ENVIRON

MEMORANDUM

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Houston Advanced Research Center

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Subject: Revised Emission Inventories for On-road Diesel Vehicles and Off-road Diesel Equipment in the Houston-Galveston Area

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INTRODUCTION

In October 2003, the Houston Advanced Research Center (HARC) retained ENVIRON International (ENVIRON) to carry out HARC Project H20 entitled "Texas Emission Reduction Plan Assessment in the Houston-Galveston-Brazoria Region," to review and revise the emission inventories for on-road and off-road mobile sources in the Houston Galveston Area (HGA) for the mid-course review, and to assess the Texas Commission on Environmental Quality (TCEQ)'s Texas Emission Reduction Plan (TERP) and Houston-Galveston Area Council (H-GAC)'s Voluntary Mobile Source Emissions Reduction Program (VMEP).

For this project, ENVIRON is to review EPA certified/CARB verified and emerging NOx emission reduction technologies for on-road vehicles and for off-road vehicles and equipment, and to assess and document the emission benefits, cost and availability of theses technologies.

In addition to the technology review, ENVIRON is to review and assess the emission reductions achieved to date from the TERP and H-GAC programs, and to review and document the development, implementation and evolution of the California Carl Moyer program for experience learned from the TERP and H-GAC programs.

Finally, based on the results of the technology review, TERP, H-GAC and Carl Moyer program assessments, ENVIRON is to develop an action plan that includes recommendations on program improvements and/or enhancements for the TERP and H-GAC programs, and promising control measures and timeline with the goal of achieving the mandatory emission reduction.

This technical memorandum presents the results of the emission inventory task. Following this introduction section, the next section provides the background for the emission inventory task. The following two sections present the results of the revised emission inventories for on-road vehicles and for off-road vehicles and equipment. Finally, the last section discusses a methodology to scale annualized emission reductions that are reported in the TERP and VMEP programs to the episodic design day emission reductions as presented in the SIP.

The scope of work for the emission inventory review and revision task for the project is as follows:

- Compile and review existing emission inventories for on-road and off-road mobile sources in the Houston Galveston Area (HGA), with emphasis on modeling assumptions and data used in developing the emission inventories;

- Identify and document modeling and assumption changes, and better or alternative data sources in the emission inventories since they were developed;

- Discuss identified emission inventory modeling approach, assumption, and data changes with TCEQ, HARC and EPA to seek approval to incorporate these changes to develop revised emission inventories for the mid-course review and TERP/VMEP program assessments;

- Develop and present revised emission inventories with approved modeling approach, assumption and data changes; and

- Compare the existing and revised emission inventories and identify notable emission inventory changes, and prepare a technical memorandum documenting the assumptions, methodologies, data used in developing the revised emission inventories, and the revised emission inventory results.

BACKGROUND

The latest State Implementation Plan (SIP) revision that is applicable to the HGA was published by TCEQ[1] on September 26, 2001. One of the provisions in that SIP revision was to require the state of Texas to perform a mid-course review by May 1, 2004, and to include recalculations and a submittal of a revised motor vehicle emission budget (MVEB) using the latest planning assumptions and the MOBILE6 emission factor model for on-road vehicles.

The mobile source emission inventory in the current SIP is provided in Table 1. Many assumptions have changed since the development of these estimates. The notable changes include the introduction of a new on-road emissions model (MOBILE6), a new NONROAD2002 model for off-road vehicles and equipment, the adoption of the Texas Low Emission Diesel program (TxLED), and the estimation of emission impacts accounting for temperature and humidity effects. In order to properly assess the potential emission reductions from the TERP and VMEP programs, as well as to be consistent with the mid-course review emission inventories, it is essential to use the emission inventories that have accounted for these changes.

[1] TCEQ was then called Texas Natural Resources Conservation Commission (TNRCC).

Table 1. 2007 mobile source emission inventory from the current (2001) SIP.

Category	NOx (tpd)
Light-Duty Vehicles	100.9
Heavy-Duty Gasoline Vehicles	13.1
Heavy-Duty Diesel Vehicles	65.5
Construction Equipment	32.1
Shipping Total (Harbor and Push Boat)	41.7 (14.9)
Industrial	15.0
Lawn and Garden	1.2
Locomotive	12.1
Commercial	5.1
Airport Ground Support Equipment	6.0
Aircraft	7.4
Agricultural	12.9
Logging (forest products)	0.5
Recreational Marine	2.3
Recreational Equipment	0.0
Commercial Fishing Boats	2.2

Recognizing that TCEQ is in the process of revising the emission inventories for the mid-course review, and that revised emission inventories will not be available during the course of this project, ENVIRON has worked in parallel with the TCEQ emission inventory staff to generate the revised emission inventories for this project. These revised emission inventories will then be used as the basis for evaluating the TERP and VMEP programs.

DATA GATHERING AND EMISSION INVENTORY DEVELOPMENT APPROACHES

This section briefly discusses the data gathering and emission inventory development approaches for the task to review and revise the on-road and off-road emission inventories for the HGA. Detailed discussions are presented in the next two sections.

In order to generate the revised emissions inventories, ENVIRON first requested TCEQ emission inventory staff to provide the latest calendar year (CY) 2007 on-road and off-road emission inventories for the HGA where available and discussed with TCEQ their anticipated changes in preparing the revised remaining portions of emission inventories. As a result of this request, ENVIRON received some emission inventory data, but not the complete emission inventory as expected since TCEQ is still in the process of preparing these revised emission inventories.

For the on-road emission inventory, TCEQ provided the CY 2007 revised emission inventory data, broken down by vehicle class and model year. These on-road emission inventory data were generated using the MOBILE6 model, and had been corrected for the TxLED effects but not the NOx temperature/humidity effect. Using the temperature and humidity correction factors that were provided by ENVIRON to TCEQ, ENVIRON corrected the CY 2007 revised emission inventories for on-road vehicles to account for the NOx temperature/humidity effects.

For the off-road category, TCEQ was still working on generating the CY 2007 basic emission inventory using the NONROAD2002 model when ENVIRON requested the information. Therefore, ENVIRON had to generate the basis emission inventory for the project in-house using the NONROAD2002 model. In order to assure that the generated CY 2007 basic emission inventory will be consistent with what TCEQ will use in the revised SIP, ENVIRON has been working and communicating extensively with TCEQ to gather input files for the NONROAD2002 model for replicating the results for the CY 2003 emission inventory provided by TCEQ so that these input files could be used confidently to generate the CY 2007 emission inventory. While TCEQ was very helpful in providing information to assist ENVIRON in completing the CY 2007 emission inventory gathering and development, ENVIRON encountered challenges in getting consistent input files and information for the off-road emission data. However, after several rounds of interaction with TCEQ and internal data searching and discussions, ENVIRON managed to combine sufficient information to generate the input files for the NONROAD2002 model runs, and was able to replicate the CY 2003 emission inventory numbers provided by TCEQ. With the ability to replicate the CY 2003 emission inventory, ENVIRON was able to generate the CY 2007 basic emission inventory for off-road equipment for the HGA. Subsequently, ENVIRON corrected the CY 2007 basic emission inventory for the temperature/humidity effect using the temperature/humidity correction factors for off-road equipment developed by Environ for TCEQ.

ON-ROAD DIESEL VEHICLE EMISSION INVENTORY

This section discusses the origin of, as well as the procedures taken, to prepare the final on-road NOx emission estimates to be used in the assessment of the TERP and VMEP programs. Both the September 2001 SIP values and the results of this work are presented in this section for comparison. In order to put the updates into context, a brief description of the September 2001 SIP estimates is also provided.

The on-road NOx emission estimates from the September 2001 SIP were the same as those reported in the December 2000 SIP revision. For that revision, emission factors were estimated using the MOBILE5 model. That version of the MOBILE model did not account for regulations that have been promulgated recently, namely the Tier 2 vehicle emission standards and fuel specifications, Phase 2 RFG, the 2004 heavy-duty vehicle standards, and the 2007 heavy-duty vehicle and diesel fuel standards. Adjustments for these effects (except the Phase 2 RFG and 2007 HD standards) were made outside of the model using EPA guidance.

In January 2002, EPA introduced the latest version of MOBILE model, called MOBILE6. It includes the effects of all the recently adopted regulations as discussed above, as well as updates in emission rates, fleet characteristics, and modeling approach. One of the most significant changes in this revision is the inclusion of the off-cycle NOx emissions and the effects of the NOx emission standards pull-ahead agreement (from the heavy-duty vehicle Consent Decree). These changes generally have the effect of increasing heavy-duty NOx (relative to the MOBILE5 model) in historic years and decreasing NOx in future years (post 2007 due to the stringent

emission standards for MY 2007 HDDVs). However, MOBILE6 does not include the effects of temperature and humidity upon NOx emissions from heavy-duty vehicles.

For this effort, ENVIRON obtained MOBILE6-based 2007 emission estimates from TCEQ. These emissions correspond to episode day August 30th. A correction had been made by TCEQ to account for the effects of Low Emission Diesel fuel.

Using the following equation, ENVIRON then applied temperature/humidity correction factors (KNOx) to the emission inventory to correct for the temperature/humidity effect[2].

$$\text{NOx-adjusted} = \text{KNOx} * \text{NOx-inventory}$$

The correction factors (KNOx) for naturally aspirated and turbocharged diesel engines are as follows:

Naturally Aspirated

$$\text{KNOx} = 1 + 0.00076\,(T - 85) - 0.00216\,(H - 75)$$

Adjusted to consistent units C and g/kg

$$\text{KNOx} = 1 + 0.001368\,(T - 29.444) - 0.01512\,(H - 10.71)$$

Turbocharged

$$\text{KNOx} = 1 + 0.00446\,(T - 25) - 0.018708\,(H - 10.71)$$

where T = ambient temperature, ^{o}C
H = ambient humidity, g/kg

Application:
Model years <1994; 100% (Naturally Aspirated)
Model year 1994 and later; 100% (Turbocharged)

Heavy-duty diesel vehicles for model years prior to 1994 were assumed to be all naturally-aspirated. Thus, the emissions from these vehicles were corrected using the equation for naturally-aspirated engines. Likewise, 1994 and later models were assumed to turbocharged and the corresponding equation was used.

[2] SWRI, 2003. "Humidity and Temperature Correction Factors for NOx Emissions from Diesel Engines." Final Report prepared by Southwest Research Institute for Environ International Corp. June.

For the hourly temperature and humidity data that were required to calculate the KNOx values, the hourly temperature and humidity values for the August 30th, 2000 episode day for Harris County provided by TCEQ were used. Daily average correction factors were obtained by combining hourly corrections with the hourly VMT distribution as weighting factors.

The September 2001 SIP 2007 NOx emission estimates, the revised TCEQ estimates, and the revised TCEQ estimates with temperature/humidity corrections for heavy-duty diesel vehicles in the HGA are presented in Table 2. The revised 2007 NOx emission inventory for on-road heavy-duty diesel vehicles by model year and vehicle class in the HGA is provided in Appendix A.

Table 2. Comparison of CY 2007 NOx emission estimates for heavy-duty diesel vehicles in the HGA.

Description	NOx Emissions (tpd)
9/2001 SIP	65.5
Revised from TCEQ (MOBILE6 & TxLED)	109.5
Revised TCEQ with temperature/humidity corrections	102.8

The reasons for the dramatic increase in the estimates of heavy-duty diesel vehicle emissions from the 2001 SIP to the most recent modeling are threefold. The estimated total daily vehicle miles traveled (VMT) has increased from 129 to 147 million miles per day, and the percentage of VMT from heavy-duty diesel vehicles has been revised upward from 5.9% to 7.3%. The effect of these two factors has increased the estimated VMT of heavy-duty diesel vehicles from 7.6 to 10.7 million miles per day from earlier modeling. Lastly, TCEQ has used the revised MOBILE6 model instead of MOBILE5b; for 2007 MOBILE6 now estimates higher NOx emissions rates at about 9.3 g/mile compared to 7.9 g/mile in MOBILE5 to account for the higher real-world NOx emissions.

OFF-ROAD DIESEL EQUIPMENT EMISSION INVENTORY

This section discusses the development of the off-road NOx emission estimates to be used in the assessment of the TERP and VMEP programs. Both the September 2001 SIP values and the revised emission inventory for the off-road equipment in the HGA are presented in this section for comparison. Again, a brief description of the September 2001 SIP estimates for the off-road equipment is provided in order to put the updates into context.

The off-road NOx emission estimates from the September 2001 SIP were unchanged since the December 2000 revision. For that revision, emissions from almost all categories were estimated using methodologies incorporated in the EPA's NONROAD model. Locomotives, aircraft, and commercial marine were estimated separately since the NONROAD model does not include these categories. Furthermore, the emissions from airport ground support equipment (GSE) and diesel construction equipment (≥ 50 hp) were estimated using non-default population and activity data.

The version of the NONROAD model used in the December 2000 revision (June 2000 draft release) accounts for both the Tier 2 gasoline sulfur rule and the 2007 heavy-duty diesel regulations. Since then EPA has promulgated the Large SI/Recreational Equipment Rule (September, 2002). While an interim NONROAD version, developed November 2000 but not publicly released, did include the effects of these Large SI/Recreational Equipment standards (except for the Large SI evaporation standards), neither the June 2000 nor June 2002 (referred to as NONROAD2002) versions included them. The NONROAD2002 model is the latest publicly released model and contains updated population data, load factors, median life, increased PM deterioration factors, new geographic allocations for most equipment, and revised growth/scrappage calculation. Similar to the MOBILE6 model, the NONROAD2002 model also does not include temperature/humidity corrections for diesel NOx emissions.

TCEQ will use NONROAD2002 to update the emission estimates for off-road equipment (other than aircraft, commercial marine, and locomotives). Furthermore, some equipment categories will be handled using non-default inputs, and TCEQ provided customized input files for these categories:

- GSE – population data
- Commercial lawn and garden – population data, state to county allocation data
- Residential lawn and garden – state to county allocation data
- Recreational marine – population data

Diesel construction equipment is to be modeled using custom inputs as well. However, TCEQ was unable to provide the exact input population and allocation files. The population file was reconstructed based on the knowledge that the population data came from the survey results that ENVIRON had previously incorporated into the NONROAD-AT model. The allocation file also follows from that which was included with NONROAD-AT (the indices corresponding to counties other than the eight HGA counties were zeroed and the pseudo state total index was recalculated). The CY 2003 annual emission inventory results from these assumptions match summaries provided by TCEQ exactly for all source categories except construction equipment, where ENVIRON's estimates are 1.7 percent lower (see Table 3).

Once the 2003 values were successfully replicated (indicating that the set of inputs TCEQ intends to use in the revised SIP has been identified), 2007 estimates were produced as follows. Two sets of runs were performed using the above inputs and default growth factors, an annual and an ozone season run. Annual and seasonal average temperatures, fuel sulfur content and RVP values for 2007 were provided by TCEQ. In both cases, the NONROAD2002 model was directed to estimate period totals (annual and summer season). These were then scaled to weekly totals using the methodology discussed in the next section. Finally, typical Wednesday levels were estimated by applying day-of-week adjustments supplied by TCEQ. These emissions were estimated for Wednesday so as to make the analysis compatible with the on-road case.

In addition, the temperature and humidity correction factors were applied to diesel NOx emissions as well. For the summer season, an average of the Harris County 8/30/2000 hourly mixing ratio (absolute humidity) values along with summer temperatures from TCEQ were used

to estimate correction factors. For annual emissions, thirty-year (through 1998) annual average relative humidity values for Houston[3] along with standard barometric pressure at sea level and annual average temperatures from TCEQ were used to calculate the mixing ratios. These ratios and temperatures were then used in the NOx correction equations.

Table 3. Comparison of the CY 2003 NOx emission inventories for off-road equipment in the HGA estimated by TCEQ and ENVIRON.

Equipment Category	NOx Emissions (tons per year)	
	TCEQ	ENVIRON
Agricultural	760.0	760.1
Airport GSE	578.9	578.8
Commercial	2,423.1	2,423.2
Construction	13,157.9	12,934.5
Industrial	4,834.1	4,834.1
Lawn and Garden	909.4	909.4
Logging	95.1	95.1
Recreational Marine	383.5	383.5
Recreational equipment	54.1	54.1
Total	23,196.2	22,972.8

Temperature and humidity NOx correction factors were estimated using the same correction factor equations given earlier for the on-road category; however, the application of each equation was different, being based upon horsepower rather than model year as follows:

Application:
<50 hp; 100% (Naturally Aspirated)
50-100 hp; 10% (Turbocharged - adjusted up from 0%; engineering judgment based on certification models)
100-175 hp; 58% (Turbocharged)
>175 hp; 100% (Turbocharged)

The resulting NOx emissions estimated by ENVIRON, along with the September 2001 SIP estimates, are presented in Table 4; the emission data presented in the table include both diesel and gasoline, and only for the equipment categories that are included in the NONROAD2002 model. The results generated by ENVIRON differs from the reported 2001 SIP values because of the following (some of which were discussed above): (1) they were based upon an updated version of NONROAD; (2) they contain adjustments for a typical Wednesday; (3) they contain adjustments for effects of temperature and humidity; and (4) they were not based on summing of grid cells. Furthermore, acting on information provided by TCEQ, diesel construction emissions were estimated using the default values from the NONROAD2002 model, instead of the NONROAD-AT version of the activity file[4].

[3] http://met-www.cit.cornell.edu/ccd/relhum98.html
[4] All the customized and default input files for the NONROAD2002 model that were used by ENVIRON to generate the CY 2007 emission inventory for the off-road equipment in the HGA are provided with the memorandum in electronic format.

The NOx emissions for the diesel only off-road equipment are presented in Table 5[5]. The complete revised 2007 NOx emission inventory for off-road equipment by model year and horsepower in the HGA is provided in Appendix B.

Table 4. Comparison of the CY 2007 NOx emissions from gasoline and diesel off-road equipment in the HGA.

Equipment Category	NOx Emissions (tons per day)		
	TCEQ 2001 SIP**	Revised annual average Wednesday*	Revised summer average Wednesday*
Agricultural	12.9	1.9	2.4
Airport GSE	6.0	1.5	1.4
Commercial	5.1	6.9	6.4
Construction	32.1	34.4	41.9
Industrial	15.0	15.8	15.3
Lawn and garden	1.2	3.0	3.7
Logging	0.5	0.2	0.2
Recreational marine	2.3	0.6	1.1
Recreational equipment	0.0	0.1	0.2
Total	75.1	64.4	72.6

*These NOx emissions have been corrected for temperature/humidity effects.
**These estimates were obtained by summing emissions in grid cells.

Table 5. 2007 NOx emissions from *diesel* off-road equipment in the HGA.

Equipment Category	NOx Emissions (tons per day)	
	Revised annual average Wednesday*	Revised summer average Wednesday*
Agricultural	1.9	2.3
Airport GSE	1.0	0.9
Commercial	3.9	3.6
Construction	32.5	39.6
Industrial	4.5	4.1
Lawn and garden	1.4	1.7
Logging	0.2	0.2
Oil Field	6.4	6.6
Railroad maintenance	0.1	0.1
Recreational marine	0.1	0.1
Recreational equipment	0.0	0.0
Total	52.0	59.2

* These NOx emissions have been corrected for temperature/humidity effects.

ISSUES RELATED TO EPISODIC AND ANNUAL EMISSION INVENTORIES

Emissions modeling requires a number of temporal and other adjustments to prepare estimates specific to the ozone episode used to determine attainment with the NAAQS. While the ozone

[5] Note that data for the Oil Field and Railroad Maintenance Equipment categories were not available for comparison in Table 4. However, since no custom inputs were used for these categories and the CY 2003 values were replicable, ENVIRON assumed that the 2007 values for these categories shown in Table 5 are compatible.

modeling episode lasts several days (the HGA episode lasts from August 22 to August 30[6]), there is usually a controlling day that is used to prepare daily estimates of the control effectiveness. Most investigations of the HGA episode have centered on August 30, which was a Wednesday, as the day of most interest, so summer Wednesdays and other weekday days are considered most relevant.

For on-road vehicles, episode day modeling is straightforward because the estimates of VMT are specific for the day of week used. Many regions across the country produce at least separate weekday and weekend VMT estimates if not by the specific day of the week.

For most off-road mobile sources, the emissions are estimated using EPA's NONROAD model (with TCEQ modified input data) as estimates of seasonal or annual emissions. (Off-road emissions not addressed by the NONROAD model include aircraft, locomotive, and commercial marine sources; these have temporal allocations specific to their activity but usually vary little by the day of the week.) The NONROAD model provides daily estimates but these rely on day-of-week adjustments that distinguish only between weekday and weekend day. TCEQ has temporal adjustments by the specific day of the week.

In order to convert the other off-road emissions to a given modeling day, TCEQ uses the same procedure that the NONROAD model does, but applies specific day-of-week allocation factors. Summer season (June, July, and August) emission estimates from the NONROAD model are converted to daily estimates by dividing by 92 days in those months for an average summer day. The weekly totals are then estimated by multiplying by 7, and the relative day-of-week temporal allocations can be applied to estimate a specific day. Annual estimates could also be converted to day-of-week estimates in a similar fashion (dividing by 365 instead of 92), but most often seasonal totals are used as the initial estimates because these estimates account for seasonal ambient conditions and fuels.

[6] There are some discussions underway to expand this episodic period to include days prior to August 22 and after August 30.

APPENDIX A

CY 2007 On-Road Heavy-Duty Diesel Emission Inventory by Model Year and Vehicle Classes in the Houston Galveston Area

Table A-1. 24-Hour NOx Emissions in Tons by Model Year & Vehicle Type for HDDVs in HGA (without the Humidity/Temperature Correction)

Model Year	*Age*	*LDDV*	*LDDT12*	*HDDV2b*	*HDDV3*	*HDDV4*	*HDDV5*	*HDDV6*	*HDDV7*	*HDDV8a*	*HDDV8b*	*HDDBT*	*HDDBS*	*LDDT34*	*Total*
2007	1	0.00	0.00	0.41	0.13	0.09	0.07	0.20	0.15	0.36	2.74	0.04	0.05	0.00	4.25
2006	2	0.00	0.00	0.81	0.40	0.23	0.19	0.73	0.40	0.65	4.83	0.14	0.19	0.01	8.58
2005	3	0.00	0.00	0.75	0.41	0.30	0.23	0.76	0.47	0.81	6.47	0.13	0.18	0.01	10.52
2004	4	0.00	0.00	0.45	0.40	0.26	0.23	0.76	0.49	0.70	7.97	0.13	0.16	0.01	11.58
2003	5	0.00	0.00	0.42	0.15	0.15	0.10	0.73	0.47	0.62	3.58	0.18	0.22	0.02	6.64
2002	6	0.00	0.00	0.55	0.29	0.22	0.11	0.51	0.47	0.55	4.25	0.21	0.24	0.02	7.41
2001	7	0.00	0.00	0.22	0.14	0.18	0.06	0.35	0.38	0.98	2.31	0.21	0.23	0.01	5.06
2000	8	0.01	0.00	0.23	0.22	0.19	0.07	0.54	0.50	1.32	8.53	0.20	0.22	0.01	12.04
1999	9	0.01	0.00	0.13	0.18	0.08	0.05	0.27	0.25	0.99	3.27	0.19	0.20	0.01	5.61
1998	10	0.01	0.00	0.12	0.08	0.05	0.03	0.31	0.20	0.94	6.36	0.19	0.19	0.01	8.48
1997	11	0.00	0.00	0.07	0.07	0.05	0.04	0.17	0.17	0.70	2.04	0.23	0.22	0.00	3.76
1996	12	0.00	0.00	0.05	0.05	0.03	0.03	0.18	0.23	0.76	3.60	0.22	0.21	0.00	5.36
1995	13	0.00	0.00	0.02	0.03	0.02	0.02	0.13	0.11	0.53	2.66	0.21	0.17	0.00	3.90
1994	14	0.00	0.00	0.03	0.03	0.02	0.02	0.10	0.11	0.73	3.24	0.19	0.15	0.00	4.62
1993	15	0.00	0.00	0.03	0.03	0.02	0.02	0.08	0.08	0.64	2.42	0.14	0.15	0.00	3.60
1992	16	0.00	0.00	0.01	0.01	0.01	0.02	0.05	0.05	0.37	1.54	0.12	0.15	0.00	2.35
1991	17	0.00	0.00	0.01	0.01	0.01	0.02	0.04	0.05	0.22	0.53	0.07	0.13	0.00	1.08
1990	18	0.00	0.00	0.01	0.01	0.01	0.01	0.04	0.04	0.22	0.42	0.04	0.12	0.00	0.92
1989	19	0.00	0.00	0.01	0.00	0.01	0.01	0.04	0.04	0.24	0.68	0.04	0.13	0.00	1.20
1988	20	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.06	0.13	0.03	0.12	0.00	0.38
1987	21	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.12	0.35	0.02	0.08	0.00	0.64
1986	22	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.10	0.10	0.02	0.07	0.00	0.34
1985	23	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.09	0.09	0.01	0.05	0.00	0.27
1984	24	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.09	0.16	0.01	0.03	0.00	0.34
1983	25	0.03	0.02	0.00	0.01	0.01	0.01	0.02	0.02	0.14	0.18	0.03	0.14	0.00	0.60
Total		0.09	0.02	4.34	2.64	1.95	1.35	6.10	4.75	12.94	68.46	2.99	3.79	0.13	109.54

Table A-2. 24-Hour NOx Emissions in Tons by Model Year & Vehicle Type for HDDVs in HGA (with the Humidity/Temperature Correction)

Model Year	*Age*	*LDDV*	*LDDT12*	*HDDV2b*	*HDDV3*	*HDDV4*	*HDDV5*	*HDDV6*	*HDDV7*	*HDDV8a*	*HDDV8b*	*HDDBT*	*HDDBS*	*LDDT34*	*Total*
2007	1	0.00	0.00	0.38	0.12	0.09	0.06	0.19	0.14	0.34	2.57	0.04	0.05	0.00	3.99
2006	2	0.00	0.00	0.77	0.38	0.21	0.18	0.68	0.37	0.62	4.54	0.13	0.18	0.01	8.06
2005	3	0.00	0.00	0.71	0.39	0.28	0.21	0.71	0.44	0.76	6.09	0.13	0.16	0.01	9.89
2004	4	0.00	0.00	0.42	0.38	0.25	0.22	0.72	0.46	0.66	7.49	0.12	0.15	0.01	10.89
2003	5	0.00	0.00	0.40	0.14	0.14	0.09	0.69	0.45	0.58	3.37	0.17	0.21	0.02	6.24
2002	6	0.00	0.00	0.52	0.27	0.21	0.10	0.48	0.45	0.51	3.99	0.19	0.23	0.02	6.97
2001	7	0.00	0.00	0.20	0.13	0.17	0.06	0.33	0.36	0.92	2.17	0.19	0.22	0.01	4.75
2000	8	0.01	0.00	0.21	0.21	0.18	0.07	0.51	0.47	1.24	8.02	0.19	0.20	0.01	11.31
1999	9	0.01	0.00	0.12	0.16	0.07	0.04	0.25	0.23	0.93	3.08	0.18	0.19	0.01	5.28
1998	10	0.01	0.00	0.11	0.07	0.05	0.03	0.30	0.18	0.89	5.98	0.18	0.18	0.01	7.97
1997	11	0.00	0.00	0.07	0.07	0.05	0.04	0.16	0.16	0.66	1.92	0.21	0.21	0.00	3.54
1996	12	0.00	0.00	0.05	0.04	0.03	0.03	0.17	0.22	0.72	3.38	0.20	0.19	0.00	5.04
1995	13	0.00	0.00	0.02	0.02	0.02	0.02	0.12	0.10	0.50	2.50	0.19	0.16	0.00	3.66
1994	14	0.00	0.00	0.03	0.03	0.02	0.02	0.10	0.10	0.68	3.04	0.18	0.14	0.00	4.34
1993	15	0.00	0.00	0.02	0.03	0.02	0.02	0.07	0.07	0.60	2.25	0.13	0.13	0.00	3.34
1992	16	0.00	0.00	0.01	0.01	0.01	0.02	0.05	0.05	0.34	1.43	0.11	0.14	0.00	2.18
1991	17	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.05	0.21	0.49	0.07	0.12	0.00	1.01
1990	18	0.00	0.00	0.01	0.01	0.01	0.01	0.04	0.04	0.20	0.39	0.03	0.11	0.00	0.86
1989	19	0.00	0.00	0.01	0.00	0.01	0.01	0.04	0.04	0.22	0.63	0.03	0.12	0.00	1.11
1988	20	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.06	0.12	0.03	0.11	0.00	0.36
1987	21	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.11	0.33	0.02	0.07	0.00	0.59
1986	22	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.10	0.09	0.02	0.06	0.00	0.31
1985	23	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.08	0.09	0.01	0.05	0.00	0.25
1984	24	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.09	0.15	0.01	0.03	0.00	0.32
1983	25	0.03	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.13	0.16	0.03	0.13	0.00	0.56
Total		0.08	0.02	4.08	2.48	1.83	1.27	5.73	4.46	12.14	64.27	2.80	3.55	0.12	102.82

APPENDIX B

Detailed CY 2007 Emission Inventory for
Off-Road Diesel Equipment
in the Houston Galveston Area

Appendix B-1: CY 2007 NOx Ozone Season Day Emission Inventory for Diesel Off-Road Equipment by Model Year in the HGA (tons per day)

Model year	Agricultural	Airport GSE	Commercial	Construction	Industrial	Lawn & Garden	Logging	Recreational Marine	Recreational Equipment	Total
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
1959	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**
1960	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**
1961	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**
1962	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**
1963	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**
1964	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.03**
1965	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.03**
1966	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	**0.03**
1967	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	**0.03**
1968	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	**0.03**
1969	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	**0.04**
1970	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	**0.04**
1971	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	**0.04**
1972	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	**0.05**
1973	0.01	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	**0.05**
1974	0.01	0.00	0.02	0.02	0.00	0.01	0.00	0.00	0.00	**0.06**
1975	0.01	0.00	0.02	0.02	0.00	0.01	0.00	0.00	0.00	**0.07**
1976	0.01	0.00	0.04	0.03	0.00	0.01	0.00	0.00	0.00	**0.09**
1977	0.01	0.00	0.04	0.03	0.00	0.01	0.00	0.00	0.00	**0.10**
1978	0.01	0.00	0.04	0.04	0.00	0.01	0.00	0.00	0.00	**0.12**
1979	0.01	0.00	0.05	0.04	0.00	0.02	0.00	0.00	0.00	**0.13**
1980	0.02	0.00	0.05	0.05	0.00	0.02	0.00	0.00	0.00	**0.15**
1981	0.02	0.00	0.05	0.07	0.00	0.02	0.00	0.00	0.00	**0.17**
1982	0.02	0.00	0.06	0.08	0.00	0.03	0.00	0.00	0.00	**0.20**
1983	0.03	0.00	0.06	0.11	0.00	0.03	0.00	0.00	0.00	**0.23**
1984	0.04	0.00	0.06	0.17	0.01	0.03	0.00	0.00	0.00	**0.31**
1985	0.04	0.00	0.07	0.21	0.01	0.03	0.00	0.00	0.00	**0.36**

1986	0.05	0.00	0.07	0.24	0.01	0.03	0.00	0.00	0.00	**0.40**
1987	0.05	0.00	0.07	0.28	0.01	0.04	0.00	0.00	0.00	**0.45**
1988	0.04	0.00	0.07	0.24	0.01	0.05	0.00	0.00	0.00	**0.42**
1989	0.05	0.00	0.08	0.28	0.01	0.06	0.00	0.00	0.00	**0.48**
1990	0.05	0.00	0.09	0.37	0.01	0.07	0.00	0.00	0.00	**0.59**
1991	0.06	0.00	0.10	0.47	0.01	0.07	0.00	0.00	0.00	**0.72**
1992	0.10	0.01	0.11	0.57	0.01	0.08	0.00	0.00	0.00	**0.88**
1993	0.11	0.01	0.12	0.71	0.02	0.08	0.00	0.00	0.00	**1.05**
1994	0.12	0.01	0.13	1.10	0.02	0.08	0.00	0.00	0.00	**1.47**
1995	0.13	0.02	0.16	1.41	0.03	0.08	0.00	0.00	0.00	**1.85**
1996	0.11	0.02	0.17	1.27	0.06	0.07	0.00	0.00	0.00	**1.71**
1997	0.10	0.02	0.17	1.36	0.06	0.07	0.00	0.00	0.00	**1.80**
1998	0.10	0.03	0.16	1.57	0.07	0.07	0.01	0.00	0.00	**2.01**
1999	0.11	0.07	0.16	2.01	0.10	0.07	0.01	0.00	0.00	**2.52**
2000	0.11	0.08	0.15	2.87	0.21	0.07	0.01	0.00	0.00	**3.51**
2001	0.11	0.09	0.15	3.52	0.27	0.07	0.02	0.00	0.00	**4.23**
2002	0.12	0.10	0.16	3.75	0.36	0.07	0.03	0.00	0.00	**4.59**
2003	0.10	0.08	0.15	3.42	0.39	0.07	0.03	0.00	0.00	**4.25**
2004	0.10	0.09	0.15	3.52	0.54	0.07	0.03	0.00	0.00	**4.50**
2005	0.10	0.09	0.15	3.58	0.60	0.07	0.03	0.00	0.00	**4.62**
2006	0.09	0.08	0.14	3.21	0.62	0.06	0.02	0.00	0.00	**4.23**
2007	0.08	0.07	0.14	2.92	0.62	0.06	0.02	0.00	0.00	**3.92**
Total	**2.33**	**0.89**	**3.59**	**39.64**	**4.14**	**1.73**	**0.22**	**0.11**	**0.03**	**52.67**

Appendix B-2: CY 2007 NOx Ozone Season Day Emission Inventory for Diesel Off-Road Equipment by Horsepower in the HGA (tons per day)										
HP	Agricultural	Airport GSE	Commercial	Construction	Industrial	Lawn and Garden	Logging	Recreational Marine	Recreational equipment	Total
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
6	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	**0.03**
11	0.00	0.00	0.05	0.03	0.02	0.00	0.00	0.00	0.00	**0.10**
16	0.00	0.00	0.06	0.05	0.04	0.00	0.00	0.00	0.00	**0.15**
25	0.01	0.00	0.21	0.20	0.09	0.03	0.00	0.00	0.01	**0.55**
40	0.06	0.00	0.24	0.20	0.05	0.02	0.00	0.00	0.00	**0.57**
50	0.05	0.01	0.21	0.20	0.31	0.02	0.00	0.00	0.00	**0.80**
100	0.37	0.10	1.60	5.89	2.31	0.58	0.01	0.00	0.00	**10.85**
175	0.53	0.34	0.42	10.89	0.69	0.17	0.07	0.01	0.00	**13.13**
300	0.78	0.24	0.42	9.91	0.49	0.22	0.10	0.03	0.01	**12.21**
600	0.53	0.17	0.37	3.74	0.12	0.47	0.02	0.04	0.01	**5.46**
750	0.00	0.02	0.00	8.24	0.01	0.17	0.02	0.00	0.00	**8.46**
1000	0.00	0.00	0.00	0.29	0.00	0.05	0.00	0.01	0.00	**0.36**
1500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
3000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Total	**2.33**	**0.89**	**3.59**	**39.64**	**4.14**	**1.73**	**0.22**	**0.11**	**0.03**	**52.67**