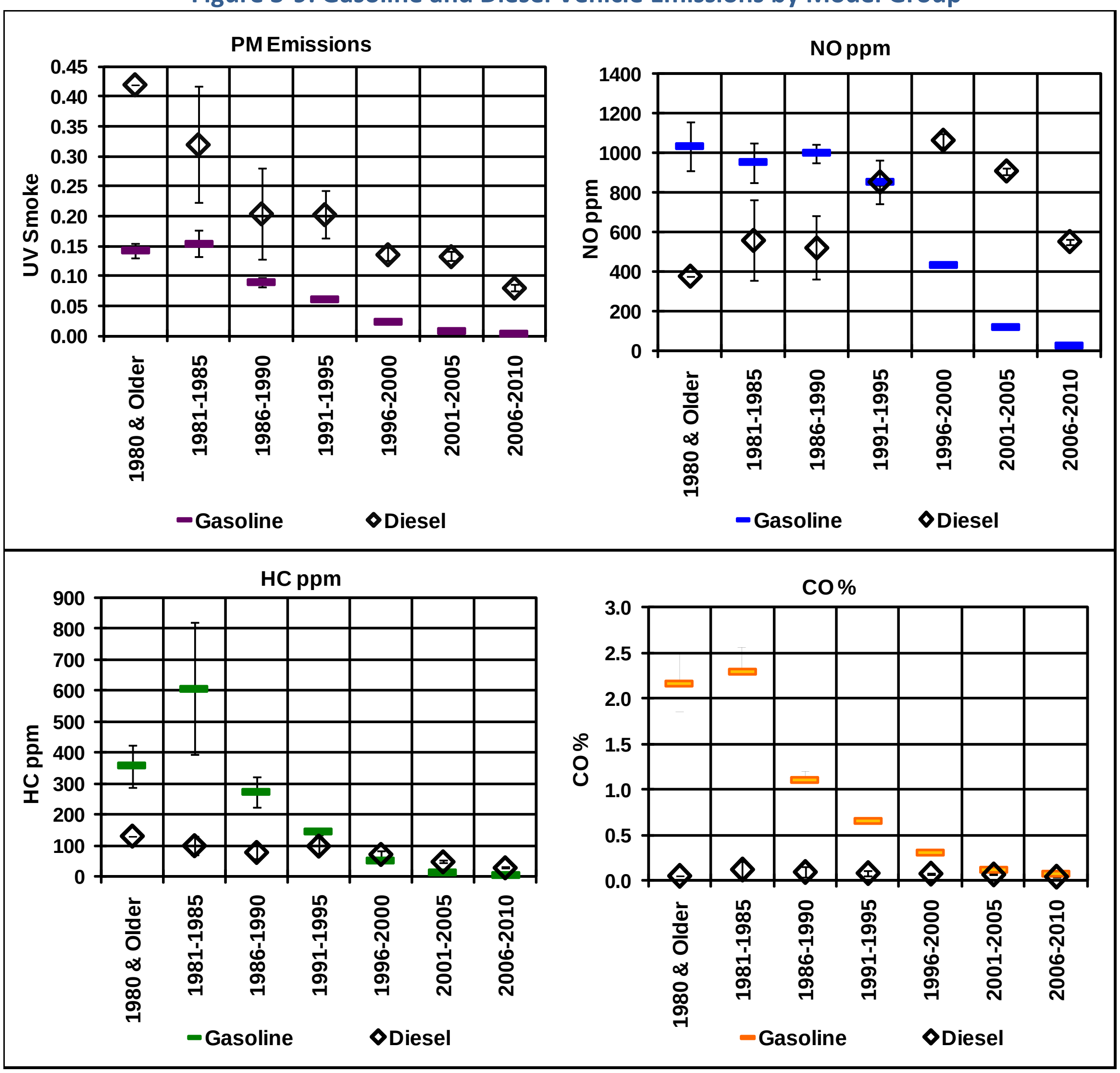
3.3 Emissions by Model Year

Emissions for different models by 5-year bins are shown in Figure 3-9.

The difference in average emissions between the oldest and newest gasoline models is extreme. 1985 and older models, which were no longer subject to I/M testing, had the highest emissions. 1986-1995 models were many times dirtier than new models. Even 1996-2000 models had emissions several times those of 2006-2010 models.

Diesel vehicles had generally lower HC and CO emissions than gasoline vehicles – except that 1996 and newer gasoline vehicles had lower HC. The reductions in emissions for newer model diesels were less dramatic than for gasoline vehicles. Diesel NO emissions were highest among 1996-2000 models and averaged over 500 ppm for newer 2006-2010 models. Diesel particulate (PM) emissions showed continuously lower levels for newer models but remained high compared to gasoline vehicles. Average diesel vehicle PM values for 1996 and newer models were 12 times higher than those of gasoline vehicles.

Figure 3-9: Gasoline and Diesel Vehicle Emissions by Model Group



The first section of Table 3-4 shows the split between gasoline and diesel vehicles in numbers and their estimated emissions contributions. Gasoline vehicles were far more numerous than diesels and were 97% of measurements. Because of their large numbers, total emissions from gasoline vehicles were far greater than total emissions from diesel vehicles. Diesel vehicles, however, had higher average emissions than gasoline models and the 2.8% of the fleet that were diesels emitted 11.3% of NO and 21% of PM.

Relative emissions contributions in Table 3-4 were calculated using a simplified approach: emissions contribution is proportional to the number of measurements times the emissions levels. This is reasonable if fuel economy is similar across all groups (fuel economy has changed little since the early 1980's) and the number of observations of a group is proportional to their miles driven, which has been demonstrated in other studies[6]. More accurate estimates could be obtained by determining and applying the individual fuel economy for each vehicle.

The gasoline PM estimates should be considered as approximate. Gasoline particulates have different characteristics than diesel particulates and an accurate characterization of typical gasoline vehicle particulates and their correlation to RSD Smoke Factor is the subject of continuing study.

Table 3-4: Approximate Emissions Contributions

		Emissions Contributions			
Fuel	**Vehicles**	**CO**	**HC**	**NO**	**PM**
Gasoline	97.2%	99.0%	94.8%	88.7%	78.8%
Diesel	2.8%	1.0%	5.2%	11.3%	21.2%
Total	100.00%	100.00%	100.00%	100.00%	100.00%
		Gasoline Vehicle Emissions Contributions			
Model Years	**Vehicles**	**CO**	**HC**	**NO**	**PM**
1985 & Older	0.3%	3.9%	6.4%	1.7%	3.7%
1986-1990	0.7%	4.5%	8.1%	4.0%	5.2%
1991-1995	3.9%	15.2%	24.9%	19.7%	20.2%
1996-2000	16.8%	29.8%	36.0%	42.3%	32.9%
2001-2005	37.4%	27.1%	18.7%	25.5%	24.1%
2006-2010	40.9%	19.7%	5.8%	6.8%	13.9%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
		Diesel Vehicle Emissions Contributions			
Model Years	**Vehicles**	**CO**	**HC**	**NO**	**PM**
1985 & Older	0.5%	0.9%	1.1%	0.3%	1.4%
1986-1990	0.5%	0.7%	0.8%	0.3%	0.9%
1991-1995	1.5%	2.2%	3.5%	1.8%	2.8%
1996-2000	11.5%	15.1%	19.3%	16.4%	14.3%
2001-2005	36.1%	42.4%	40.9%	44.1%	43.9%
2006-2010	50.0%	38.6%	34.2%	37.1%	36.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Within gasoline vehicles, the second section of Table 3-4, 1986-1995 models were 4.6% of measurements contributing 33.0% of HC and 23.7% of NO. In contrast, 2006-2010 models were 40.9% of measurements contributing only 5.8% of HC and 6.8% of NO.

The third section of Table 3-4 shows light-diesel vehicles measured were predominantly 2001 and newer models (86.1%) contributing 81.2% of light-diesel NO and 80.7% of light-diesel PM.

Figures 3-10 and 3-11 further illustrate the split of vehicles and contributions within gasoline and diesel vehicles. 2001 and newer gasoline vehicles emit less than half the total gasoline vehicle emissions. By contrast, 2001 and newer light-diesel vehicles emit the majority of light-diesel emissions.

Figure 3-10: Gasoline Vehicle Measurements and Contributions

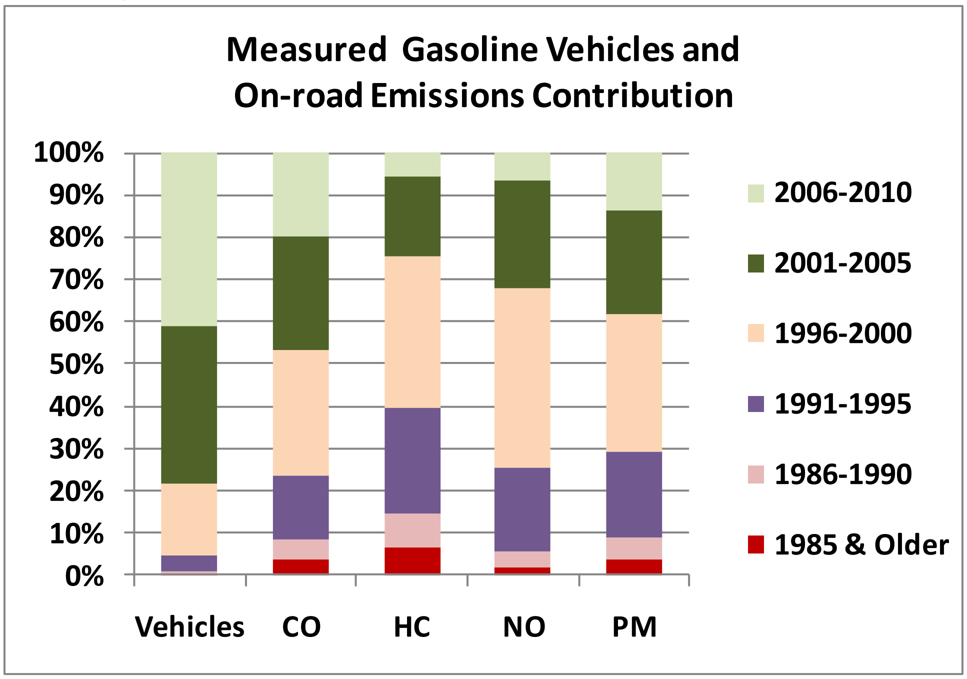
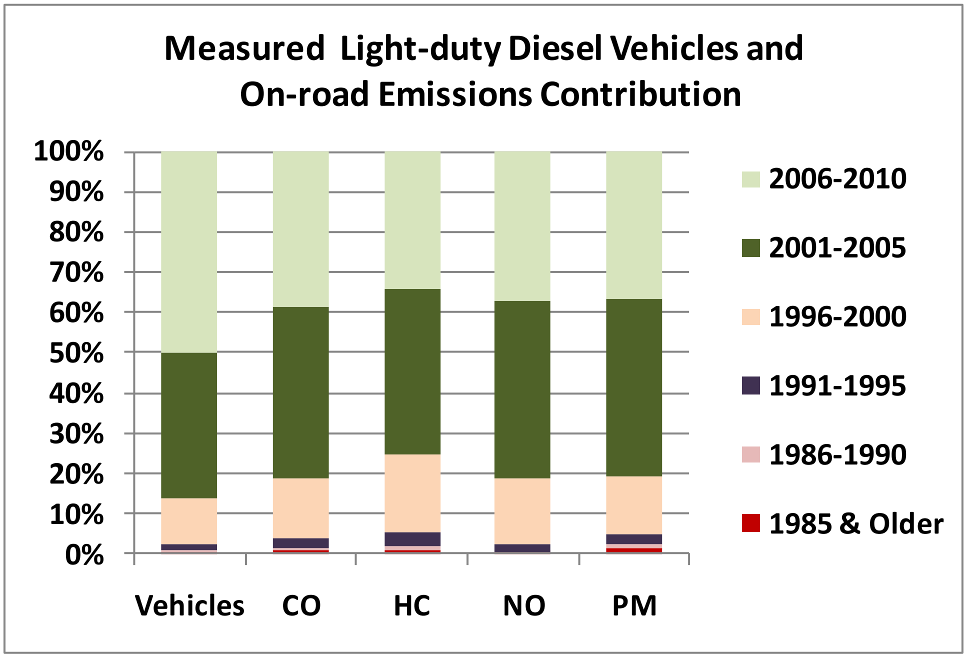


Figure 3-11: Light-duty Diesel Vehicle Measurements and Contributions



3.4 Emissions Rates by Ambient Temperature

Figure 3-12 and 3-13 compare emission rates by temperature Celsius. There was an increase in CO with temperature. Other pollutants were generally insensitive to temperature. Temperatures over 40C may cause increased HC on gasoline vehicles. NO and PM for gasoline vehicles showed a slight reduction with increasing temperature.

Figure 3-12: HC and CO Emissions by Temperature Centigrade

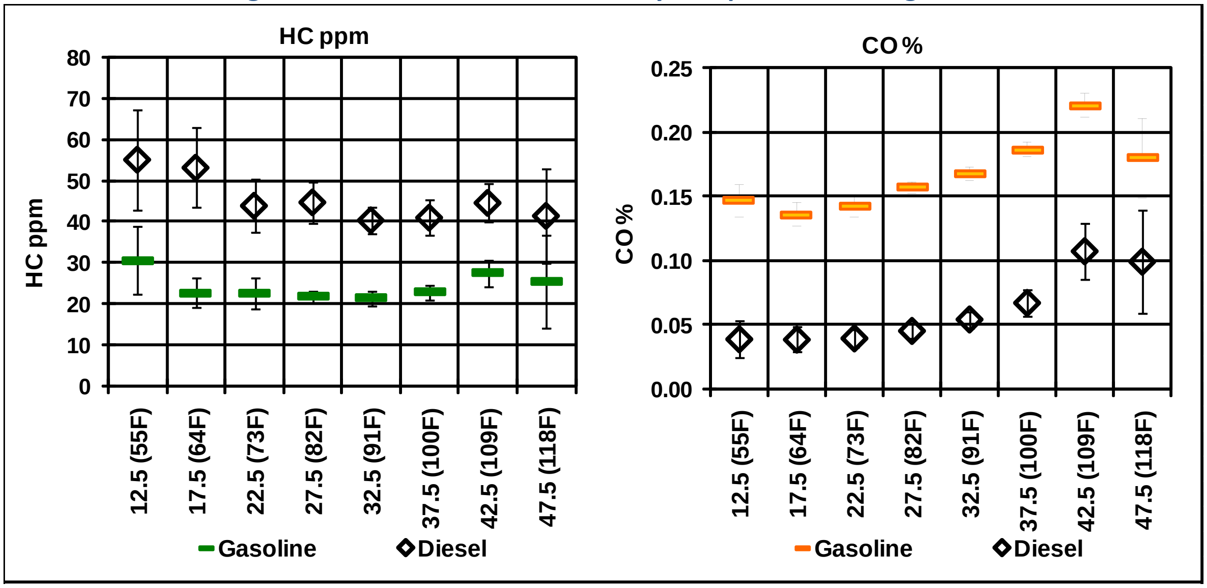
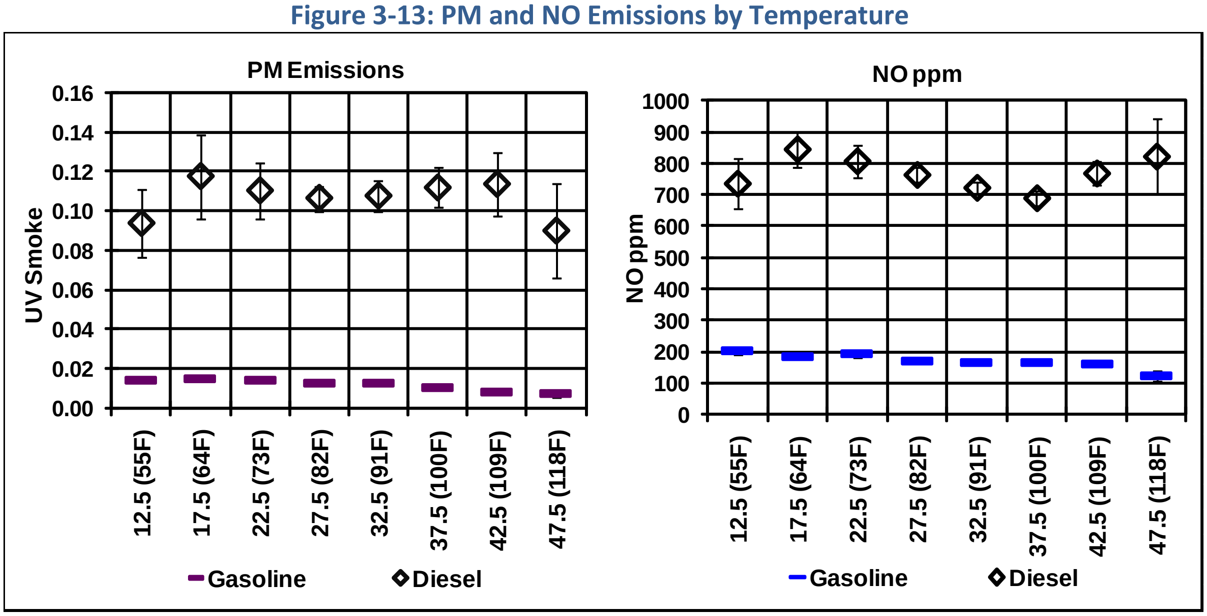


Figure 3-13: PM and NO Emissions by Temperature



4 EMISSIONS BY I/M STATUS

ESP compared on-road emissions to the previous I/M inspection result for gasoline vehicles registered within the nine counties. ESP received I/M records from 2006-2010 via NCTCOG and these data were analyzed to extract the date and the result of the last I/M test.

Figure 4-1: I/M Status of On-road Vehicles summarizes the status of vehicles observed on-road by model year. The upper black line confirms that 99.5% of 1987-2007 models had obtained at least one inspection between 1/1/2006 and 12/26/2010. Because of the two-year new model exemption, not all 2008 models were required to have obtained an emission inspection at the time the data were reviewed.

Vehicles over 24 years old were exempt from emission inspection. Consequently, among the latest tests, emissions inspection results were found for only some of the 1986 models.

A follow-up action is to review the 0.5% of 1987-2007 model vehicles with no test found to determine if they were recent transfers into the nine counties or other reason.

Vehicles subject to the I/M Program are required to obtain an annual inspection and inspection certificate. There is a five-day grace period. An expired motor vehicle inspection falls under Texas Transportation Code statute 548.605, which allows that a citation for an expired motor vehicle inspection will be dismissed if the owner "remedies the defect within 20 working days" and "the inspection certificate has not been expired for more than 60 days".

The normal interval between inspections could be up to 13 months and subject vehicles observed on-road were expected to have had an inspection within the last 13 months if they were complying with the Program. Records of inspection within 13 months were not found for 2.8% of vehicles that had been inspected since 2006. Further investigation is required to determine the reasons for the missing or late inspections.

A further 0.8% of the last test records did not have an emission test result. A portion of these vehicles did have safety inspections and it is possible they may have migrated into the emissions I/M Program area within the past year.

For 0.2% of vehicles the last inspection recorded was a failure that occurred more than three months before the vehicle was observed on-road. Vehicles failing less than three months prior to being observed on-road could still be in the process of obtaining repairs.

Figure 4-2: I/M Status of On-road Vehicles by County shows similar statistics by county for the 1987-2007 models expected to have been fully tested. There was 2.5% variability between counties in the percentages of vehicles tested and passed within the thirteen months prior to their on-road observation.

As noted in section 5, high-emitters had higher rates of non-compliance than the general population.

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

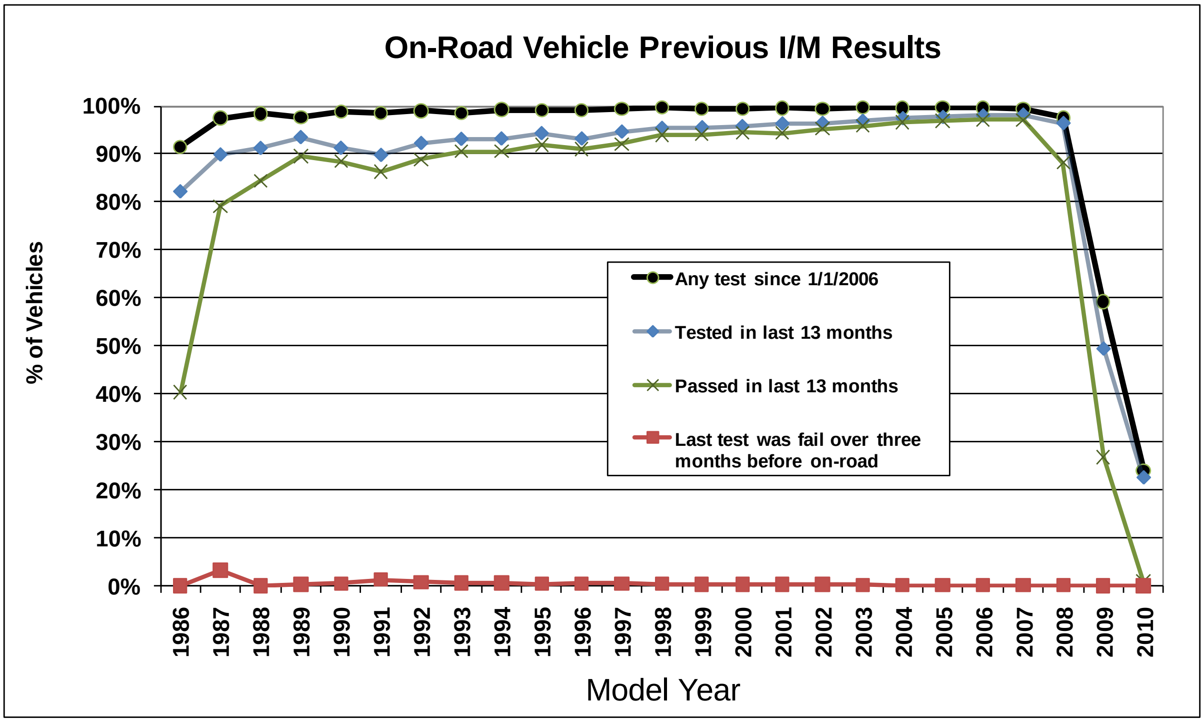
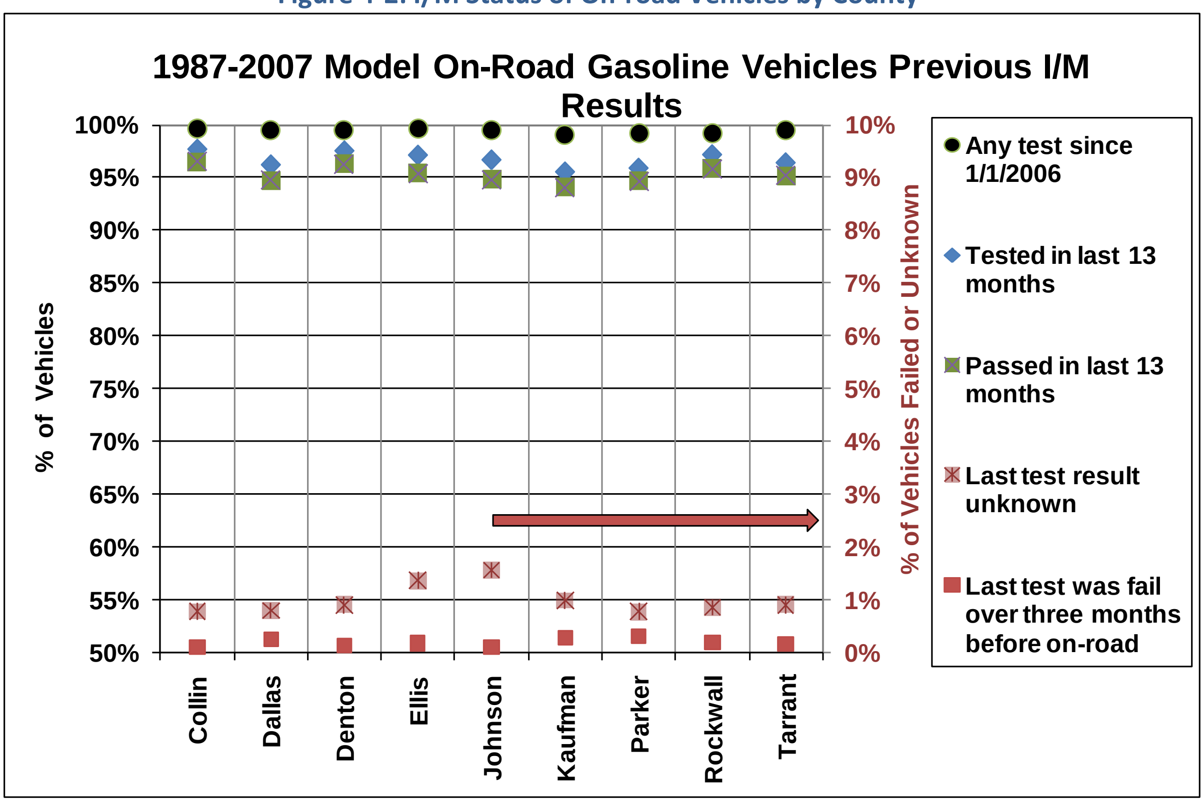


Figure 4-2: I/M Status of On-road Vehicles by County

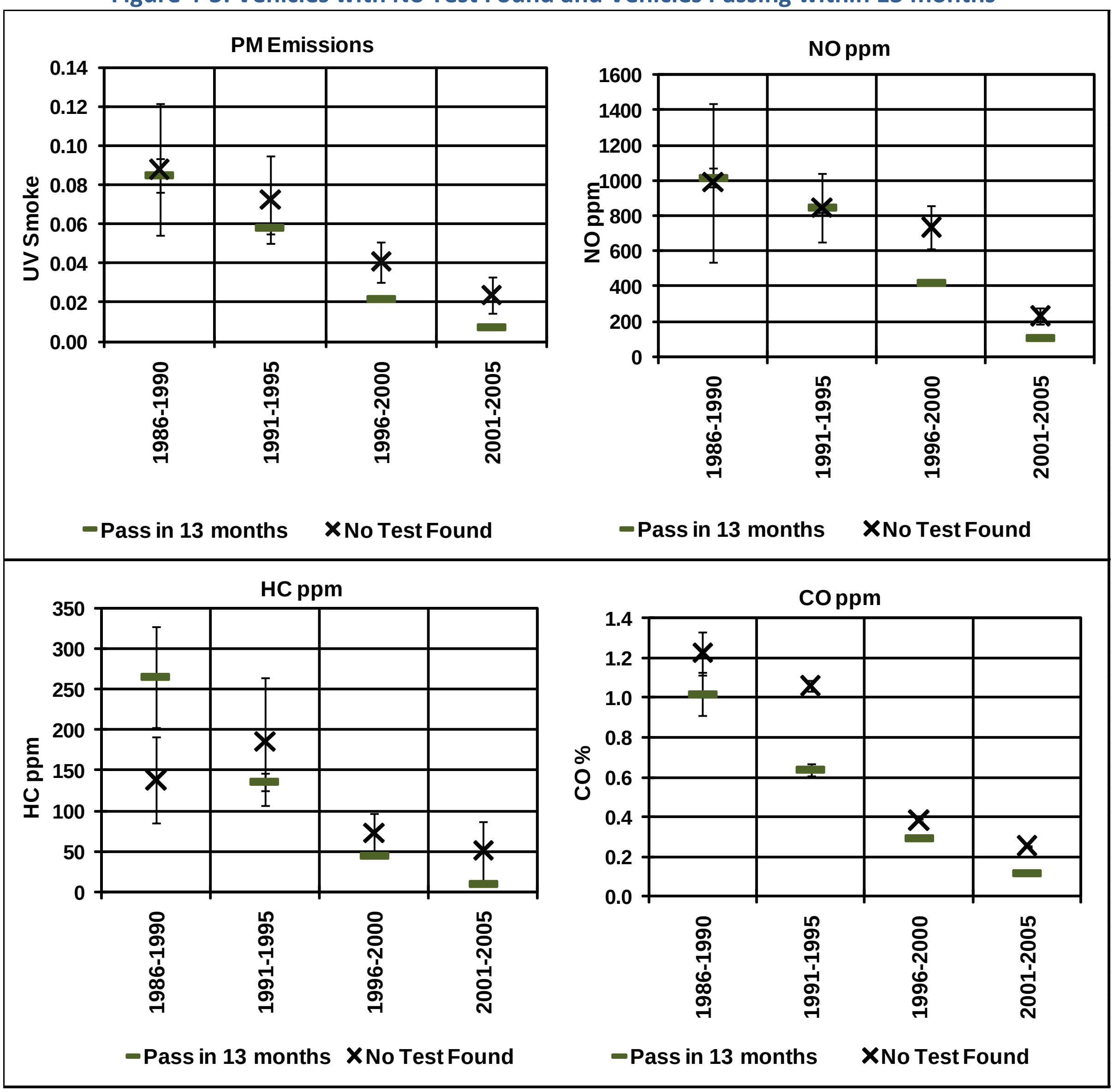


To assess the impact of vehicles with various I/M status, emissions of vehicles registered in the nine counties were compared between:

- Figure 4-3 Vehicles passing within 13 months and vehicles with no test found;
- Figure 4-4 Vehicles passing within 13 months and those last passing more than 13 months ago;
- Figure 4-5 Vehicles passing within 13 months and those with an unknown status;
- Figure 4-6 Vehicles passing within 13 months and those failing their last test more than 3 months ago;
- Figure 4-7 Vehicles failed more than three months ago and those failing their last test less than 3 months ago.

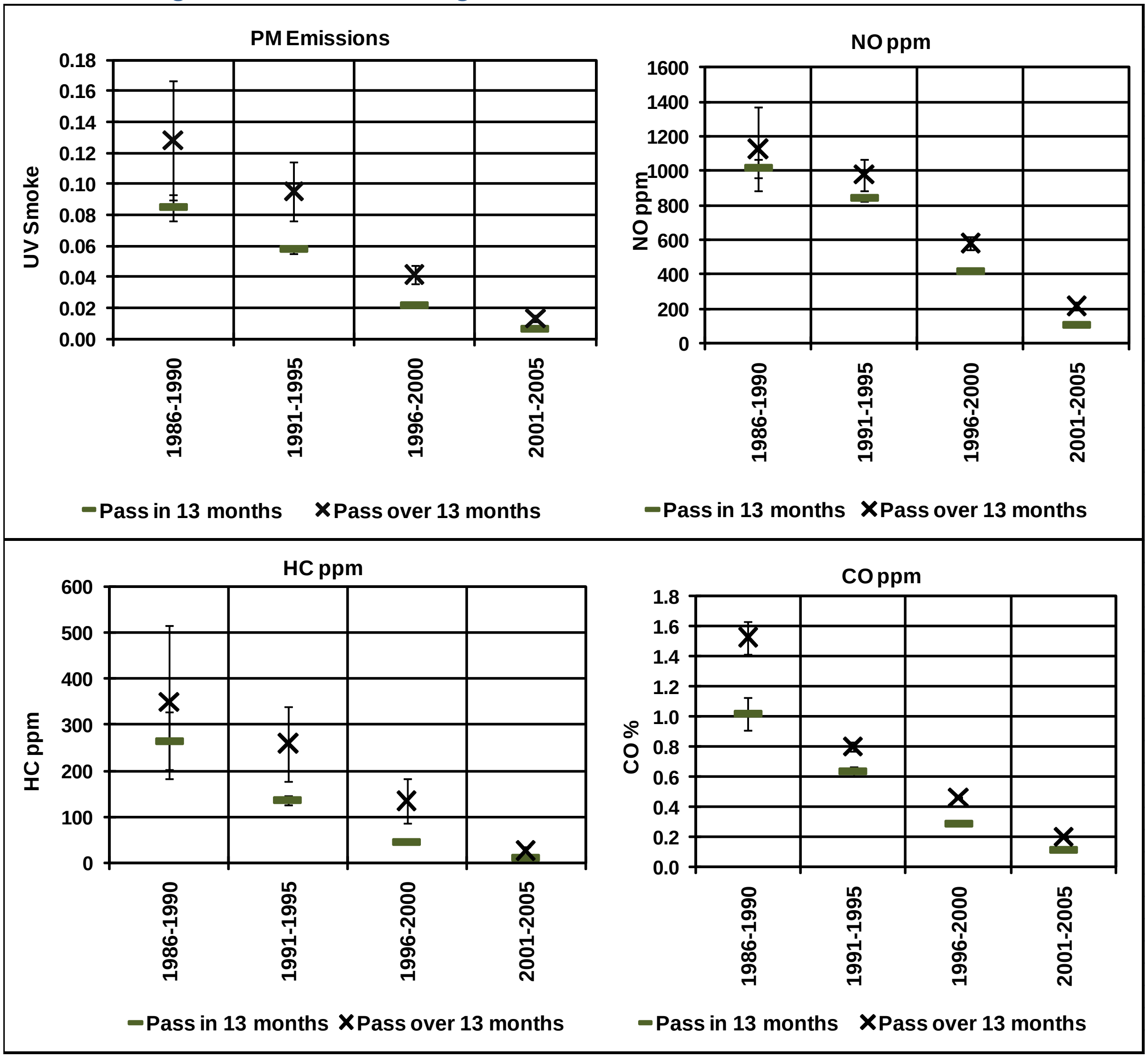
The weighted average emissions of vehicle models 1986-2005 with no test found were more than double those of vehicles passing within 13 months.

Figure 4-3: Vehicles with No Test Found and Vehicles Passing within 13 months



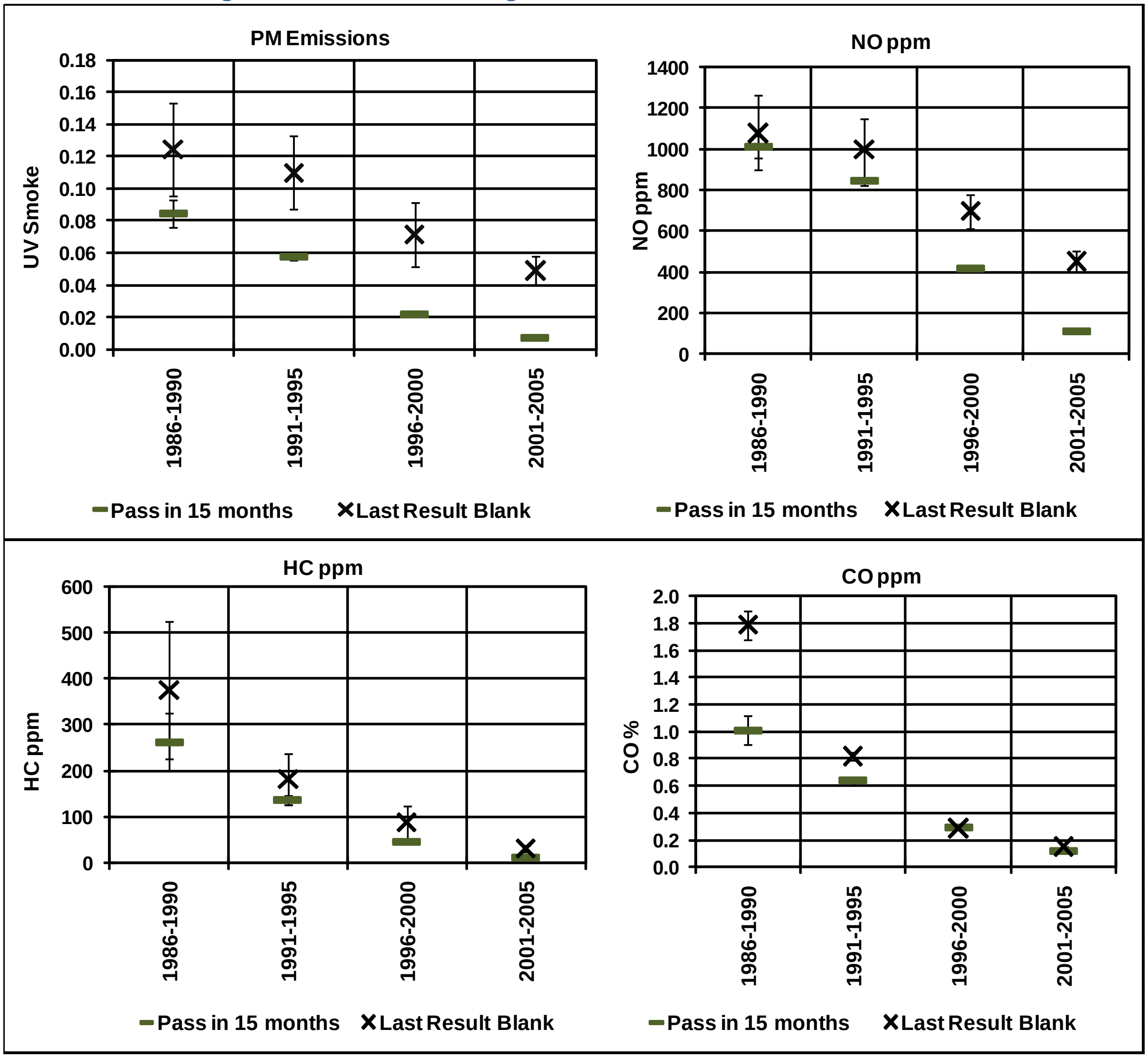
The weighted average emissions of vehicles with passing test over 13 months ago were double those of vehicles passing within 13 months.

Figure 4-4: Vehicles Passing within 15 months and More than 15 months



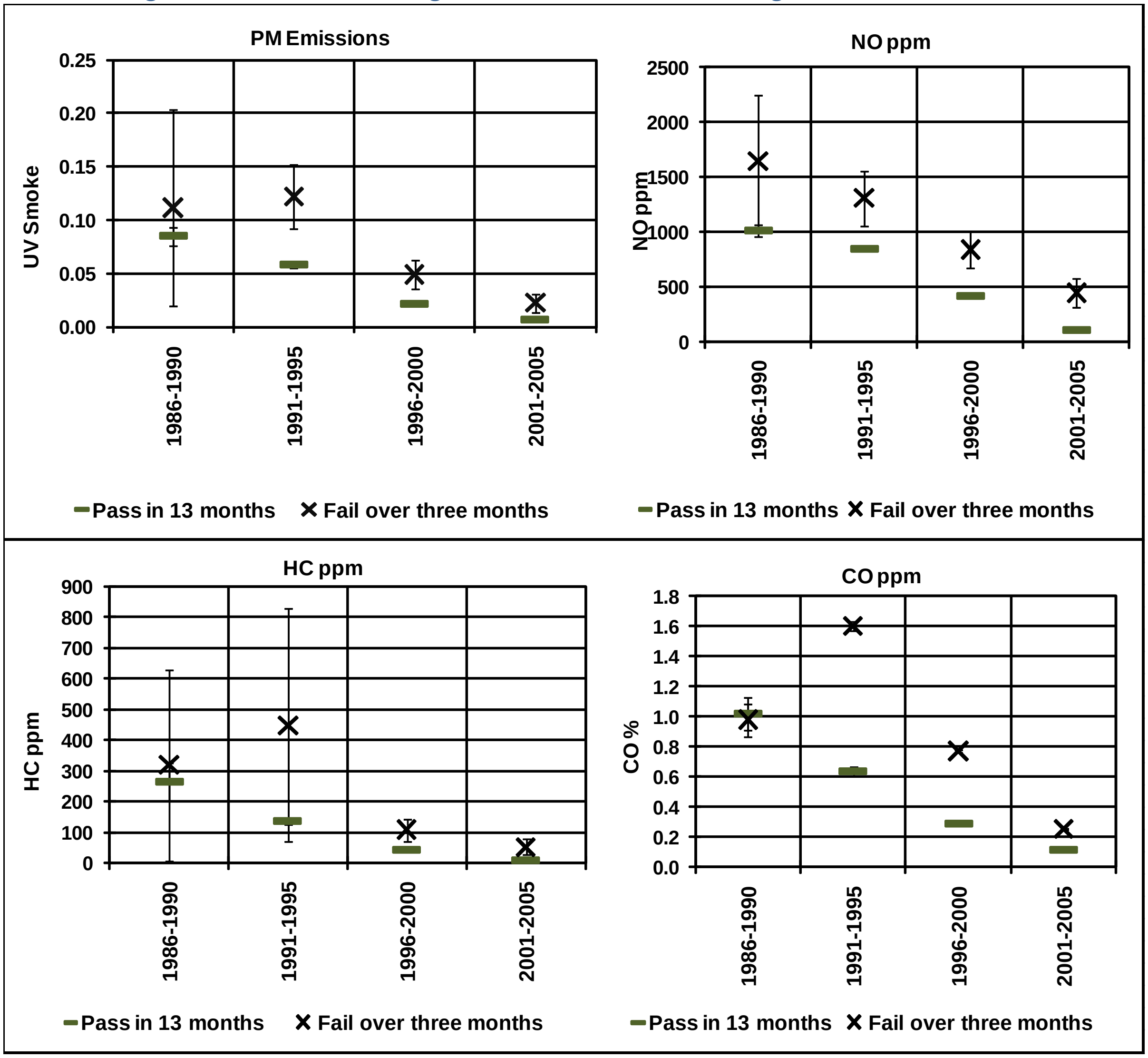
Vehicles with unknown results also had emissions that were double those of vehicle passing within 13 months.

Figure 4-5: Vehicles Passing within 15 months and Blank Results



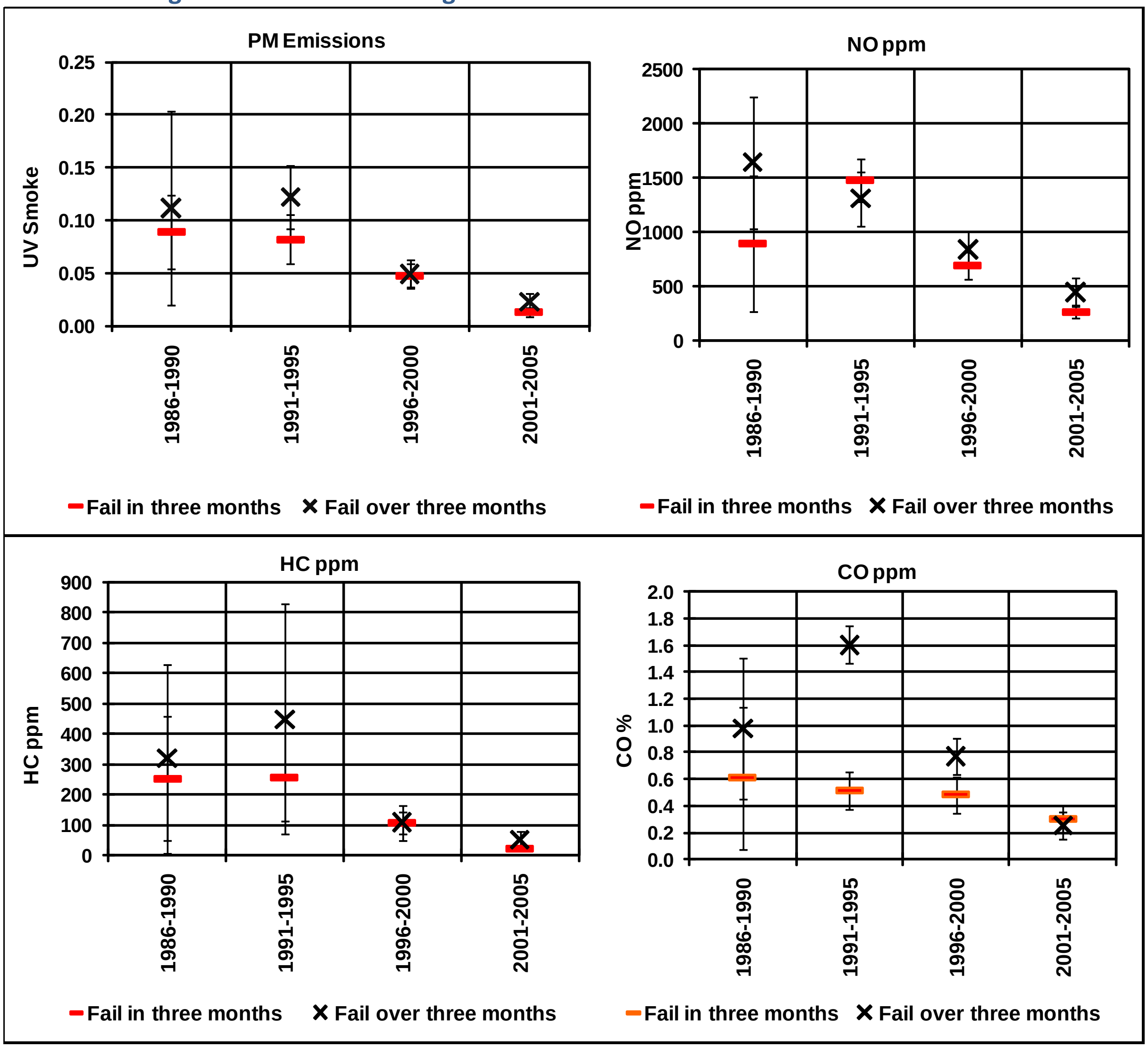
The weighted average emissions of vehicles failing their last test more than three months before being observed on-road were up to five times those of passing vehicles. Emissions of failing 1991-1995 models were especially high.

Figure 4-6: Vehicles Passing within 13 months and Failing Over Three Months



Older model vehicles failing their last test more than three months before being observed on-road had higher emissions than those failing within the last three months.

Figure 4-7: Vehicles Failing Over Three Months and Within Three Months



5 HIGH-EMITTERS IDENTIFIED

5.1 Summary

The Pilot Program successfully identified 4,719 unique high-emitters. Of these 86 were identified a second time more three months after their initial identification. Gasoline and diesel high-emitters were 2.7% of the gasoline vehicles and 1.5% of the light-duty diesel vehicles measured. Seventy-four of the vehicles were diesel high-emitters.

As indicated in Figure 5-1, 95% of the high-emitters identified were registered in the nine county nonattainment region. Out-of-state and unmatched plates were not categorized as high-emitters because their type and model year were unknown.

Figure 5-1: Registration Jurisdictions of High-Emitters Measured in the Nonattainment Region

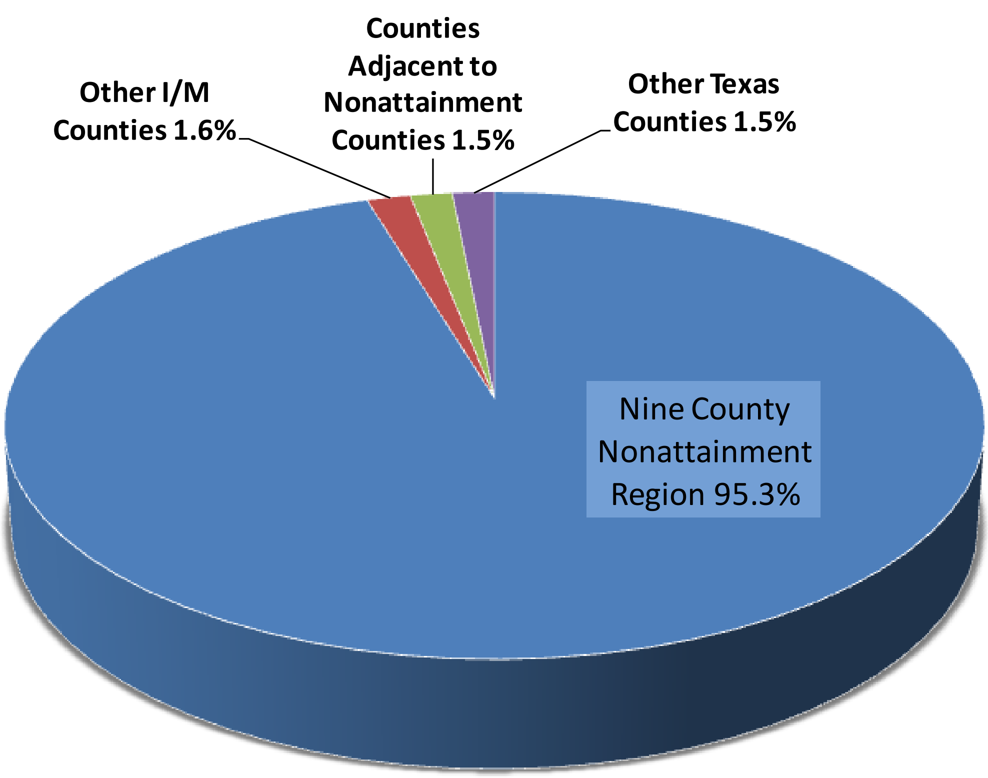


Table 5-1 shows the number of high-emitters and percentage identified by county. The last column shows the rate of high-emitters among 1986-2008 models. Dallas County had the highest rate of high-emitters.

Table 5-1: High-emitters by Jurisdiction

Jurisdiction	High Emitters	% of High Emitters	% of Unique 1986-2008 Models
Collin	538	11%	1.83%
Dallas	2,400	51%	3.87%
Denton	365	8%	1.87%
Ellis	62	1%	2.34%
Johnson	34	1%	1.55%
Kaufman	50	1%	2.48%
Parker	77	2%	1.47%
Rockwall	46	1%	2.58%
Tarrant	925	20%	2.23%
Subtotal nine counties	**4,497**	**95%**	2.70%
Other I/M Counties	76	2%	2.68%
Counties Adjacent to Nonattainment Counties	73	2%	1.58%
Other Texas Counties	73	2%	1.36%
Other States	n/a		
Total	**4,719**	**100%**	**2.63%**

Emissions of gasoline high-emitters were eighteen times higher for HC and almost eight times higher for NO than the average of the on-road gasoline fleet. The high-emitters identified contributed up to 26%, 50%, 20% and 29% of all 1986-2008 model gasoline vehicle CO, HC, NO and particulate emissions. Thirty percent of gasoline high-emitters failed a previous I/M inspection since 1/1/2005.

Emissions of diesel high-emitters were six times higher for PM than the average of the on-road diesel fleet. NO emissions were comparable. Vehicles with high particulates tend to have lower NO and a majority of the diesel high-emitters were high-emitters of smoke/particulates. Hence, average NO among high-emitters was not elevated. The high-emitters identified contributed up to 9%, 5%, 1% and 9% of all 1986-2008 model diesel vehicle CO, HC, NO and particulate emissions.

Over 90% of the diesel high-emitters were identified as high-emitters of visible smoke and 38% of these visible smoke emitters were also flagged as high-emitters of UV Smoke. Opacity testing of diesel vehicles would be a beneficial addition to the I/M Program.

5.2 Identifying High-Emitters

The observed plates of vehicles measured on-road were matched to DMV records to determine the type, make, and model and fuel type of each vehicle. ESP then applied criteria to identify the high-emitters.

NCTCOG and ESP developed an initial set of criteria for identifying high-emitters. The NCTCOG high-emitter identification criteria were intended to identify a relatively larger number of vehicles than the current DPS Remote Sensing high-emitter program. Lower emissions cutpoints were established and some procedural differences were included.

In July 2010, NCTCOG cutpoints were adjusted by aligning a cutpoint change with the 1995/6 model step between ASM and OBD testing and segregating the OBD vehicles into two tiers: 1996-2001 and 2002 & newer. On the recommendation of ESP, CO and NO cutpoints were loosened for some models and VSP was capped for making CO high-emitter determinations.

The DPS cutpoints and procedures include considerable safety margins because considerable penalties and sanctions may be brought against non-complying vehicle owners. The downside of this is many vehicles with emissions exceeding I/M Program standards are not identified.

In the DPS Remote Sensing Program High-Emitter Identification program, a letter is sent to the registered vehicle owner if the vehicle is flagged at least two times as a high-emitter in a calendar year. If the vehicle is registered in an adjacent attainment county, a letter will be sent to the registered vehicle owner if the vehicle is flagged at least three times as a high-emitter in a calendar year. If the vehicle was tested in the last 90 days, or is due for an emissions inspection within the next 30 days, no notice is sent to the vehicle owner. A high-emitter index rank of between 90 and 100 can be used in lieu of one of the on-road measurements. A rank of between 90 and 100 indicates the model is among the 10% of vehicles with the highest failure rate.

Tables 5-2 and 5-3 show the initial sets of cutpoints for the pilot.

Table 5-2: Initial High-Emitter Standards

	LEVEL 1: TXDPS	LEVEL 2: NCTCOG[1]	LEVEL 3: NCTCOG[2]
HC			
1986-1990	≥ 700 ppm	≥ 550 ppm	≥ 370 ppm
1991-1995	≥ 500 ppm	≥ 440 ppm	≥ 296 ppm
1996-2008	≥ 350 ppm	≥ 330 ppm	≥ 222 ppm
CO			
1986-1990	≥ 4.0%	≥ 3.0%	≥ 2.8%
1991-1995	≥ 3.0%	≥ 2.4%	≥ 2.24%
1996-2008	≥ 3.0%	≥ 1.8%	≥ 1.68%
NOx			
1986-1990	≥ 4,000 ppm	≥ 3,455 ppm	≥ 2,910 ppm
1991-1995	≥ 3,500 ppm	≥ 2,914 ppm	≥ 2,328 ppm
1996-2008	≥ 3,000 ppm	≥ 2,359 ppm	≥ 1,719 ppm

[1]HC and CO cut points are based on current TSI cut points (HC = 220 and CO = 1.2%).
NOx cut points are the median between Level 1 & Level 3.
'86-'90 HC & CO cut points are 2.5X the current TSI cut points. '91-'95 HC & CO cut points are based on 2X the current TSI cut points. '96 and Newer HC & CO cut points are based on 1.5X the current TSI cut points.

[2]HC, CO and NOx cut points are based on a State-wide average (HC = 148 ppm, CO = 1.12% and NOx = 1146 ppm) of cut points from 1,011,327 ASM tests (09-01-06 thru 08-31-07).
86-'90 cut points are 2.5X the State-wide average. '91-'95 cut points are based on 2X the State-wide average. '96 and Newer cut points are based on 1.5X the State-wide average.

Table 5-3: Revised High-Emitter Standards

	Level 1[1]	Level 2[2]
HC		
1986-1991	≥ 550 ppm	≥ 370 ppm
1992-1995	≥ 440 ppm	≥ 296 ppm
1996-2001	≥ 330 ppm	≥ 222 ppm
≥ 2002	≥ 330 ppm	≥ 222 ppm
CO[3]		
1986-1991	≥ 3.0%	≥ 2.8%
1992-1995	≥ 2.5%	≥ 2.5%
1996-2001	≥ 2.5%	≥ 2.5%
≥ 2002	≥ 1.8%	≥ 1.68%
NOx		
1986-1991	≥ 2,910 ppm	≥ 2,910 ppm
1992-1995	≥ 2,328 ppm	≥ 2,328 ppm
1996-2001	≥ 2,250 ppm	≥ 2,250 ppm
≥ 2002	≥ 1,746 ppm	≥ 1,746 ppm

[1]HC and CO cut points are based on current TSI cut points (HC = 220 ppm, CO = 1.2%).
NOx cut points are based on a State-wide average (1,164 ppm) of cut points from 1,011,327 ASM tests (09-01-06 thru 08-31-07).
1985 - 1991= 2.5 times the TSI cut points and State-wide average.
1992 - 1995 = 2 times the TSI cut points for HC; ~2.08 times for CO; and 2 times the State-wide average for NOx.
1996 - 2001 = 1.5 times the TSI cut points for HC; ~2.08 times for CO; and ~1.93 times the State-wide average for NOx.
≥ 2002 = 1.5 times the current TSI cut points and State-wide average for HC, CO, and NOx.

[2]HC, CO and NOx cut points are based on a State-wide average (HC = 148 ppm, CO = 1.12% and NOx = 1,164 ppm) of cut points from 1,011,327 ASM tests (09-01-06 thru 08-31-07).
1985 - 1991 = 2.5 times the State-wide average for HC, CO and NOx.
1992 - 1995 = 2 times the State-wide average for HC and NOx; and ~2.23 times the State-wide average for CO.
1996 - 2001 = 1.5 times the State-wide average for HC; ~2.23 times the State-wide average for CO; and ~1.93 times the State-wide average for NOx.
≥ 2002 = 1.5 times the State-wide average for HC, CO, and NOx.

[3]ESP will cap the Vehicle Specific Power (VSP) for making CO high-emitter determinations. The following are suggested based on experience in the Colorado high-emitter pilot:
- 1995 & older - max 20 kw/t
- 1996 - 2001 - max 25 kw/t
- ≥ 2002 - max 30 kw/t

5.3 High-Emitters Identified

Figure 5-2 summarizes the numbers gasoline high-emitters identified by model year and pollutant. Overall, 4,645 (2.7%) gasoline vehicles were identified as high-emitters. Models older than 1986 and newer than 2009 were exempt from the I/M Program and not reviewed for being high-emitters.

The red line (HE Rate) indicates the % of vehicles measured on-road that met the high-emitter criteria. High-emitter rates increased with model/age. For 2008 models the rate was 0.4%. For 1986 models the rate was over 20%.

By pollutant, 1.3%, 0.7%, 1.0% and 0.1% of gasoline vehicles were high-emitters of HC, CO, NO and UV smoke respectively. The percentages by pollutant add to more than the overall 2.7% rate because some vehicles were high-emitters of more than one pollutant.

Gasoline high-emitters of CO were more skewed toward newer models than high-emitters of other pollutants. Among 2008 models, 0.29% were high-emitters of CO and 0.16% were high-emitters of one of the other three pollutants. CO emission concentrations are dependent on engine mode. It is quite likely that some of high CO emissions measured were transitory, e.g. as a result of rapid accelerator pedal movement, and not typical of the vehicle's overall emissions performance. We have seen in other high-emitter programs[7] that CO emissions are more variable than other pollutants. It is recommended that two measurements of high CO be obtained before tagging a vehicle as a high CO emitter.

Figure 5-3 summarizes the 74 (1.5%) light-diesel high-emitters identified. Although the rate of high-emitters was as high as 6% for older light-duty diesel models the increase in high-emitter rates between newer and older models was less than for gasoline vehicles. Newer light-duty diesel models were more likely to be high-emitters than newer gasoline vehicles.

Most of the diesel high-emitters were smoke emitters. By pollutant the diesel high-emitter percentages were 0.1%, 0.0%, 0.0%, 0.6% and 1.4% for HC, CO, NO, UV smoke and visible smoke respectively. Nearly all the diesel UV Smoke high-emitters (30/33) were also Visible Smoker high-emitters.

Figure 5-2: Gasoline: High-Emitters Identified

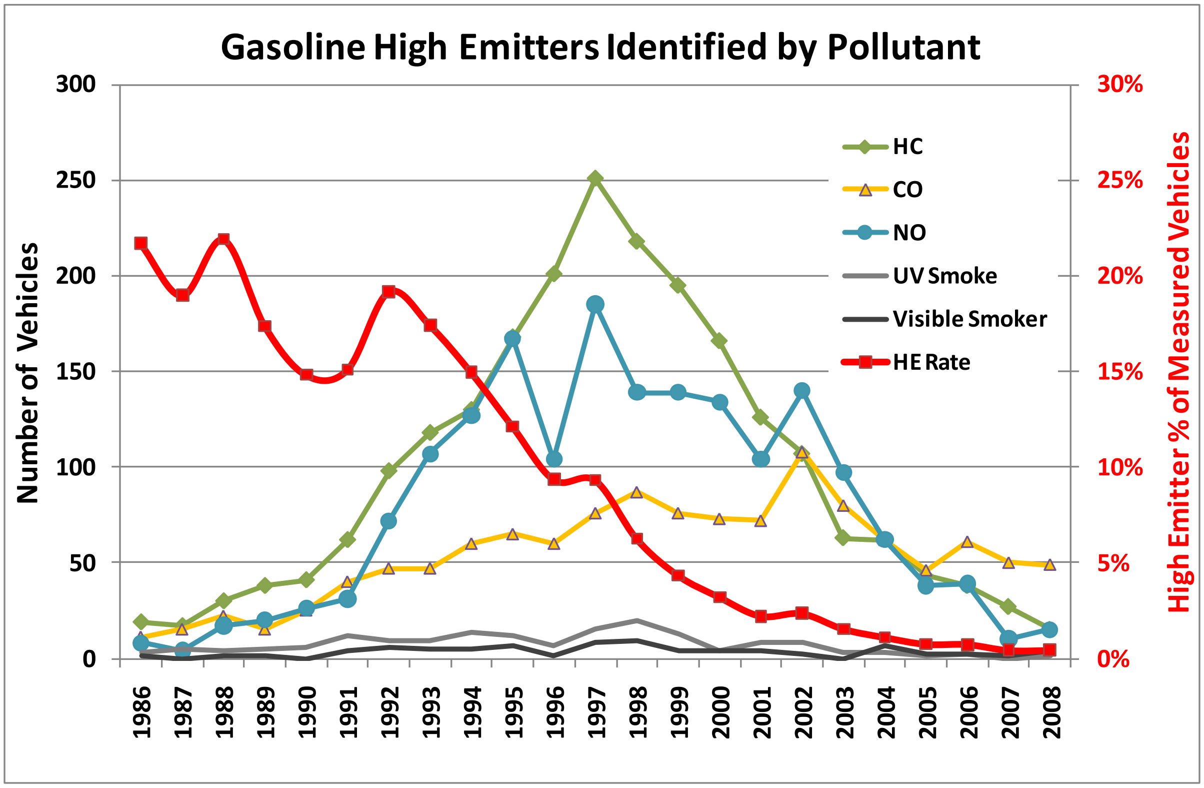
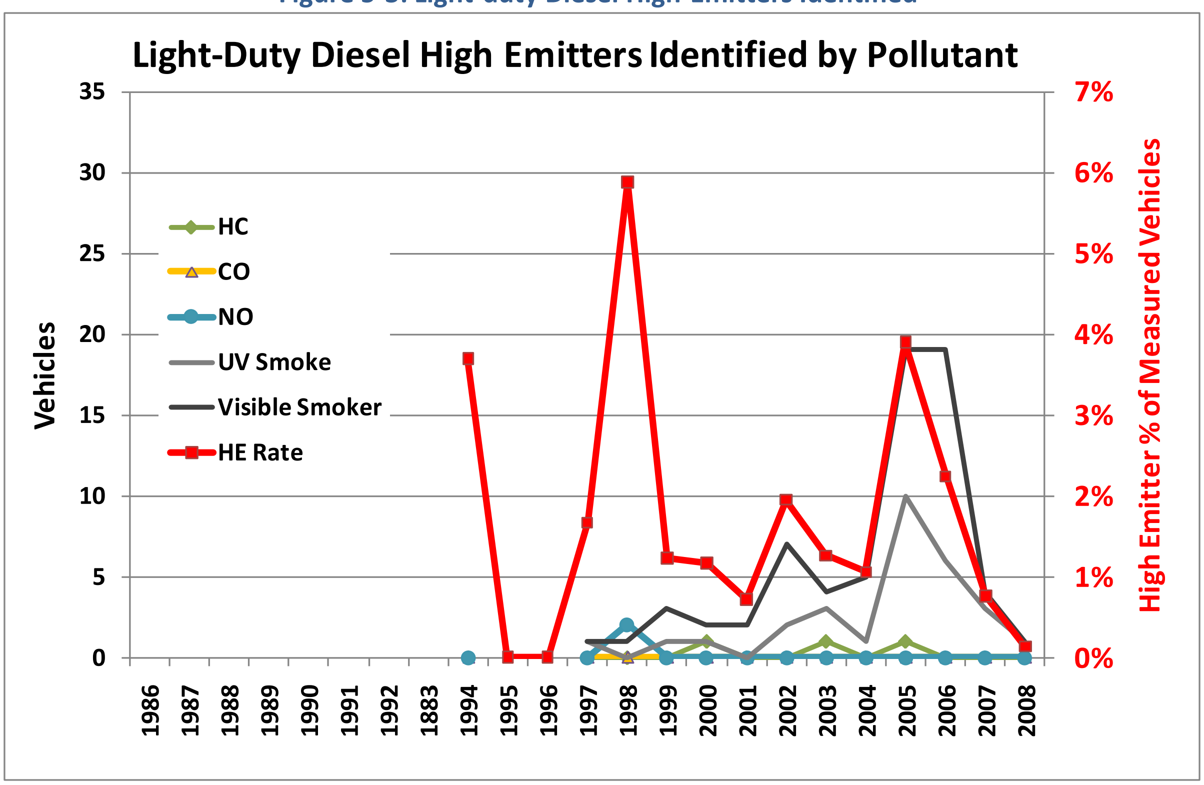
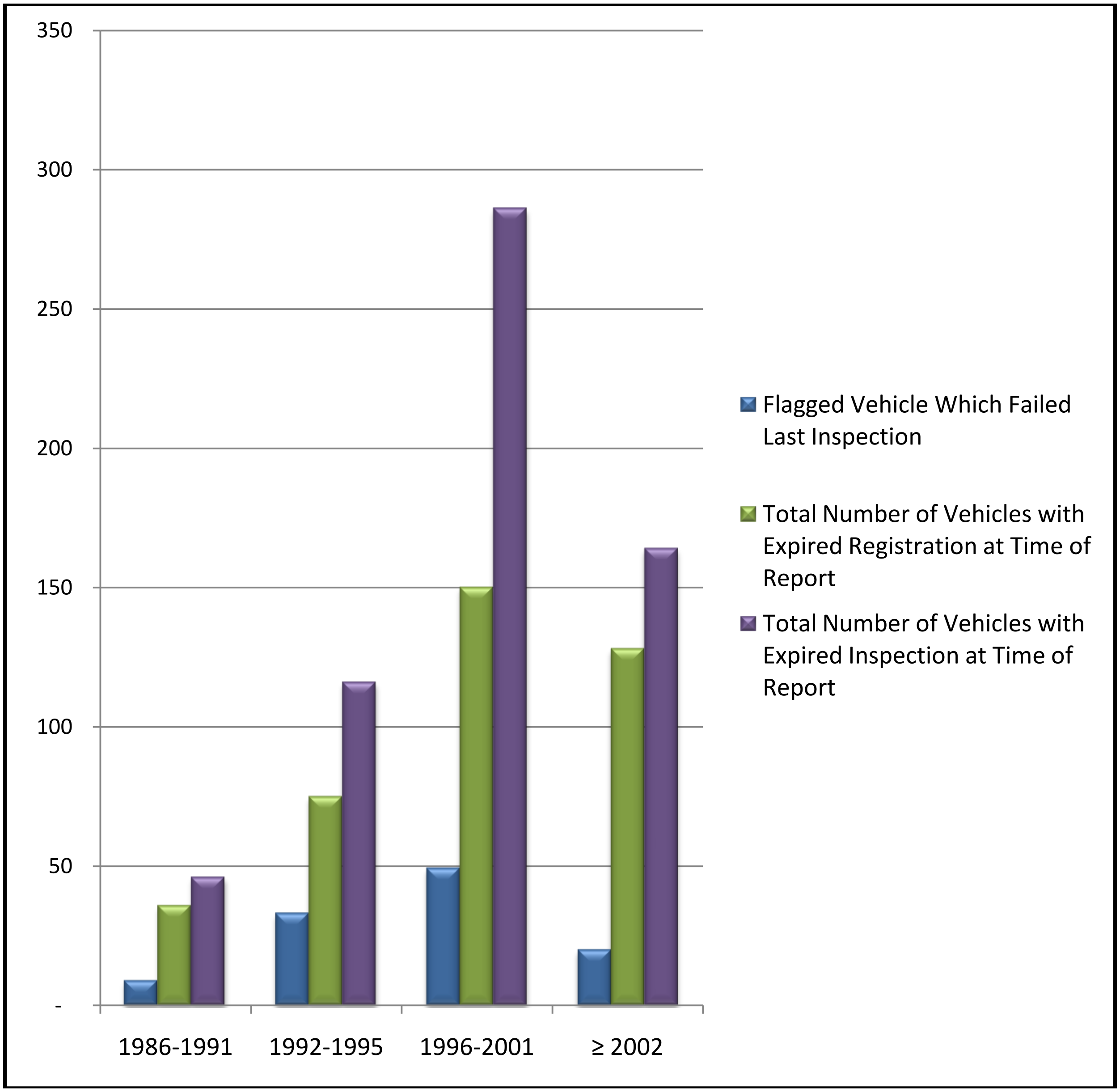


Figure 5-3: Light-duty Diesel High-Emitters Identified



High-emitters were more likely than other vehicles to have failed their last inspection, to have an expired inspection and to have an expired registration. Figure 5-4 shows the number of vehicles in each of these three categories.

Figure 5-4: Failed Last Inspection, Expired Inspection and Expired Registration



NCTCOG mailed notices to all identified high-emitters. The letter informed vehicle owners they were identified as either a high-emitting or smoking vehicle and encouraged them to have their vehicle tested and repaired, if necessary. The letter also briefly explained the current Texas statutes related to high-emitting and smoking vehicles. The notice letter also provided information on the AirCheckTexas Drive a Clean Machine Program to offer assistance to vehicle owners. Figure 5-5 represents the individual vehicle owners who had an expired or failing inspection at the time their vehicle was identified as a high-emitter. Of those vehicles represented in the Figure, the graph shows who obtained an emissions inspection at 2, 4, 6, 8 and 9+ weeks after receiving the notice from NCTCOG. The "No Inspection" column represents those vehicles not receiving a current inspection.

Figure 5-5: Response to Notice Letter

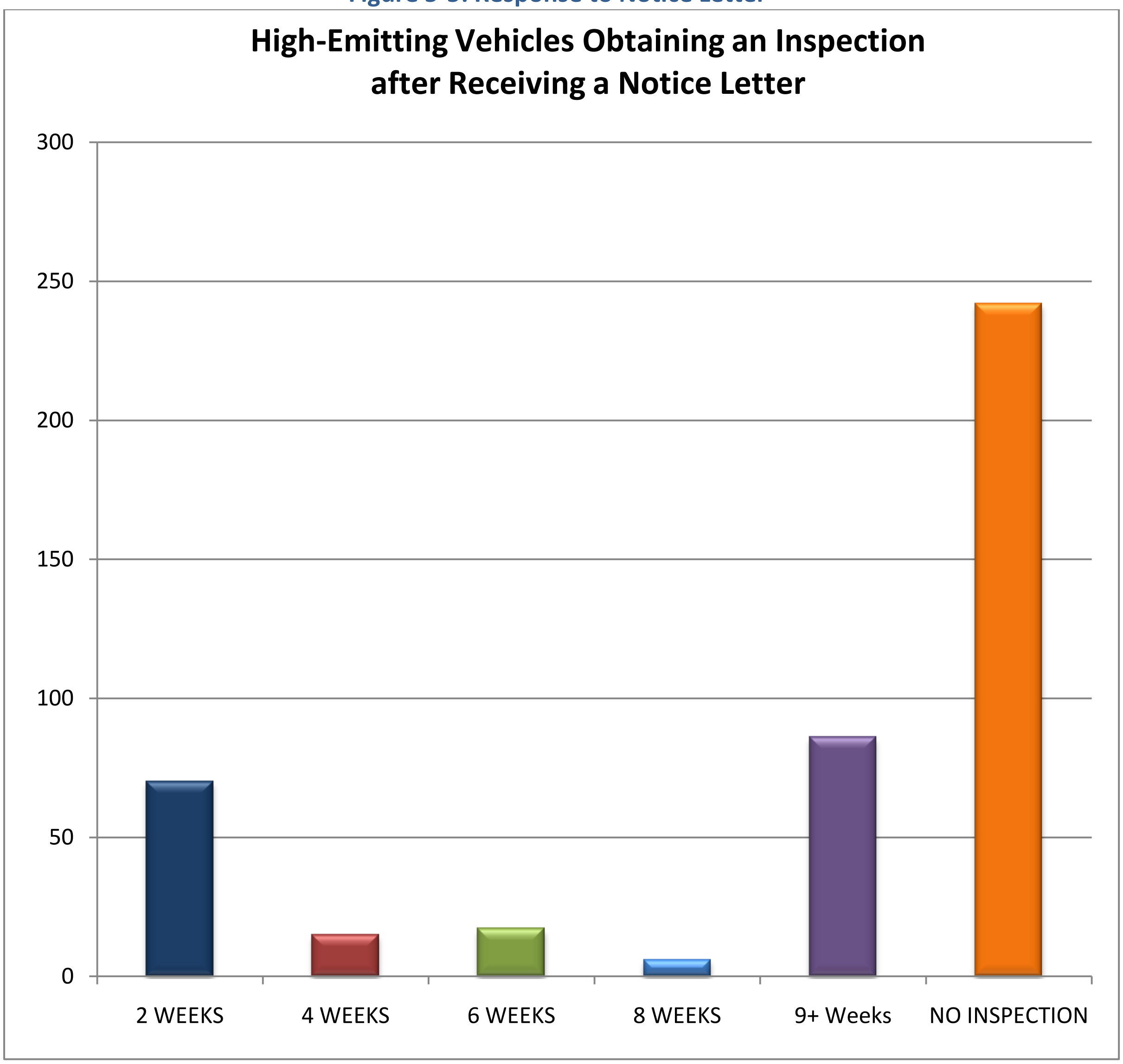
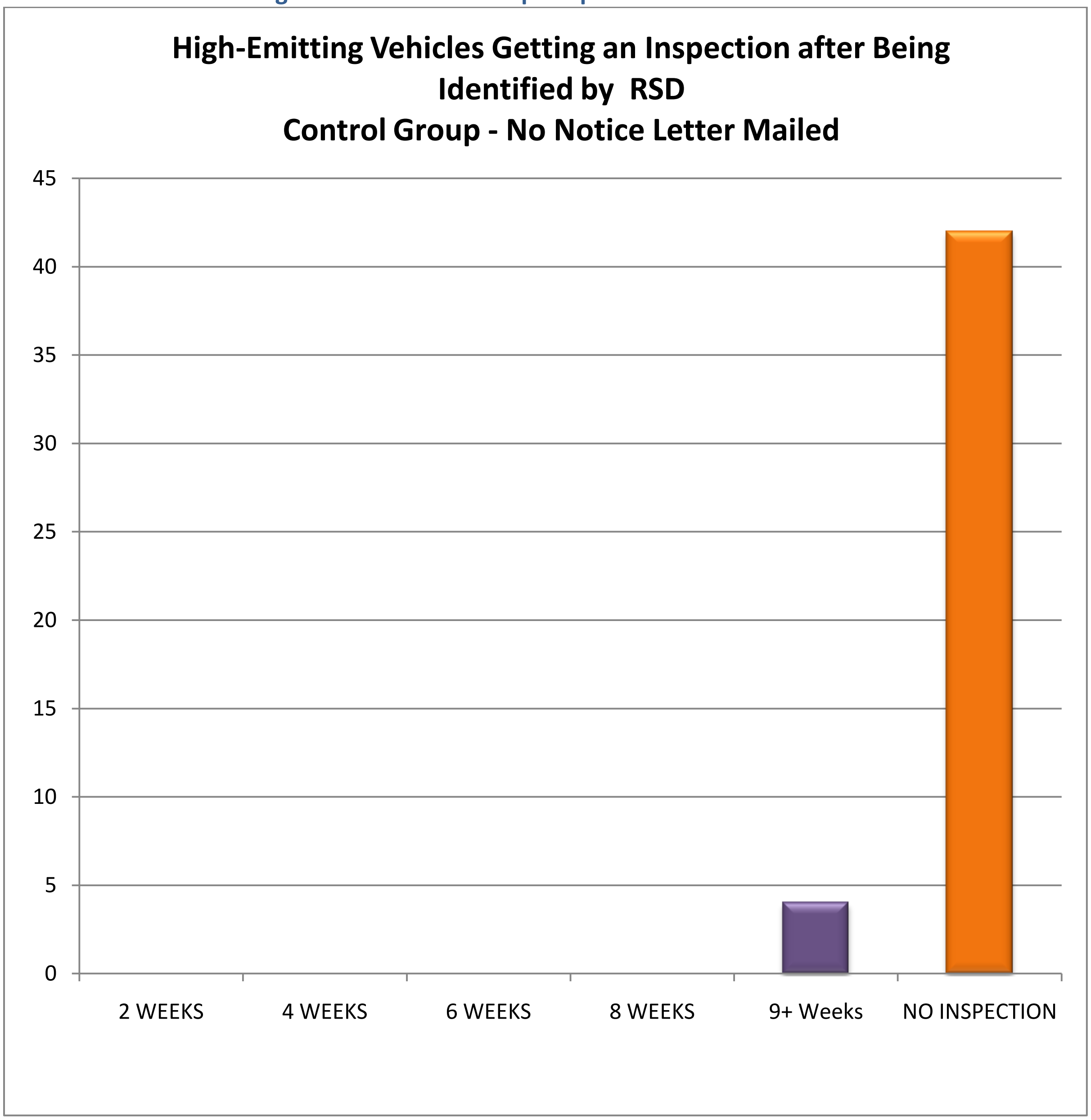


Figure 5.6 represents the high-emitting vehicles with expired or failing inspection certificates identified by the remote sensing van in September. In order to provide a control group, notices were not mailed to these vehicle owners. The purpose of the control group was to provide a baseline to determine the effect a notice letter had on vehicle owners obtaining a current inspection. When a notice was not mailed, the results showed the majority of the vehicle owners continued to operate their vehicles without a valid inspection certificate.

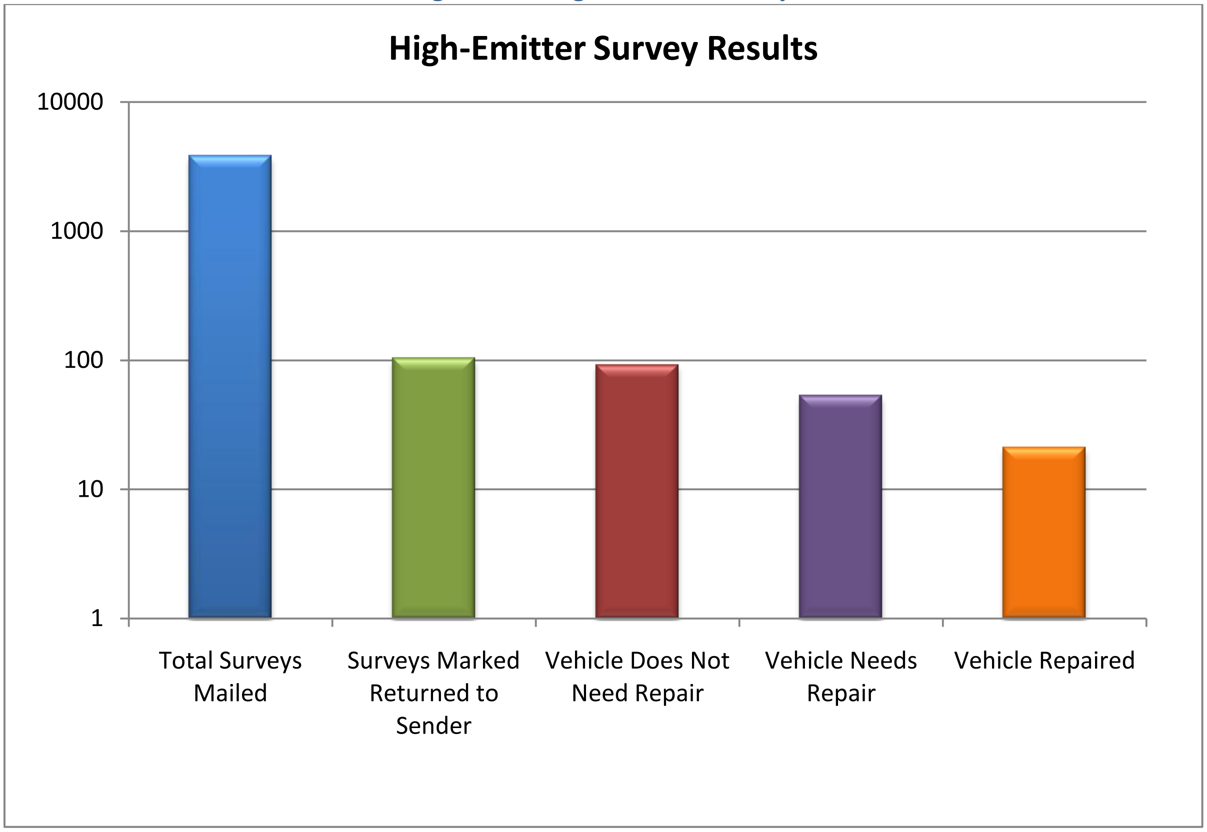
Figure 5-6: Control Group Response to Notice Letter



When comparing Figures 5.5 and 5.6, the results indicate the notice letter did have an impact on vehicle owners obtaining a current inspection certificate. The results showed 25% of the vehicles obtained an inspection within eight weeks of receiving the notice letter. Figure 5.5 and 5.6 show a correlation with a spike in vehicle inspections beyond eight weeks suggesting the notice letter had little, if any impact past this point. Overall the results indicate the majority of vehicle owners driving with expired or failing inspection certificates continue to do so, even when notified they are in violation of state law. While the data indicates mailing out notice letters resulted in 25% of the vehicle owners coming into compliance, the majority of people ignoring them is evident of the need to increase enforcement and implement other strategies to ensure compliance between annual inspections.

Figure 5-7 shows the results of the high-emitter survey. The survey form was mailed to 3,786 vehicle owners. The chart represents both verbal and mailed in survey results (the graph's y axis is in log scale).

Figure 5-7: High-Emitter Survey



5.4 Average Emissions of RSD High-Emitters

ESP examined the RSD average emissions of high-emitting vehicles identified and the results are presented in Figure 5-8 and Table 5-4. These are the average emissions of all high-emitters independent of the pollutant for which they were high. A vehicle with high HC may have low NO. Thus high HC emitters will tend to reduce the NO high-emitter average value and vice versa.

Despite this dilution, high-emitter average values were typically many times the fleet average. Gasoline high-emitters had emissions 10, 18, 7 and 10 times the average on-road gasoline vehicle for CO, HC, NO and particulates, respectively.

Diesel high-emitters had emissions 6, 3, 1 and 5 times the average on-road diesel vehicle for CO, HC, NO and particulates, respectively.

Figure 5-8: Average Emissions of High-Emitters

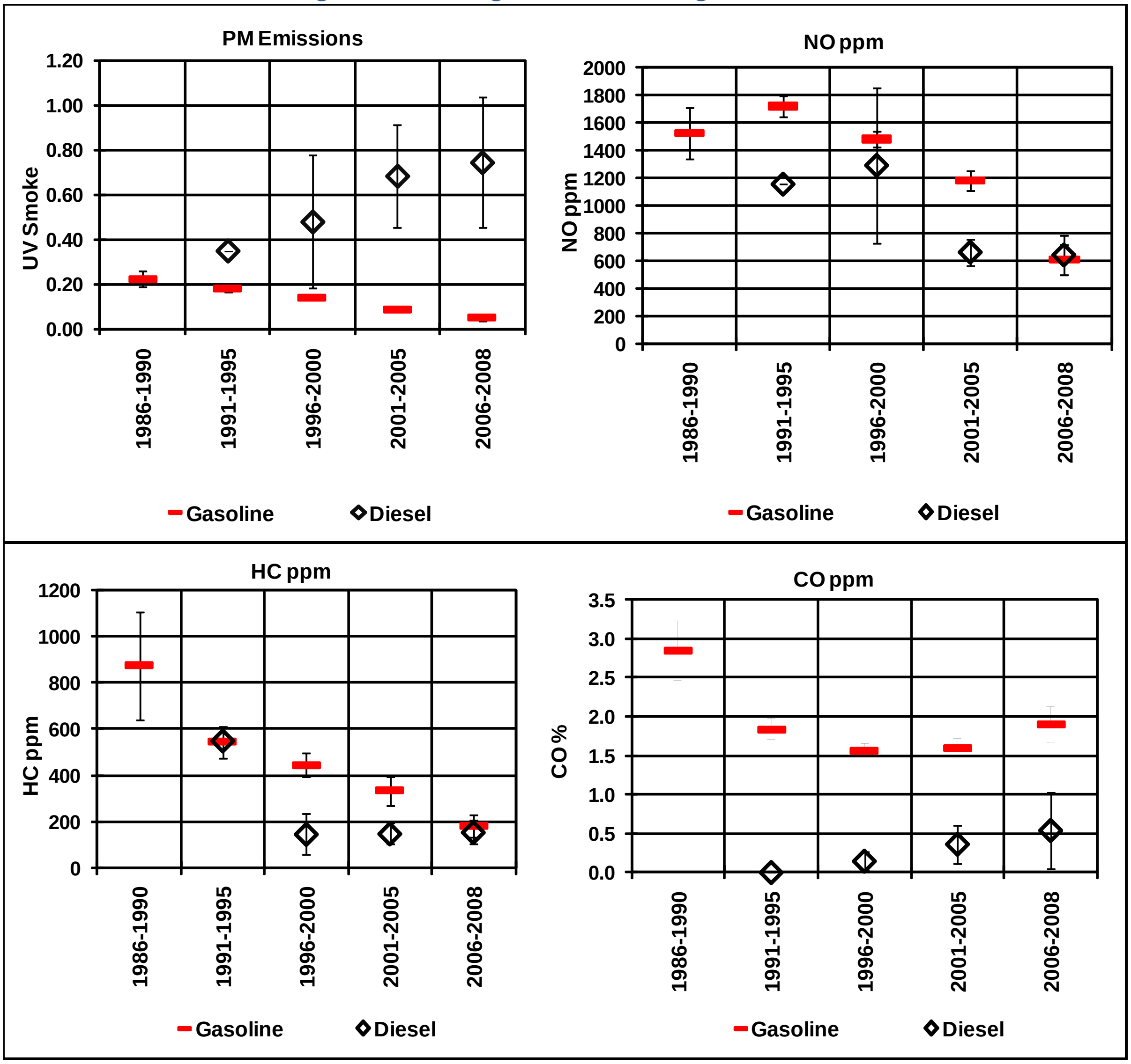


Table 5-4: High-Emitter Average Emissions

Model Years	Vehicles	Gasoline High Emitters			
		CO %	HC ppm	NO ppm	Smoke Factor
1986-1990	252	2.8	874	1,525	0.22
1991-1995	1,156	1.8	544	1,719	0.18
1996-2000	1,833	1.6	446	1,483	0.14
2001-2005	1,106	1.6	333	1,179	0.09
2006-2008	298	1.9	182	607	0.05
Total	**4,645**	**1.7**	**450**	**1,415**	**0.13**

Model Years	Vehicles	Diesel High Emitters			
		CO %	HC ppm	NO ppm	Smoke Factor
1986-1990	0	n/a	n/a	n/a	n/a
1991-1995	1	0.0	550	1,155	0.35
1996-2000	10	0.1	147	1,292	0.48
2001-2005	39	0.4	149	661	0.68
2006-2008	24	0.5	155	641	0.74
Total	**74**	**0.4**	**156**	**746**	**0.67**

The emissions contributions of high-emitters were estimated using the same simplified calculations described in section 3. Table 5-5 and Figures 5.9 and 5.10 show the high-emitter contributions to total emissions by fuel and the portion coming from each model year range.

Among gasoline vehicles, 1996 to 2000 model high-emitters were the largest contributors to HC emissions. The 1991 to 1995 model high-emitters were the second largest contributor even though there were relatively few of these models remaining in operation.

Among light-duty diesels, the 2001 to 2008 model high-emitters contributed the most to total emissions. The high-emitter diesels emitted 9% of total diesel PM and their PM emissions rate was over five times the average (9% of emissions from 1.5% of vehicles).

Figure 5-9: Gasoline High-Emitter Contributions

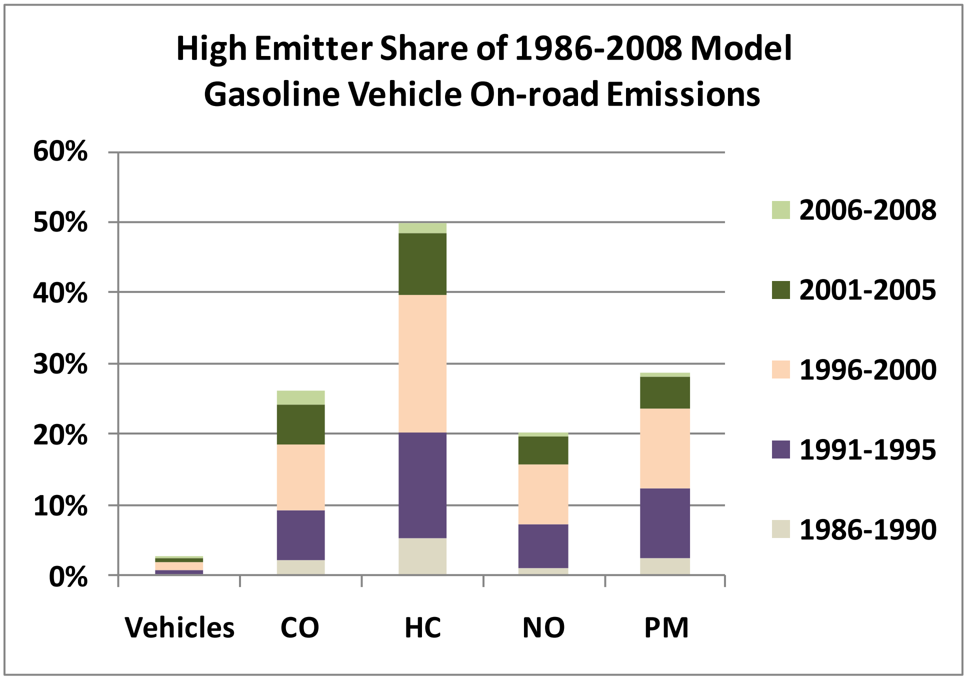


Figure 5-10: Light-Duty Diesel High-Emitter Contributions

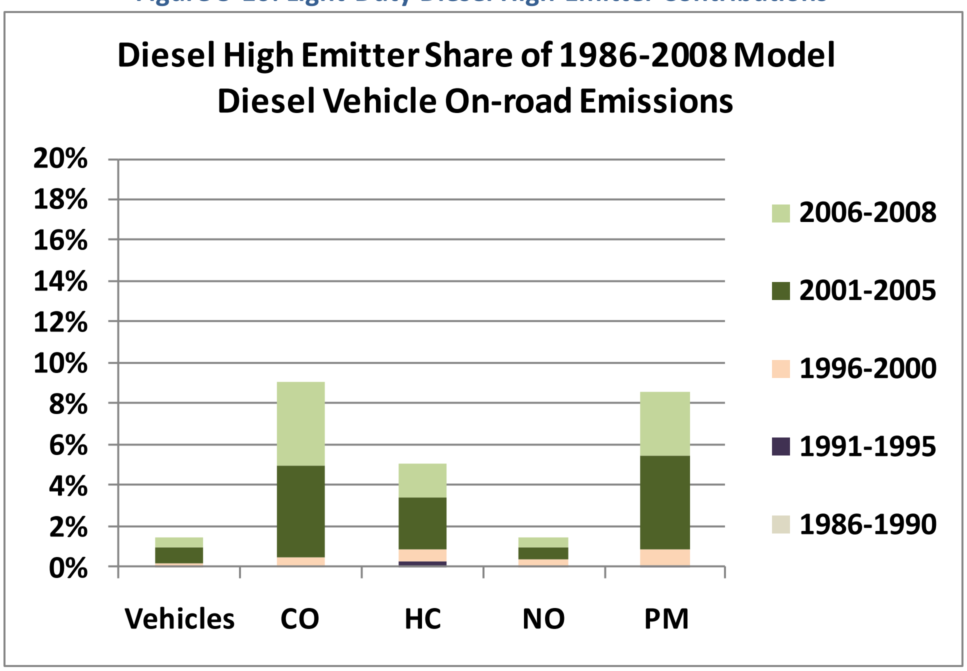


Table 5-5: High-Emitter Emission Contributions

Model Years	Vehicles	Gasoline HE Contributions			
		CO	HC	NO	PM
1986-1990	0.1%	2%	5%	1%	3%
1991-1995	0.7%	7%	15%	6%	10%
1996-2000	1.1%	9%	19%	8%	12%
2001-2005	0.6%	6%	9%	4%	4%
2006-2008	0.2%	2%	1%	1%	1%
Total	2.7%	26%	50%	20%	29%

Model Years	Vehicles	Diesel Vehicle HE Contributions			
		CO	HC	NO	PM
1986-1990	0.0%	0%	0%	0%	0%
1991-1995	0.0%	0%	0%	0%	0%
1996-2000	0.2%	0%	1%	0%	1%
2001-2005	0.8%	4%	3%	1%	5%
2006-2008	0.5%	4%	2%	0%	3%
Total	1.5%	9%	5%	1%	9%

5.5 RSD High-Emitters Using Different Standards

ESP examined the vehicles that would have been identified by different on-road emissions standards using a single RSD measurement at the DPS standards (see Table 5-2) and the revised NCTCOG study standards level 1 and 2 (see Table 5-3).

Figure 5-11 shows the number of vehicles identified by each set of standards and by pollutant. In moving from the DPS to NCTCOG level 2 cutpoints, the percentages of measured vehicles identified as high-emitters increased from 0.6% to 1.3% for HC, from 0.5% to 0.7% for CO and from 0.2% to 1.0% for NOx. The same standards were used for smoking vehicles in each case.

Figure 5-11: High-Emitters Identified by Cutpoints

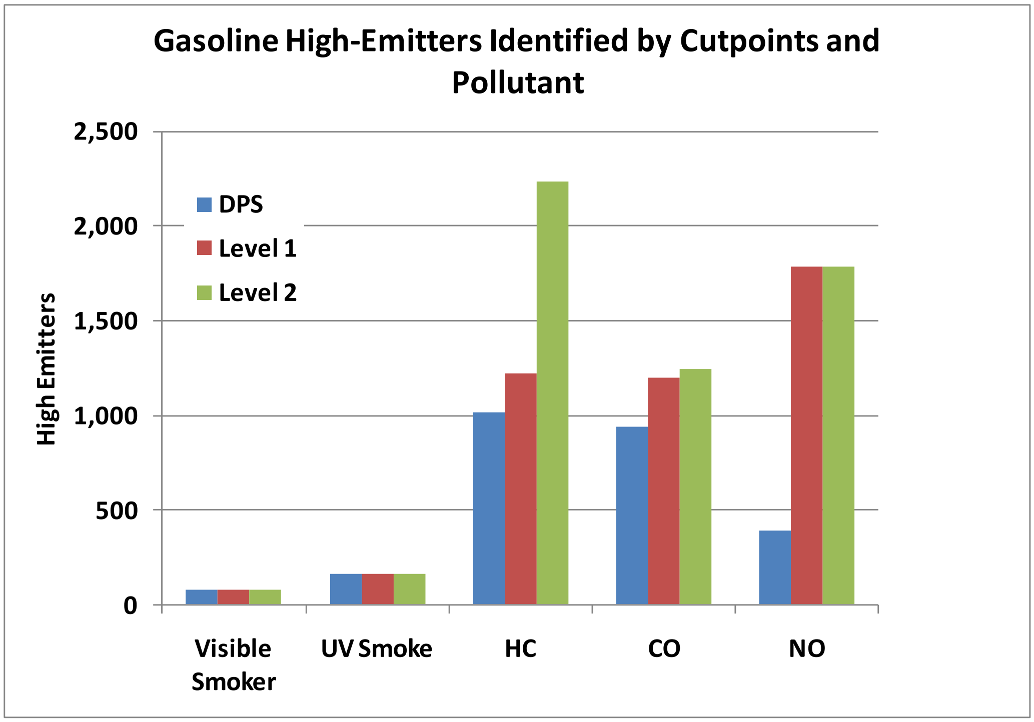


Table 5-6 lists the number of vehicles identified by each set of standards and by pollutant. Light diesel high-emitters are shown for information although they are not currently required to be inspected. Some vehicles were high-emitters of more than one pollutant.

The NCTCOG level 1 standards identified 79% more vehicles than the DPS standards. Identified HC and CO high-emitters increased by 20% and 28% respectively and NO high-emitters by over four times. The range of NOx emissions is less extreme than for HC and CO emissions. Therefore, the same % change in the NOx standard vs. HC or CO standards can result in a relatively larger change in the number of high-emitters. The NCTCOG level 2 standards increased the overall number of high-emitters identified by a further 19% with most of the increase being in HC high-emitters, which increased by 83%.

The vehicles listed in Table 5-6 were identified as high-emitters using a single RSD measurement. DPS on-road high-emitter rules currently require two on-road measurements exceed the standards, which very substantially reduces the number of qualifying high-emitters. The northern Virginia I/M Program, which also previously required two RSD measurements, in 2009 introduced the use of either two RSD measurements or a single measurement and a High-Emitter Index (HEI) to improve the numbers of high-emitters identified. The HEI is used to qualify a vehicle if the vehicle model is among the 25% of vehicles with the highest I/M failure rates.

Table 5-6: High-Emitters Identified at Different Standards

Gasoline: 1986-2008 models			
High-Emitters	**DPS**	**Level 1**	**Level 2**
Visible Smoker	78	78	78
UV Smoke	164	164	164
HC	1,018	1,224	2,236
CO	938	1,197	1,245
NO	392	1,785	1,785
Any Pollutant	**2,182**	**3,905**	**4,640**
% of vehicles	**1.3%**	**2.3%**	**2.7%**
Diesel: 1986-2008 models			
High-Emitters	**DPS**	**Level 1**	**Level 2**
Visible Smoker	69	69	69
UV Smoke	29	29	29
HC	8	10	19
CO	2	4	4
NOx	1	2	2
Any Pollutant	**72**	**73**	**74**
% of vehicles	**1.5%**	**1.5%**	**1.5%**

Figures 5-12 through 5-14 illustrate the number of high-emitters by model year for each of the three sets of standards.

Figure 5-12: High-Emitters Identified at DPS Standards with a Single Measurement

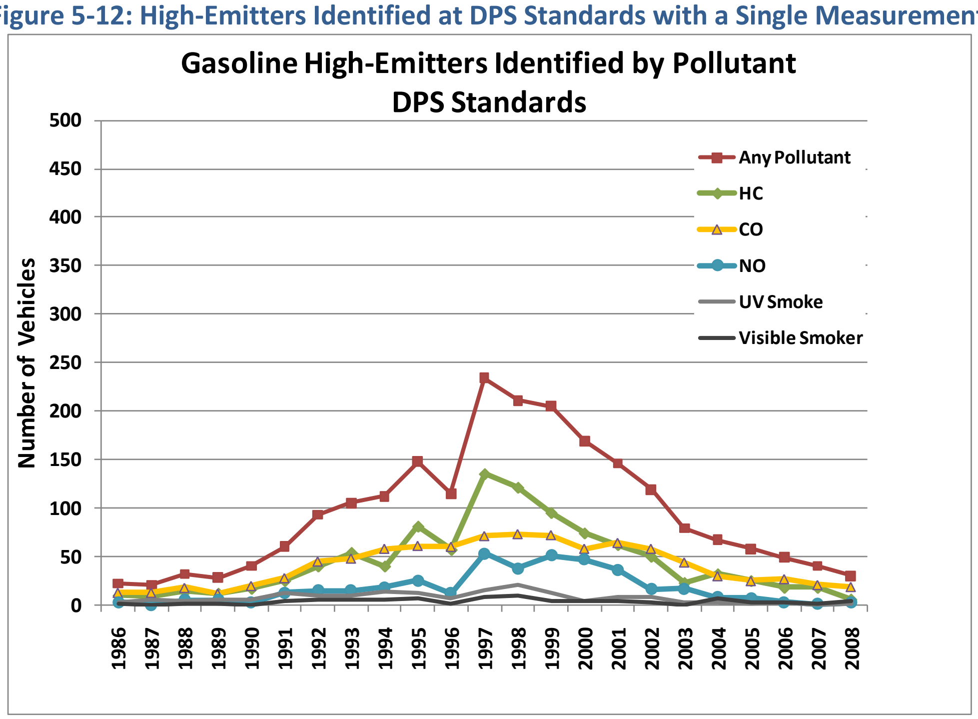


Figure 5-13: High-Emitters Identified with Revised NCTCOG Level 1 Standards

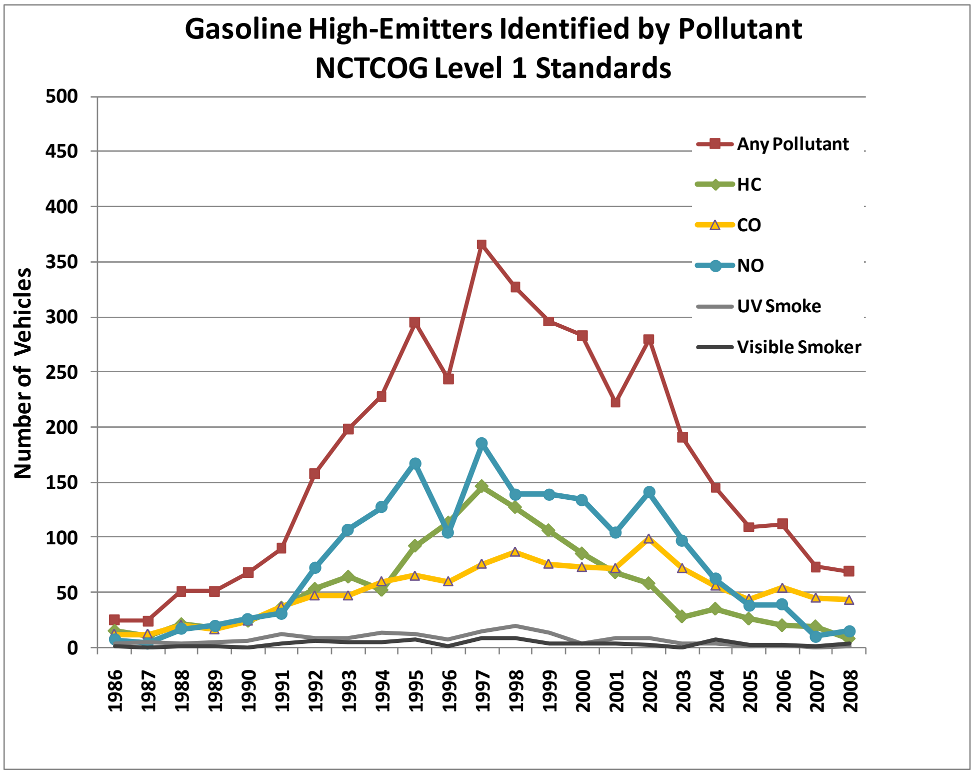
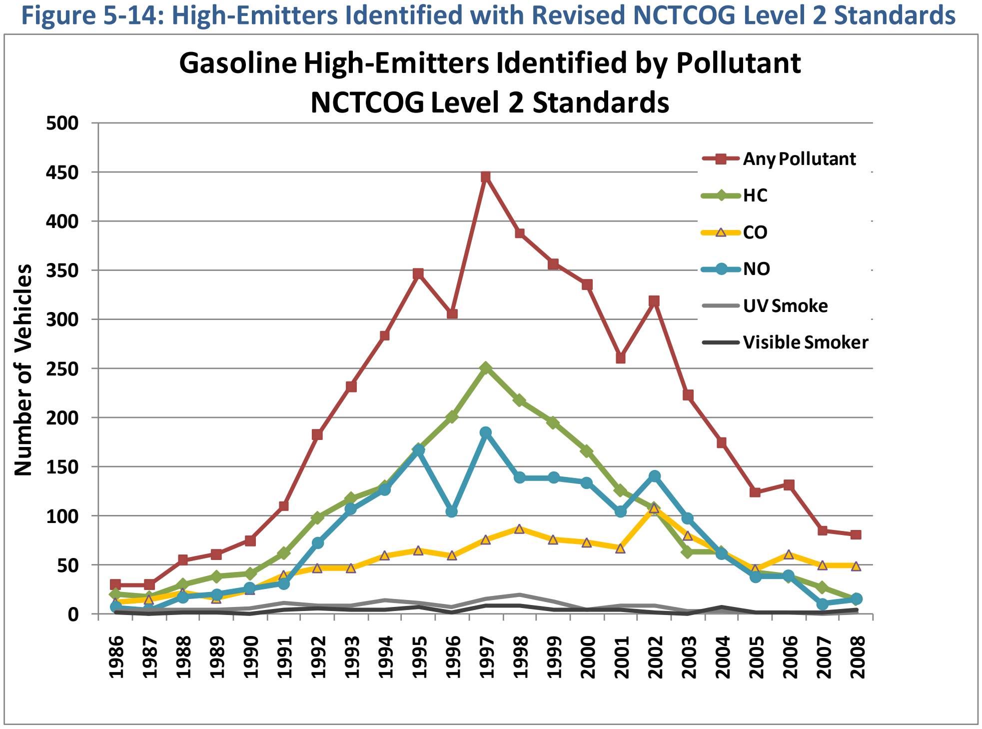


Figure 5-14: High-Emitters Identified with Revised NCTCOG Level 2 Standards



5.6 Registration Compliance

ESP reviewed registration expiration dates of vehicles measured on-road in the nonattainment counties. Figures 5-15 and 5-16 show the registration expirations by period and by month for vehicles: registered in the nonattainment region, registered elsewhere and high-emitters.

Vehicle registration information was obtained in December 2010. Vehicles with up-to-date registrations in December 2010 had registrations that were good until sometime between December 2010 and November 2011. The monthly pattern of registration expirations the second half of 2010 does not show a steady trend as might have been expected. However, over 95% of vehicles registered in the nonattainment region had expiration dates of June 2010 or newer. For vehicles registered to other jurisdictions and high-emitters the corresponding percentages were 90% and 92%. Almost 8% of high-emitters and 9% of vehicles registered outside the region had significantly expired registrations.

Figure 5-15: Registration Expirations by Period

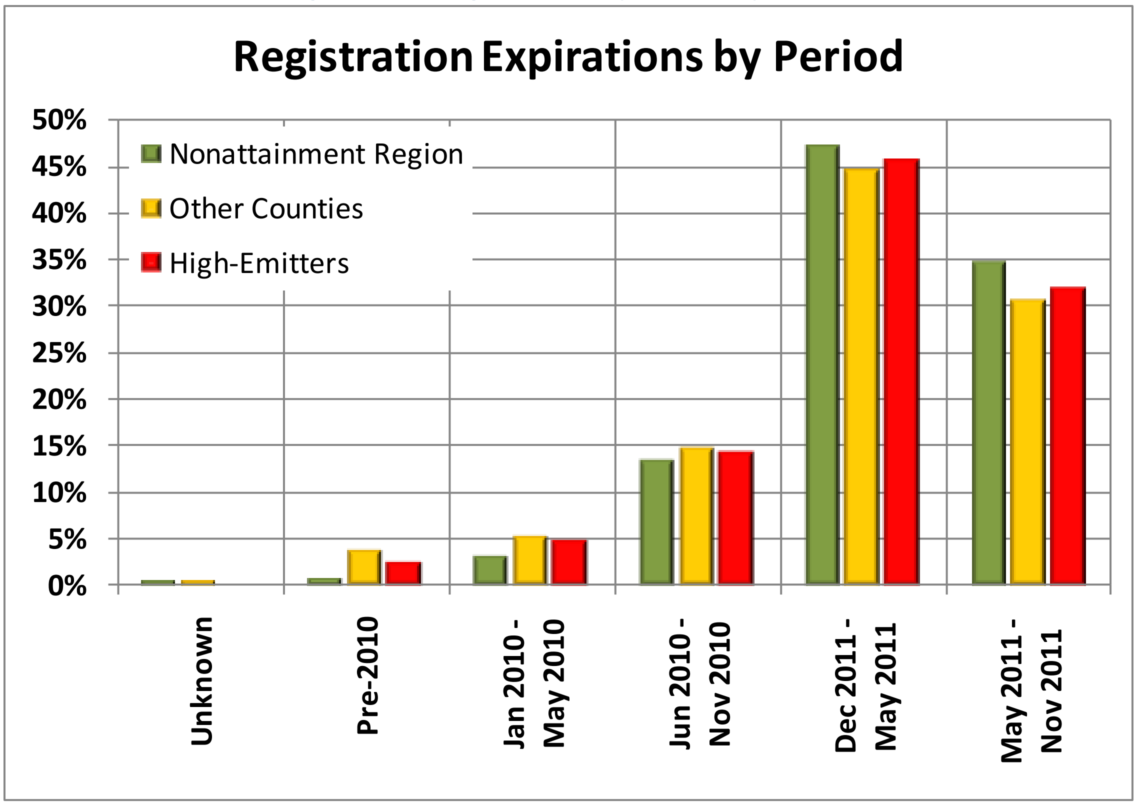
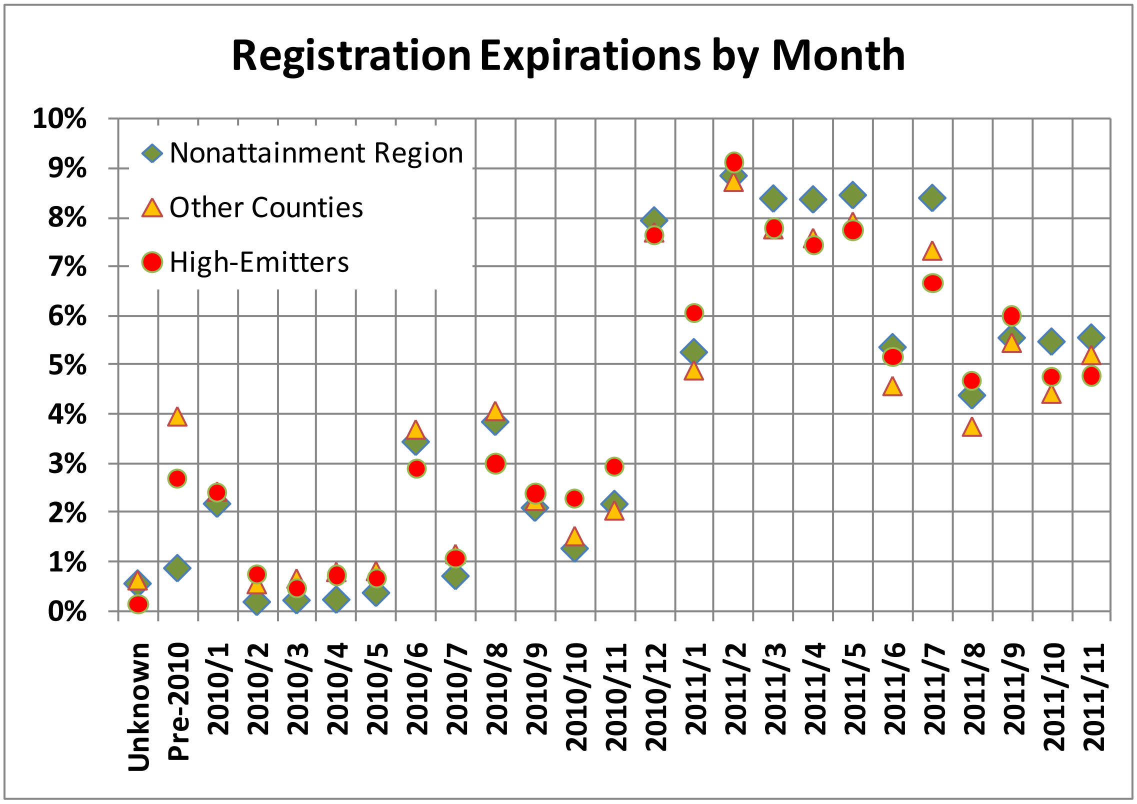


Figure 5-16: Registration Expirations by Month



6 Using RSD for Program Performance Monitoring

Remote sensing can easily be used to develop a database with millions of on-road vehicle emission measurements annually to provide a comprehensive picture of the active light-duty vehicle fleet. As shown in sections 4 and 5 these data can be used to assist I/M Programs achieve their goals by:

- Identifying vehicles operating within the I/M area that are not registered locally;
- Identifying vehicles not in compliance with their inspection requirements; and
- Identifying high-emitting and smoking vehicles.

In addition, the database can be used for:

- Monitoring the effectiveness of I/M procedures and rules;
- Monitoring the effectiveness of the I/M inspections and repairs at a station or inspector level;
- Monitoring the effectiveness of types of repair; and
- Monitoring the emissions of specific classes and models of vehicles.

As an example of monitoring the effectiveness of specific inspection procedures, RSD has been used to estimate the emissions impact of the optional OBD I/M readiness exemptions allowed by EPA and have been adopted by most states. An analysis performed with Virginia DEQ showed readiness exemptions reduce program effectiveness by up to 50%[8]. The example tables below are copied from the report and show the on-road emissions of vehicles before and after the inspection and repair cycle according to their inspection result and their OBD catalyst monitor status recorded during their initial test. There are several points to note:

- The 2,394 vehicles passing the OBDII test with the catalyst monitor not ready were numerically more than half the number (54%) of those initially failing OBD for any reason.
- Vehicles passing OBD with the monitor not ready had higher average emission than the vehicles failing OBD (except for those failing OBD with monitors not ready).
- Vehicles that initially failed the OBD inspection had lower emissions after the test and repair cycle. Their emissions were reduced.
- Vehicles that passed the initial inspection with the catalyst monitor not ready had similar emissions after the inspection as before. There was no reduction in their emissions.
- A small number of OBDII tests had the catalyst monitor reported as unsupported and these were to be investigated.

Virginia Table 6-3 On-road Emissions by Catalyst Monitor Status before OBD Test

RSD Emissions within 180 days before OBD I/M Test						
Catalyst Monitor Status						
Test Result	Catalyst Mon	Vehicles	HC ppm	CO %	NO ppm	VSP
OBD Pass	Ready	75,712	7	0.07	93	12.4
	Not Ready	2,394	27	0.24	350	12.2
	Unsupported	112	36	0.21	251	12.6
OBD Fail	Ready	3,981	21	0.19	244	12.2
	Not Ready	463	51	0.34	434	12.5
	Unsupported	10	32	0.06	177	8.9
Overall		**82,672**	**8**	**0.08**	**110**	**12.4**

Virginia Table 6-4 On-road Emissions by Catalyst Monitor Status after OBD Test

RSD Emissions within 180 days after OBD I/M Test						
Catalyst Monitor Status						
Test Result	Catalyst Mon	Vehicles	HC ppm	CO %	NO ppm	VSP
OBD Pass	Ready	63,684	8	0.07	96	12.4
	Not Ready	2,168	31	0.22	344	12.2
	Unsupported	102	13	0.08	243	13.0
OBD Fail	Ready	3,189	17	0.16	219	12.2
	Not Ready	354	31	0.23	375	12.1
	Unsupported	5	88	0.38	1012	9.9
Overall		**69,502**	**9**	**0.08**	**111**	**12.4**

RSD data can provide a supplement to the various quality assurance and station audit procedures typically used by decentralized I/M Programs to ensure effective program performance. Average on-road measurements following station inspections can show statistically significant differences in average emissions for similar vehicles inspected at different stations.

Given adequate repair data, the performance of specific types of repair can be tracked over time through on-road measurements. This may identify problems with replacement components, e.g. short lived catalytic converter replacements, or incomplete repairs, e.g. a 'tune-up' rather than a component replacement. These types of data can provide feedback to the repair industry.

Estimates of the relative mass emissions contributions from all classes of light and medium-duty vehicles, including tested and untested vehicle classes, can be determined from their on-road emissions, fuel economy and frequency of observation. Emissions distributions can be reviewed to estimate the potential excess emissions from the different classes of vehicles. This information can be used include additional vehicles that have large potential benefits or to exclude those with very little potential benefits.

Through these methods, comprehensive on-road monitoring of vehicle emissions can enhance I/M Programs and increase emission reductions. This becomes more important as station based measurement of vehicle emissions is no longer performed for most vehicles and I/M Programs rely solely on snapshot data from the vehicle manufacturer OBD-II systems.

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