APPENDIX 4

DEVELOPMENT OF REASONABLE FURTHER PROGRESS NON-ROAD MOBILE SOURCE EMISSIONS INVENTORIES FOR THE DALLAS-FORT WORTH NONATTAINMENT AREA

Source Categories in the United States Environmental Protections Agency's NONROAD 2005 Model

Technical Support Document

DEVELOPMENT OF REASONABLE FURTHER PROGRESS NON-ROAD MOBILE SOURCE EMISSIONS INVENTORIES FOR SOURCE CATEGORIES IN THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY'S NONROAD MODEL

November 2010

Prepared by the Mobile Source Programs Team
Air Quality Division
Texas Commission on Environmental Quality

INTRODUCTION

This technical support document describes the methodologies used to develop reasonable further progress (RFP) emissions inventory (EI) data for all source categories contained within the United States Environmental Protection Agency's (EPA's) NONROAD model. The EIs developed include county level ozone season day controlled and uncontrolled emissions estimates for years 2002, 2008, 2011, 2012, and 2013 for the nine counties in the Dallas-Fort Worth (DFW) ozone nonattainment area. The nine counties in the DFW area are Collin, Dallas, Denton, Ellis, Johnson, Kaufman, Parker, Rockwall, and Tarrant.

A Texas specific version of the EPA's NONROAD 2008a model, the Texas NONROAD (TexN) model, was used in calculating emissions from all non-road mobile equipment and recreational vehicles except aircrafts, locomotives, and commercial marine vessels. The TexN model was designed to develop emissions estimates that are consistent with the latest EI data available for all counties in Texas and for all source classification codes (SCC) included in the EPA's NONROAD model. Texas specific data files included county specific equipment population, activity, growth, and temporal allocation files as appropriate.

The TexN model also incorporates extensive data collected to estimate equipment population growth and geographic allocation. Unlike the EPA's NONROAD model, the TexN model utilizes unique population files for each county and analysis year. Since the population files in the TexN model for all the years (1970 through 2050) are created outside the model, for every evaluation year, using county and SCC specific growth factors, the corresponding growth (*.grw) and geographic allocation (*.alo) files used in the EPA's NONROAD model are effectively bypassed in the TexN application. Several of the EPA's NONROAD files have not been revised for state implementation plan (SIP) development or other purposes, largely due to the difficulty in collecting the required data. The EPA's NONROAD default files used in TexN include: emission factors (*.emf); deterioration factors (*.det); and engine technology phase-in schedule (tech.dat) files. The EPA does not expect users to have local data on emission factors or on deterioration factors.

An overview of the TexN model is attached to this RFP SIP revision as Attachment A. The overview includes sources of data used in the TexN model as well as calculation procedures. Information was extracted from the TexN user's guide prepared by Eastern Research Group, Inc. The details of activity projections for TexN equipment categories with non-default values can be found in Attachment A, Section 1.2.4: *Forecasting and Back-Casting Equipment Populations*.

The TexN model includes emission factors, county level population, and activity data. The model, therefore, estimates not just emission factors but also emissions. The emission factors are combined with horsepower-hour (hp-hr) and fuel consumption estimates to calculate mass emission estimates at the county level for different evaluation years and time periods.

The latest TexN model version 1.5, used for this RFP analysis, is available on the TCEQ's non-road file transfer protocol (FTP) directory.
(ftp://ftp.tceq.state.tx.us/pub/OEPAA/TAD/Modeling/ Nonroad_EI/TexN)

The non-road FTP directory also contains the *Texas NONROAD (TexN) model Version 1.0 User's Guide*. Since the development of this user's guide, several updates to the model have been made, including incorporation of the EPA's NONROAD2008a model. The non-road FTP directory also contains a TexN User's Guide Addendum (April 2009) that provides details regarding the updates to the TexN model following the incorporation of two additional federal rules:

- The Diesel Recreational Marine standards in the Locomotive/Marine final rule, (Federal Register Vol 73, No. 88, page 25098, May 6, 2008); and
- The Small SI and SI Recreational Marine final rule (Federal Register Vol 73, No. 196, page 59034, October 8, 2008).

The technical documentation of all aspects of the non-road modeling can be found on the EPA's NONROAD modeling web page (http://www.epa.gov/omswww/nonrdmdl.htm).

The TexN model includes more than 80 basic and 260 specific types of non-road equipment, and further stratifies equipment types by horsepower rating and fuel type. The primary equipment categories in the TexN model include:

- Recreational Vehicles
- Logging
- Agricultural
- Construction/Mining
- Industrial/Commercial
- Residential Lawn and Garden
- Commercial Lawn and Garden
- Recreational Marine Engines
- Railway Maintenance

The TexN model estimates emissions for seven exhaust pollutants: hydrocarbons (HC), nitrogen oxides (NO_X), carbon monoxide (CO), carbon dioxide (CO_2), sulfur oxides (SO_X), ammonia, and particulate matter (PM). The model also estimates emissions of non-exhaust HC for six modes—hot soak, diurnal, refueling, resting loss, running loss, and crankcase emissions.

FEDERAL AND STATE CONTROL PROGRAMS ANALYSIS

The effects of federal and state control programs were evaluated. The TexN model was executed for ozone season daily emission for the years 2008, 2011, 2012, and 2013. To evaluate RFP requirements, a series of TexN model runs was executed for both controlled and uncontrolled scenarios for each federal and state control program for each analysis year.

Federal Controls

The Federal Clean Air Act (FCAA) provides the EPA with the authority to establish emissions standards only for new engines; therefore non-road engine emissions standards phase in over time as older engines undergo turnover and replacement. The first of the non-road regulations that the EPA has issued since 1994 to control non-road mobile emission sources went into effect in 1996, and the last went into effect in 2008. The EPA has taken a phased-in approach when adopting these regulations and has issued multiple tiers for certain categories of engines. The TexN model used in this study incorporates the effects of all of the following federal non-road equipment regulations:

Table 1: Existing Federal Non-Road Regulations and Phase -In Dates

Applicable Rules	Category	Implementation Phase-In Period
Phase I Small Spark-Ignition (SI) Rule	Land-Based SI Engines < 25hp (except marine and recreational)	1997
Phase II Small SI Rule	Non-Handheld SI Engines < 25hp	2001-2007
Phase II Small SI Rule	Handheld SI < 25hp	2002-2007
1998 HD/Non-road Rule or Tier I Rule	Land-Based Diesel Engines > 50hp	1996-2000
1998 HD/Non-road Rule or Tier I Rule	Small Diesel Engines < 50hp	1999-2000
Tier 2 Standards	Diesel Engines all sizes	2001-2006
Tier 3 Standards	Diesel Engines 50-750 hp	2006-2008
Large SI Rule	SI engines > 25hp	Tier 1 - 2004 Tier 2 - 2007
Tier 4 Standards	Land-Based Diesel Engines	1996-2000
Diesel recreational Marine Rule	Commercial and recreational Category 1 and 2 marine diesel engines	2009-2018
Phase III Small SI Rule	Small non-road SI engines < 25hp and Marine SI Engines and vessels	2010

For more details on the applicable rules and how the TexN model is designed to evaluate the effects of individual federal rules impacting non-road emissions for RFP analysis, please see Attachment D. In order to evaluate individual control reduction benefits of each federal rule, a series of TexN model runs was executed for controlled and uncontrolled scenarios. For a summary of control reductions, see Table 4.

State Controls

The state rules evaluated for this analysis, Texas Low Emissions Diesel (TexLED) and Reformulated Gasoline (RFG), are discussed below.

TEXAS LOW EMISSION DIESEL

The TexLED program was implemented on January 31, 2006, for 110 counties in Texas. The TexLED program is incorporated as part of the TexN model's post processing function. The TexLED flag was activated for 2006 and later analyses for the 110 counties. Annual modeling scenarios for 2007 and beyond receive a full credit of 6.2% NO_X reduction applied to all diesel emissions in the TexLED counties.

Table 2: TexLED Typical Summer Weekday NOx Emission Reduction Benefits for the DFW Area

Analysis Year	NOX (tons per day)
2002	0.00
2008	5.64
2011	5.79
2012	5.77

REFORMULATED GASOLINE

The RFG benefits were calculated by running the TexN model for all SI equipment categories and all scenario years, with Reid Vapor Pressure (RVP) values set to 6.8 pounds per square inch (psi) (representative of RFG) and 8.7 psi (federal default RVP for summer fuel in Texas). The resulting difference in exhaust and evaporative VOC levels is reported in Table 3 for each analysis year.

Table 3: RFG Typical Summer Weekday VOC Emission Reduction Benefits for the DFW Area

Analysis Year	VOC (tons per day)
2002	1.07
2008	3.87
2011	4.36
2012	4.47

Table 4: State and Federal Control Reduction Summary for NON-ROAD Mobile Source Categories that are in EPA's NONROAD Model (tons per day)

RFP Analysis Year	NOx Uncontrolled	NOx Controlled	Total NOx Reduction	VOC Uncontrolled	VOC Controlled	Total VOC Reduction
2002	115.230	103.53	11.700	105.920	73.490	57.200
2008	126.240	79.360	46.880	122.930	55.120	67.810
2011	132.990	67.746	65.244	129.520	46.011	83.509
2012	136.059	63.569	72.490	132.155	42.565	89.590

Note: Emissions are typical summer weekday emissions.

REFERENCES

1. User's Guide for the Final NONROAD2005 Model, EPA420-R-05-013, December 2005: http://www.epa.gov/otaq/nonrdmdl.htm
2. NONROAD2005 Emission Factor Model, available from http://www.epa.gov/otaq/nonrdmdl.htm, last validated 11-18-2006.

3. Texas NONROAD (TexN) Model Version 1.0 User's Guide, Eastern Research Group prepared for the Texas Commission on Environmental Quality, August 18, 2008: ftp://ftp.tceq.state.tx.us/pub/OEPAA/TAD/Modeling/Nonroad_EI/TexN/.
4. Eastern Research Group, Ozone Science and Air Modeling Research Project H43T163: Diesel Construction Equipment Activity and Emissions Estimates for the Dallas/Ft. Worth Region, prepared for The Houston Advanced Research Center, August 31, 2005.
5. Eastern Research Group, Statewide Diesel Construction Equipment Inventory, prepared for the Texas Commission on Environmental Quality, August 31, 2005.
6. Eastern Research Group, Nonroad Mobile Source Emissions Inventory Development for the Houston-Galveston-Brazoria Area, submitted to the Houston-Galveston Area Council, July 28, 2006.

ATTACHMENT A

TEXN OVERVIEW – DATA SOURCES AND CALCULATION PROCEDURES

Source: Texas NONROAD (TexN) Model Version 1.0 User's Guide, Chapter 4
Prepared by: Eastern Research Group, August 18, 2008

The TexN model consists of four basic elements:

1. A Graphical User Interface (GUI)
2. A MySQL database
3. EPA's NONROAD2005 model, and
4. An enhanced Reporting Utility

The TexN GUI was designed to incorporate more user-friendly features than the NONROAD model, accommodating the need for a finer level of emissions processing, and allowing for more detailed documentation of each run. The interface interacts with a MySQL5.0 database, which enhances the user's ability to manage data, group runs, and document scenarios. The database was populated with all of the equipment population and related activity data developed for the latest state implementation plans (SIP) and other periodic inventories for Texas. The database automatically applies post-processing adjustments as appropriate, and creates output files that can be imported into the modified Reporting Utility. The Reporting Utility allows the user enhanced reporting options.

This section provides a detailed overview of TexN data sources, functionality, and processing methodology, focusing on those features not included in the standard NONROAD modeling package.

ACCOMMODATION OF CONSTRUCTION EQUIPMENT SUBCATEGORIES

Diesel construction equipment (DCE) is usually the largest single emitter of nitrogen oxides (NO_X) emissions in urban areas. DCE is also used in a wide variety of different tasks, with different activity and emissions profiles. Accordingly, the DCE emissions inventory has been highly disaggregated for Texas, characterizing construction equipment use for 24 sectors, including highway, commercial building, residential, utility, and other distinct construction activities or specialty equipment profiles. Each of the 24 DCE sectors is listed below.

Agricultural Activities
Boring and Drilling Equipment
Brick and Stone Operations
City and County Road Construction
Commercial Construction
Concrete Operations
County-Owned Construction Equipment
Cranes
Heavy Highway Construction
Landfill Operations
Landscaping Activities
Manufacturing Operations
Municipal-Owned Construction Equipment
Transportation/Sales/Services
Residential Construction
Rough Terrain Forklifts
Scrap/Recycling Operations
Skid Steer Loaders
Special Trades Construction
Trenchers
TxDOT Construction Equipment
Utility Construction
Mining and Quarry Operation
Off-Road Tractors, Miscellaneous Equipment, and all Equipment under 25 horsepower

The TexN modeling system was designed to calculate emissions for each of these sectors individually.

Three factors were considered when defining the DCE categories for Texas. First, the categories are fundamentally different in their equipment use requirements (e.g., the tasks required for highway and residential projects are quite different). Second, available population and activity surrogates for each project category should be clearly associated with actual equipment use to the extent possible.[1] Third, all categories, when considered together, cover the vast majority of DCE use in the state.

In a previous study completed for the Houston Advanced Research Center titled *Ozone Science and Air Modeling Research Project H43T163: Diesel Construction Equipment Activity and Emissions Estimates for the Dallas/Ft. Worth Region*, experts from various construction sectors and technical representatives from the TCEQ were solicited for their opinions regarding the distinct types of construction project categories, the likely relative contribution of the different categories, and the availability of appropriate surrogate data for each category. Based on this input, it was determined that there are two fundamentally different types of DCE categories – those that have significant earthwork and surfacing requirements and those that do not. Earthwork project categories include:

- highway construction (state highway and bridge work, and city/county roads);
- utility installation (sewer, water, gas, power, and communication line installation and repair);
- single family housing (residential developments/subdivisions); and
- commercial structures.

Exhaust emissions are directly related to the hp-hours of work output by an engine. The hp-hours are associated with the amount of work performed for a given task. While the engine work performed during non-earthwork tasks may be difficult to quantify (e.g., pothole patching, or the amount of lifting performed by cranes), earthwork and surfacing tasks are reasonably straightforward to quantify and link to available physical quantity surrogates. Therefore, by developing equipment activity profiles directly in terms of physical quantities such as cubic yards of earth moved, it became possible to develop more precise correlates for equipment activity for the earthwork categories listed above.

Non-earthwork project categories may also involve the use of DCE. Equipment use for these categories may involve specialized activities (e.g., landfill compacting). In other cases the work performed may involve earthmoving and/or surfacing, but cannot be determined from available surrogates (e.g., for mining activities, where production data is considered confidential business information).

The following lists the non-earthwork DCE categories used in Texas:

- road or utility maintenance/repair activities performed by municipalities/counties/state agencies;
- landfill operations;
- surface mining – including stone/quarry operations, sand/aggregate pits; and
- boring/drilling operations, including water wells, deep foundation work (piles/piers), and utility pole installation/repair.

---

[1] While it is not possible to directly estimate hours of equipment use for all DCE categories, certain correlates of activity have been identified and collected for the different project categories, such as the linear feet of utility line installation per year.

A database of DCE purchases in the Dallas- Fort Worth area was obtained to help identify other industry sectors that are also significant users of DCE. These include:

- special construction trades (e.g., performing post-earthwork activities such as concrete, electrical, heating and air conditioning installation, and other tasks);
- landscaping companies;
- agricultural entities;
- scrap handling and recycling facilities;
- concrete product manufacturers;
- brick and stone product manufacturers;
- general manufacturing operations; and
- transportation/wholesale and retail sales/services.

Other DCE categories were also found to be inadequately characterized by the earthwork profiles. These equipment types are numerous and therefore potentially significant emitters, but were often difficult to link to available earthwork or surfacing surrogates. These included:

- cranes;
- rough terrain forklifts;
- skid steer loaders; and
- trenchers.

Population data for these equipment types were derived from an equipment sales database, with activity estimates provided by industry experts, for both earthwork and non-earthwork project categories.

Table A-1 summarizes the equipment types found within each of the 24 DCE sub sectors.

Table A-1: DCE Type by Sub Sector

Equipment Description	SCC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Pavers	2270002003				x	x	x	x		x				x		x				x		x	x	x	x
Tampers/Rammers	2270002006																								x
Plate Compactors	2270002009																								x
Rollers	2270002015				x	x	x	x		x	x	x		x	x	x				x		x	x		x
Scrapers	2270002018	x			x	x		x		x	x	x		x	x	x				x		x	x	x	
Paving Equipment	2270002021							x		x				x	x							x			x
Surfacing Equipment	2270002024						x	x		x		x			x	x				x					x
Signal Boards/Light Plants	2270002027																								x
Trenchers	2270002030																				x				x
Bore/Drill Rigs	2270002033		x																						x
Excavators	2270002036	x		x	x	x	x	x		x	x	x	x	x	x	x		x		x		x	x	x	x
Concrete/Industrial Saws	2270002039																								x
Cement & Mortar Mixers	2270002042																								x
Cranes	2270002045								x																x
Graders	2270002048	x		x	x	x	x	x		x	x	x		x	x	x				x		x	x	x	
Off-highway Trucks	2270002051	x				x	x	x		x	x		x	x	x					x				x	
Crushing/Proc. Equipment	2270002054																							x	x
Rough Terrain Forklifts	2270002057																x								x
Rubber Tire Loaders	2270002060	x		x	x	x	x	x		x	x	x	x	x	x	x		x		x		x	x	x	x
Tractors/Loaders/Backhoes	2270002066	x		x	x	x	x	x		x	x	x	x	x	x	x		x		x		x	x	x	x
Crawler Tractor/Dozers	2270002069	x		x	x	x	x	x		x	x	x	x	x	x	x		x		x		x	x	x	
Skid Steer Loaders	2270002072																		x						x
Off-Highway Tractors	2270002075																							x	x
Dumpers/Tenders	2270002078																								x
Other Construction Equipment	2270002081																								x

Sub-sector key: (1) Agricultural Activities; (2) Boring/Drilling Equipment; (3) Brick and Stone Operations; (4) City and County Road Construction; (5) Commercial Construction; (6) Concrete Operations; (7) County-Owned Construction Equipment; (8) Cranes; (9) Heavy-Highway Construction; (10) Landfill Operations; (11) Landscaping Activities; (12) Manufacturing Operations; (13) Municipal Owned Construction Equipment; (14) Transportation/Sales/Services; (15) Residential Construction; (16) Rough Terrain Forklifts; (17) Scrap/Recycling Operations; (18) Skid Steer Loaders; (19) Special Trades Contractors; (20) Trenchers; (21) TxDOT Equipment; (22) Utility Construction; (23) Mining and Quarry Operations; (24) Off-road Tractors, Misc. Equipment, and all Equipment < 25 hp

DEVELOPMENT OF TEXAS-SPECIFIC DATA FILES

TexN was designed to develop emission estimates (including ammonia) that are consistent with the latest emission inventory data available for all counties in Texas, for all SCCs included in the NONROAD model. The resulting emission factors are combined with hp-hr and fuel consumption estimates to calculate mass emission estimates at the county level, for different evaluation years and time periods.

In order to develop the required Texas-specific data files, ERG developed, compiled, and organized the NONROAD model files needed to generate the most up-to-date county level non-road mobile emissions inventories for the state. These data included area specific equipment population, activity, growth, and temporal allocation files as appropriate. Base years for these data included 1999, 2000, 2002, and 2004.

ERG then developed and populated baseline and projected inventory lookup tables, reflecting variations in fuel properties, temperature, and selected control strategies at the county and SCC level. These tables can be easily modified using the TexN GUI to perform sensitivity or other analyses. Look-up tables for county-specific diesel activity adjustment factors were also compiled for altitude, ground cover, and soil properties. These adjustment factors are not input directly into the model, but are applied as linear corrections during the post-processing of output files. (Details regarding these and other post-processing adjustments are provided in the *Data Processing* section.)

Using the files described above, TexN can produce emissions estimates of VOC, NOx, SO_2, CO, PM_{10}, and $PM_{2.5}$ for any county and time period of interest. For ammonia estimates, selected ammonia emission factors are applied to the adjusted NONROAD output files for each county and SCC and for each base year. The NONROAD output files are then post-processed to aggregate by model year and technology groups and fuel types. Emission factors are then combined with the NONROAD output data, using the appropriate aggregated hp-hr and/or fuel consumption estimates to obtain mass emissions estimates for ammonia.

The most recent available data were identified and collected in order to populate the following NONROAD model files, for each county and SCC combination, for the possible range of analysis years (1970-2050). File naming conventions are provided in parentheses.

- Option file (*.opt - temperature and fuel specification data)
- Equipment Population by hp bin (*.pop – equipment counts by hp bin)
- Activity (activity.dat - hr/yr)
- Temporal allocation (season.dat - weekday/weekend, and seasonal)

In addition, extensive data were also collected to estimate equipment population growth and geographic allocation. However, due to the calculation methodology employed within TexN, which utilizes unique population files for each county and analysis year, the corresponding growth (*.grw) and geographic allocation (*.alo) files used in NONROAD are effectively bypassed in the TexN application.[2]

[2] Unlike NONROAD, which utilizes one state-level population file, which is in turn allocated to the county level using the *.alo files, TexN contains unique population files for all 254 counties in the state. Therefore the additional allocation step employed by NONROAD is not required within TexN. In addition, separate population files have been developed for every possible episode year, utilizing county and SCC-specific

Several NONROAD files have not been revised for SIP development or other purposes, largely due to the difficulty in collecting the required data. In these cases NONROAD default files were used for emissions estimation. These default files include:

- emission factors (*.emf);
- deterioration factors (*.det files); and
- engine technology phase-in schedule (tech.dat).

The following summarizes the sources of the data collected in order to generate the above NONROAD files.

TexN Fuel Specification Data

The NONROAD2005 model requires inputs for the following fields in order to generate the primary input file (known as the OPT or Options file).

- Gasoline Reid Vapor Pressure (RVP)
- Gasoline oxygen weight percent
- Gasoline sulfur weight percent
- Diesel sulfur weight percent
- Recreational marine diesel sulfur weight percent
- CNG/LPG sulfur weight percent

No Texas-specific data were identified for recreational marine diesel and CNG/LPG sulfur levels, so NONROAD default values were retained—0.2637% and 0.003%, respectively. [2]

General summer fuel specifications for Texas are summarized in Table A-2 below, developed for the TCEQ for on-road modeling.

Table A-2: Federal and State Fuels Controls in Texas During Summer Season Period[3]

Program	Start Year	Control/Standard	Geographic Coverage
Federal Controls on Gasoline Volatility[1]	1992	• Max RVP, 7.8 pounds per square inch (psi) • Max RVP, 9.0 psi	• One-hour ozone nonattainment counties[2] • Remainder of state
Federal Reformulated Gasoline (RFG[3])	1995	Performance standard reductions: VOC, NO_X, Toxics	One-hour ozone nonattainment counties for HGB, DFW
El Paso Low-RVP Gasoline[4]	1996	Max RVP, 7.0 psi	El Paso County

growth factors, as discussed in Section 4.2.3. While NONROAD's default growth file is retained within TexN to establish model year distributions, it is not used to forecast or back-cast actual equipment populations.

[3] Texas Transportation Institute, Development of On-Road, Mobile Source, 1999 Through 2035 Emissions Trends for all 254 Counties, prepared for the TCEQ, August 2004.

Program	Start Year	Control/Standard	Geographic Coverage
Regional Low-RVP Gasoline[5]	2000	Max RVP, 7.8 psi	95 central and eastern Texas counties[6]
Tier 2 Low-Sulfur Gasoline	2005	Refinery average 30 parts per million (ppm) gasoline sulfur content	National
Federal Low-Sulfur Highway Diesel[7, 8]	1993/2006	• 500 ppm maximum sulfur content • 15 ppm maximum sulfur content	National
Texas Low-Emission Diesel[9]	2005/2006	• 500 ppm maximum sulfur • 15 ppm maximum sulfur • Low aromatic HC and high cetane number to control NO_X	110 counties: 95 central and eastern Texas counties[6] and the 15 HGB, BPA, and DFW one-hour ozone nonattainment counties

1. 40 CFR § 80.27. Controls and Prohibitions on Gasoline Volatility.
2. The 16 Texas one-hour ozone nonattainment areas and respective counties are: Beaumont-Port Arthur (BPA): Hardin, Jefferson, Orange; Dallas-Fort Worth (DFW): Collin, Denton, Dallas, Tarrant; Houston-Galveston-Brazoria (HGB): Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller; and El Paso County.
3. 40 CFR § 80.41 Standards and Requirements for Compliance (federal RFG).
4. 30 TAC §§ 115.252. Control Requirements (for gasoline RVP).
5. 30 TAC § 114.301. Control Requirements For Reid Vapor Pressure.
6. Anderson, Angelina, Aransas, Atascosa, Austin, Bastrop, Bee, Bell, Bexar, Bosque, Bowie, Brazos, Burleson, Caldwell, Calhoun, Camp, Cass, Cherokee, Colorado, Comal, Cooke, Coryell, De Witt, Delta, Ellis, Falls, Fannin, Fayette, Franklin, Freestone, Goliad, Gonzales, Grayson, Gregg, Grimes, Guadalupe, Harrison, Hays, Henderson, Hill, Hood, Hopkins, Houston, Hunt, Jackson, Jasper, Johnson, Karnes, Kaufman, Lamar, Lavaca, Lee, Leon, Limestone, Live Oak, Madison, Marion, Matagorda, McLennan, Milam, Morris, Nacogdoches, Navarro, Newton, Nueces, Panola, Parker, Polk, Rains, Red River, Refugio, Robertson, Rockwall, Rusk, Sabine, San Jacinto, San Patricio, San Augustine, Shelby, Smith, Somervell, Titus, Travis, Trinity, Tyler, Upshur, Van Zandt, Victoria, Walker, Washington, Wharton, Williamson, Wilson, Wise, and Wood.
7. 1993 sulfur limit source: "Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements." EPA, December 2000 (EPA420-R-00-026).
8. 2006 sulfur limit source: heavy-duty 2007 rule.
9. 30 TAC § 114.312. Low Emission Diesel (LED) Standards.

More detailed, site-specific fuel specifications were also sought by season and year at the county level for inclusion within TexN. Historical gasoline and diesel fuel sampling data collected for the TCEQ were used to populate the needed specification table. Gasoline data were collected in different regions across the state for summertime fuel in 2001, 2003, 2004, and 2005 [3, 4, 5, and 6]. Diesel samples were collected in 2003, 2004, and 2005 [3, 4, and 5]. In addition, one set of wintertime gasoline sampling was performed in 2006 [6]. In each of the studies, fuel samples were collected at randomly selected retail stations in each of the 25 Texas Department of Transportation (TxDOT) regions of the state. In order to obtain county level specificity, each county in the state was assigned to one of the 25 TxDOT regions. This data provided gasoline RVP, oxygen weight percent, and gasoline as well as diesel sulfur weight percent for all locations.

In consultation with the TCEQ, alternative data and assumptions were employed in order to gap fill gasoline and diesel fuel specifications for years in which there was no sampling performed.

The following summarizes the decision rules developed to estimate gasoline and diesel fuel specifications for years without sampling data.

1. Summer gasoline parameters for 2002 are set equal to measured 2001 values.
2. Summer gasoline RVP values for 2006 and beyond are set equal to 6.8 for counties using reformulated gasoline (RFG) and El Paso, 7.8 for counties subject to the East Texas RVP limitation, and 8.7 for all other counties.
3. Summertime gasoline RVP levels for 2000 are set equal to values from the TRW Petroleum Technologies Survey (formerly the National Institute for Petroleum and Energy Research), obtained from the TCEQ.
4. Gasoline RVP levels for non-RFG counties from 1999 and earlier are set equal to 9.0, representing levels prior to the East Texas RVP limitation.
5. Summertime gasoline sulfur levels for years without sampling data are set equal to the values in the EPA's on-road emission factor model, MOBILE6.2, as shown in Table A-3.

Table A-3: Gasoline Average Sulfur Levels (% weight) [15]

Year	RFG	Conventional Gas
1999 and earlier*	0.0300	0.0300
2000*	0.0150	0.0300
2001	0.0149	0.0299
2002*	0.0129	0.0279
2003	0.0120	0.0259
2004	0.0120	0.0121
2005	0.0090	0.0092
2006*	0.0030	0.0033
2007**	0.0030	0.0033
2008+**	0.0030	0.0030

* Years without sampling data

** Data available but not yet incorporated into TexN

1. Gasoline oxygenate levels for years without sampling data are set equal to 2.1% by weight for summertime RFG areas, 3.5% for wintertime RFG areas, and to 0% for other areas.
2. If the sampled oxygenate content for gasoline is greater than 5.0%, then the value was set equal to 5.0%.[4]
3. For wintertime gasoline, sampled data for 2006 were used for RVP, sulfur and oxygenate content. For other years MOBILE6.2 defaults were used for sulfur content (see Table A-2), and RVP data from TRW wintertime surveys, obtained from the TCEQ.
4. For diesel fuel other than that used by recreational marine engines, the sampled data for 2003, 2004, and 2005 were used. (Note that diesel fuel specifications do not vary seasonally as do gasoline specifications, so parameter values are not differentiated by season.)
5. Diesel sulfur levels prior to 2003 were set equal to measured 2003 values. Values for 2006-2009 were set equal to 2005 values to account for the introduction of the federal non-road diesel fuel standards in 2007.[5]

[4] NONROAD2005 does not accept oxygenate inputs greater than 5.0% by weight [2].

6. Diesel sulfur levels beyond 2009 were set equal to the average value of 0.0015% by weight under the EPA Clean Air Nonroad Diesel-Tier 4 Final Rule.

The final county level fuel specifications are summarized for each season and calendar year, for both gasoline and diesel fuel, in Attachment B. These data were used to generate NONROAD OPT files specific to each county, season, and analysis year.

TexN Climate Data

NONROAD utilizes daily high, low, and average temperature data, primarily to calculate evaporative emissions from gasoline engines. These data are required as part of NONROAD's OPT file. In addition, related data on relative humidity and atmospheric pressure are also used during TexN's post-processing of NONROAD model outputs to adjust diesel NO_X emissions for temperature and humidity effects. Ideally, these data should be specific to each county and episode day of interest. Although meteorological data were not available at this level for all counties, daily temperature, relative humidity, and atmospheric pressure information was available for 17 weather stations across the state, from the Texas A&M Energy Systems Laboratory [7]. The 17 weather stations with available data are presented in Table A-4.

Table A-4: Weather Stations Providing Daily Climate Data [7]

No.	Weather Station	City	County	Location
1	ABI	Abilene	Taylor	Abilene Regional Airport
2	AMA	Amarillo	Potter	Amarillo International Airport
3	ATT	Austin	Travis	Austin Camp Mabry
4	BRO	Brownsville	Cameron	Brownsville S. Padre Island International
5	CRP	Corpus Christi	Nueces	Corpus Christi International Airport
6	ELP	El Paso	El Paso	El Paso International Airport
7	DFW	Fort Worth	Tarrant	Dallas - Fort Worth International Airport
8	IAH	Houston	Harris	Houston Bush Intercontinental
9	LBB	Lubbock	Lubbock	Lubbock International Airport
10	GGG	Lufkin	Angelina	Longview E. Texas Regional Airport
11	MAF	Midland	Midland	Midland International Airport
12	BPT	Port Arthur	Jefferson	Port Arthur S.E. Texas Regional Airport
13	SJT	San Angelo	Tom Green	San Angelo Mathis Field
14	SAT	San Antonio	Bexar	San Antonio International Airport
15	VCT	Victoria	Victoria	Victoria Regional Airport
16	ACT	Waco	McLennan	Waco Regional Airport
17	SPS	Wichita Falls	Wichita	Wichita Falls Municipal Airport

[5] The 2005 diesel sulfur values were all lower than the 500 ppm cap set by the federal non-road requirements for Large Refiners and Importers for the 2007 – 2009 period. For this reason 2005 sulfur levels were assumed to hold constant until the 2010 non-road requirements commence (15 ppm).

Hourly temperature and relative humidity data were obtained for each of these weather stations for 1999, 2000, and 2002, as well as an averaged "typical meteorological year" developed by the Energy Systems Laboratory. These data have been provided to the TCEQ in electronic format. From the hourly data, ERG extracted the daily minimum, maximum, and average temperatures, and average relative humidity. These values were then sorted into four seasonal groups: winter (December – February); spring (March – May); summer (June – August); and fall (September – November). For each of these seasonal groupings, and for each of the four years, averages were calculated for daily minimum, maximum, and average temperatures, as well as averages for relative humidity. These values are used as inputs by TexN for NONROAD modeling as well as post-processing adjustments for NO_X, and are provided in Attachment B.

Population, Activity, and Allocation Data

The NONROAD model utilizes equipment population and activity data specific to each region of the country, allowing the user to characterize equipment emissions at the county level for past and future years, at different temporal scales (i.e., daily, seasonal, and annual emissions). The default values developed by the EPA are based on national level population and activity data. The model allocates equipment counts and activity to the county level using readily available surrogates, such as census population for lawn and garden equipment, and dollar value of construction projects for construction equipment.

The TCEQ and others have conducted several studies over the years to collect region specific population and activity data for selected non-road engine categories in order to improve upon NONROAD default estimates. Working with TCEQ staff, ERG compiled a comprehensive list of the most recent data developed for different equipment types and regions of the State for inclusion in the TexN model. The sources of the data for each equipment type and region are presented in Tables A-5 through A-10 below. The methods used to estimate equipment populations and activity levels can be quite complex; in depth discussions of the various methodologies used are provided in the referenced studies.

Table A-5: Sources of Equipment Population Data

Equipment Types	Region	Data Source
Diesel Construction Equipment > 25 hp	Dallas-Fort Worth (DFW) 9-county nonattainment area [6]	Eastern Research Group, Ozone Science and Air Modeling Research Project H43T163: Diesel Construction Equipment Activity and Emissions Estimates for the Dallas/Ft. Worth Region, prepared for The Houston Advanced Research Center, August 31, 2005 [8]
Diesel Construction Equipment > 25 hp, except HGB[7] cranes	Statewide excluding 9-county DFW area	Eastern Research Group, Nonroad Ammonia Emissions Inventory Development, prepared for Texas Commission on Environmental Quality, November 24, 2006 [14]
Diesel Cranes	Houston-Galveston-Brazoria (HGB) nonattainment area	Eastern Research Group, Nonroad Mobile Source Emissions Inventory Development for the Houston-Galveston-Brazoria Area, submitted to the Houston-Galveston Area Council, July 28, 2006 [10]
LPG Forklifts	DFW 9-county area and HGB nonattainment areas	Eastern Research Group, Data Collection, Sampling and Emissions Inventory Preparation Plan for Selected Commercial and Industrial Equipment: Phase II, Final Report, prepared for the Texas Commission on Environmental Quality, August 31, 2005 [11]
Terminal Tractors and Transportation Refrigeration Units	DFW 9-county nonattainment area	Eastern Research Group, Data Collection, Sampling and Emissions Inventory Preparation Plan for Selected Commercial and Industrial Equipment: Phase II, Final Report, prepared for the Texas Commission on Environmental Quality, August 31, 2005 [11]

[6] Includes Collin, Dallas, Denton, Ellis, Johnson, Kaufman, Parker, Rockwall, and Tarrant Counties.
[7] Includes Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller Counties.

Equipment Types	Region	Data Source
Transportation Refrigeration Units	HGB nonattainment area	Eastern Research Group, Nonroad Mobile Source Emissions Inventory Development for the Houston-Galveston-Brazoria Area, submitted to the Houston-Galveston Area Council, July 28, 2006 [10]
Commercial Lawn and Garden	Statewide	Eastern Research Group, Development of Commercial Lawn and Garden Emissions Estimates for the State of Texas and Selected Metropolitan Areas, prepared for Texas Commission on Environmental Quality, November 24, 2003 [12]
Recreational Marine	Statewide	Eastern Research Group, Recreational Marine Emissions Inventory, prepared for the Texas Commission on Environmental Quality, August 28, 2002 [13]
All remaining equipment –see below	See below	NONROAD defaults - User's Guide for the Final NONROAD2005 Model, EPA420-R-05-013, December 2005 [1]

Equipment population estimates were taken from NONROAD defaults for the following equipment categories.

Agricultural – all equipment/fuel types
Commercial – all equipment/fuel types
Logging – all equipment/fuel types
Railroad – all equipment/fuel types
Recreational vehicles – all equipment/fuel types
Residential lawn and garden – all equipment/fuel types
Industrial – all equipment/fuel types excluding LPG forklifts in DFW and HGB, Transportation Refrigeration Units and Terminal Tractors in DFW
Construction and Mining – all gasoline, LPG, CNG
Construction and Mining – diesel < 25 hp
Construction and Mining – diesel > 25 hp:

- Tampers/Rammers
- Plate Compactors
- Signal Boards/Light Plants
- Concrete/Industrial Saws
- Crushing/Processing Equipment
- Cement/Mortar Mixers
- Dumpers/Tenders
- Off-Highway Tractors
- Other Construction Equipment

Table A-6: Spatial Allocation Surrogates for Diesel Construction Equipment

Sector	Surrogate
Agricultural	Dollar value outputs from Texas Regional Economic Models, Inc. (REMI) model*
Boring and Drilling Equipment	EDA data and dollar value outputs from TX REMI model*
Brick and Stone Operations	Dollar value outputs from TX REMI model*
City and County Road Construction	Project Dollar Value from Reed Construction Data
Commercial Construction	Building footprint data from McGraw Hill Corporation (MHC)
Concrete Operations	Dollar value outputs from TX REMI model*
County-Owned Construction Equipment	County level census projections
Cranes	EDA data and dollar value outputs from TX REMI model*
Heavy Highway Construction	Project lane-mile data by county from TxDOT
Landfill Operations	Landfill disposal volumes from TCEQ
Landscaping Activities	Dollar value outputs from TX REMI model*

Sector	Surrogate
Manufacturing Operations	Dollar value outputs from TX REMI model*
Municipal-Owned Construction Equipment	County level census projections
Transportation Sales/Services	Dollar value outputs from TX REMI model*
Residential Construction	Historical housing permit records and population growth rates from county-level census projections
Rough Terrain Forklifts	EDA data and dollar value outputs from TX REMI model*
Scrap/Recycling Operations	Dollar value outputs from TX REMI model*
Skid Steer Loaders	EDA data and dollar value outputs from TX REMI model*
Special Trades Construction	Dollar value outputs from TX REMI model*
Trenchers	EDA data and dollar value outputs from TX REMI model*
TxDOT Construction Equipment	None – TxDOT provided complete county-level population data
Utility Construction	Project Dollar value from Reed Construction Data and MHC

* State level extrapolation and county allocation using 9-county DFW population as basis.

Table A-7: Sources of Geographic Allocation Data (Non-DCE)

Equipment Types	Region	Data Source
LPG Forklifts	9-county DFW area and HGB nonattainment areas	Eastern Research Group, Data Collection, Sampling and Emissions Inventory Preparation Plan for Selected Commercial and Industrial Equipment: Phase II, Final Report, prepared for the Texas Commission on Environmental Quality, August 31, 2005 [11]
Terminal Tractors and Transportation Refrigeration Units	9-county DFW nonattainment area	Eastern Research Group, Data Collection, Sampling and Emissions Inventory Preparation Plan for Selected Commercial and Industrial Equipment: Phase II, Final Report, prepared for the Texas Commission on Environmental Quality, August 31, 2005 [11]
Transportation Refrigeration Units	HGB nonattainment area	Eastern Research Group, Nonroad Mobile Source Emissions Inventory Development for the Houston-Galveston-Brazoria Area, submitted to the Houston-Galveston Area Council, July 28, 2006 [10]
Commercial Lawn and Garden	Statewide	Eastern Research Group, Development of Commercial Lawn and Garden Emissions Estimates for the State of Texas and Selected Metropolitan Areas, prepared for Texas Commission on Environmental Quality, November 24, 2003 [12]
Recreational Marine	Statewide	Eastern Research Group, Recreational Marine Emissions Inventory, prepared for the Texas Commission on Environmental Quality, August 28, 2002 [13]
All remaining equipment – see below	See below	NONROAD defaults - User's Guide for the Final NONROAD2005 Model, EPA420-R-05-013, December 2005 [1]

Geographic allocation surrogates were taken from NONROAD defaults for the following equipment categories.

Agricultural – all equipment
Commercial – all equipment
Logging – all equipment
Railroad – all equipment
Recreational vehicles – all equipment
Residential lawn and garden – all equipment

Industrial – all equipment/fuel types excluding LPG forklifts in DFW and HGB, TRUs and Terminal Tractors in DFW

Table A-8: Sources of Equipment Activity Data

Equipment Types	Region	Data Source
Diesel Cranes	HGB nonattainment area	Eastern Research Group, Nonroad Mobile Source Emissions Inventory Development for the Houston-Galveston-Brazoria Area, submitted to the Houston-Galveston Area Council, July 28, 2006 [10]
Diesel Construction Equipment > 25 hp	9-county DFW nonattainment area	Eastern Research Group, Ozone Science and Air Modeling Research Project H43T163: Diesel Construction Equipment Activity and Emissions Estimates for the Dallas/Ft. Worth Region, prepared for The Houston Advanced Research Center, August 31, 2005 [8]
Diesel Construction Equipment > 25 hp	Remainder of State, except HGB cranes	Eastern Research Group, Nonroad Ammonia Emissions Inventory Development, prepared for Texas Commission on Environmental Quality, November 24, 2006 [14]
LPG Forklifts	9-county DFW and HGB nonattainment areas	Eastern Research Group, Data Collection, Sampling and Emissions Inventory Preparation Plan for Selected Commercial and Industrial Equipment: Phase II, Final Report, prepared for the Texas Commission on Environmental Quality, August 31, 2005 [11]
Terminal Tractors and Transportation Refrigeration Units	9-county DFW nonattainment area	Eastern Research Group, Data Collection, Sampling and Emissions Inventory Preparation Plan for Selected Commercial and Industrial Equipment: Phase II, Final Report, prepared for the Texas Commission on Environmental Quality, August 31, 2005 [11]

Equipment Types	Region	Data Source
Transportation Refrigeration Units	HGB nonattainment area	Eastern Research Group, Nonroad Mobile Source Emissions Inventory Development for the Houston-Galveston-Brazoria Area, submitted to the Houston-Galveston Area Council, July 28, 2006 [10]
Commercial Lawn and Garden	Statewide	Eastern Research Group, Development of Commercial Lawn and Garden Emissions Estimates for the State of Texas and Selected Metropolitan Areas, prepared for Texas Commission on Environmental Quality, November 24, 2003 [12]
All remaining equipment – see equipment population list above	See equipment population list above	NONROAD defaults - User's Guide for the Final NONROAD2005 Model, EPA420-R-05-013, December 2005 [1]

Table A-9: Activity Surrogates for Construction Equipment

Sector	Estimation Method
Agricultural	Industry expert profiles
Boring and Drilling Equipment	Industry expert profiles
Brick and Stone Operations	Industry expert profiles
City and County Road Construction	Reed Construction profile
Commercial Construction	Square feet of installed building space from MHC
Concrete Operations	Industry expert profiles
County-Owned Construction Equipment	Survey findings from HARC study
Cranes	Industry expert profiles
Heavy Highway Construction	Survey findings from H-GAC study
Landfill Operations	Survey profile from TCEQ study
Landscaping Activities	Industry expert profiles
Manufacturing Operations	Industry expert profiles
Municipal-Owned Construction Equipment	Survey findings from HARC study
Transportation Sales/Services	Industry expert profiles
Residential Construction	Single family housing construction profile
Rough Terrain Forklifts	Industry expert profiles
Scrap/Recycling Operations	Industry expert profiles
Skid Steer Loaders	Industry expert profiles
Special Trades Construction	Industry expert profiles
Trenchers	Industry expert profiles
TxDOT Construction Equipment	Engine clock hours provided by TxDOT
Utility Construction	Linear feet installed from Reed Construction Data

Table A-10: Sources of Temporal Allocation Factors

Equipment Types	Region	Data Source
Diesel Construction Equipment > 25 hp	9-county DFW nonattainment area	Eastern Research Group, Ozone Science and Air Modeling Research Project H43T163: Diesel Construction Equipment Activity and Emissions Estimates for the Dallas/Ft. Worth Region, prepared for The Houston Advanced Research Center, August 31, 2005 [8]
Diesel Construction Equipment > 25 hp	Statewide excluding 9-county DFW area	Eastern Research Group, Nonroad Ammonia Emissions Inventory Development, prepared for Texas Commission on Environmental Quality, November 24, 2006 [14]
LPG Forklifts	9-county DFW and HGB nonattainment areas	Eastern Research Group, Data Collection, Sampling and Emissions Inventory Preparation Plan for Selected Commercial and Industrial Equipment: Phase II, Final Report, prepared for the Texas Commission on Environmental Quality, August 31, 2005 [11]
All remaining equipment – see equipment population list above	See equipment population list above	NONROAD defaults - User's Guide for the Final NONROAD2005 Model, EPA420-R-05-013, December 2005 [1]

Once identified, data were obtained for inclusion in the TexN data files. In all but one instance, the required data were available in electronic format at ERG. For the remaining instance, ERG contacted TCEQ staff to obtain revised county level allocation factors for oil field equipment. See an explanation from the TCEQ about the oil field equipment allocation methodology in Attachment C.[8] Default statewide oil field equipment population estimates from NONROAD were subsequently allocated to the county level using these factors (see Attachment D).

Development of Population Files by Analysis Year

Upon review of the above data sets, the commercial, utility, and heavy-highway sectors for diesel construction equipment were found to have highly variable population surrogate values from one year to the next. The variability was most pronounced for certain rural counties where the amount of project work can change dramatically from year to year. Accordingly, the surrogates used as growth indicators for these sectors (dollar value of construction for commercial, linear feet of installation for utility, and lane-miles of construction for heavy-highway), can also vary dramatically from one year to the next in these locations.

In these instances equipment activity does not increase or decrease relatively smoothly from year to year, as assumed by the NONROAD model, reflecting regional economic patterns. In actuality, contractors increase the equipment population as needed to complete projects, subsequently removing them upon project completion. In counties containing large metropolitan areas, project-specific fluctuations are usually not noticeable, and changes in overall equipment population will likely follow economic factors for the most part, as assumed by NONROAD. However, in some rural counties, project specific fluctuations can be the dominant factor in determining overall activity levels. In these cases, the yearly change in activity does not follow a smooth, relatively small annual increase or decrease, but more closely resembles a step function up or down. Such step functions create discontinuities in the NONROAD growth algorithm, and can result in anomalously large equipment population estimates for these construction sectors.

For example, the data on lane-miles of construction indicate that a relatively large highway project was performed in Blanco County in 2002-2003. If these data were used without adjustment in the NONROAD growth files, the model would assume a several-fold increase in the county's highway equipment population beginning in 2002. More importantly, the model would assume that this equipment remained operating in the county in subsequent years, even as growth factors drop back down dramatically in 2004 and beyond. This is because the growth factors only impact the assumed incremental equipment purchases in the county for that year. In order to properly account for a drastic reduction in equipment population after completion of a large project in these counties, the NONROAD model's scrap curve would have to be altered for each county and year, for each construction sector.

Therefore, in order to correct for these "project-induced" discontinuities, separate population files were developed for every possible Analysis Year, for each county and equipment category. To that end, growth factors (described in Section 1.2.4) were applied to the base year equipment population files, forecasting population totals for each SCC through 2050, and back-casting estimates to 1970. In this way TexN bypasses NONROAD's growth algorithm, effectively running base year equipment profiles for every scenario. (The default NONROAD growth file, nation.grw, is retained within TexN though, and is used to develop model year distributions for any given analysis year.)

[8] Email from Greg Lauderdale, TCEQ, November 13, 2007

FORECASTING AND BACK-CASTING EQUIPMENT POPULATIONS

A variety of growth indicators or surrogates may be used to forecast and back-cast non-road equipment population and activity estimates, depending upon the equipment type. The Emissions Inventory Improvement Program (EIIP) recommends several options, as shown in Table A-11.

Table A-11: EIIP Non-road Growth Indicator Recommendations[9]

Engine Category	Growth Indicators	Information Sources*
Aircraft – Commercial	Landings and takeoffs	Local airport authorities, commercial carriers, FAA
Aircraft – General	Landings and takeoffs	Local airport authorities
Aircraft – Military	Landings and takeoffs	Local airport authorities, appropriate military agencies
Railroads	Fuel consumption, revenue ton-miles (if revenue ton-miles are used, changes in fuel and engine efficiency should be considered)	American Association of Railroads, local carriers
Commercial Marine Vessels	Cargo tonnage	Local port authorities, US Maritime Administration, US Army Corps of Engineers
Recreational Marine Vessels	Equipment population, general population	Local MPO, NONROAD model
Recreational Vehicles	Equipment population, general population	Local MPO, NONROAD model
Construction Equipment	Equipment population, construction GSP, earnings, employment	Local MPO, NONROAD model
Industrial Equipment	Equipment population, industrial GSP, earnings, employment	Local MPO, NONROAD model
Lawn and Garden Equipment	Equipment population, single-unit housing, general population	Local MPO, NONROAD model
Farm Equipment	Equipment population, agricultural land use, farm GSP, earnings, employment	Local MPO, NONROAD model, Census of Agriculture
Light Commercial Equipment	Equipment population, commercial GSP, earnings, employment, population	Local MPO, NONROAD model
Logging Equipment	Equipment population, logging industry GSP, earnings, employment	Local MPO, NONROAD model
Airport Service Equipment	Equipment population, LTOs, airport GSP, earnings, employment	Local airport authority, commercial carriers, NONROAD model, FAA Emission Dispersion Modeling System (EDMS)

* E-GAS and BEA are additional data sources for value-added GSP, earnings, and employment data.

[9] GSP = Gross State Product; LTO = Landing/Take-Off cycle.

The previous version of the TexN model projected emissions from 1999 through 2013, utilizing the most appropriate available surrogates for each DCE sub sector. This section documents the efforts ERG made to update the TexN model to accommodate emissions projections for the entire NONROAD model reporting period, from 1970-2050. Activity projections for TexN equipment categories with non-default values were developed from existing data, consistent with current projection methodologies to the extent possible.

The TexN model contains 24 distinct "sectors" with distinct equipment population and activity profiles, 23 of which involve diesel construction equipment (DCE) profiles developed specifically for the TCEQ and the TexN model. A summary of the growth factor surrogates selected for each sector is presented in table A-12.

Table A-12: Summary of Growth Factor Surrogates for Equipment Sectors

Equipment Sector	Growth Factor Surrogates
Non-DCE	Default NONROAD005
Agricultural DCE	Texas Agricultural Census for land in farms, forecast and back-cast using total county acreage as a constraint to projections
Commercial Construction	Economy.com output projections for non-residential construction sectors
Heavy-Highway	TxDOT Annual Expenditures (1998 - 2006), forecast and back-cast using Economy.Com projections for highway construction sector
Residential	1970 - 1979 based on state-level growth rates from Comptroller's Office; 1980 - 2006 from housing permits by county from Texas AM Real Estate Center; 2007 - 2009 from statewide Comptroller Fall Economic Forecast (2007 publication); 2010 - 2040 from Texas State Data Center Population Growth Estimates, 2041-2050 no growth assumed
Skid Steer Loaders	1990 - 2004 from DFW area sales data; no growth assumed before 1990 (no significant market presence before this time); 2005+ from Economy.com projections for all construction sectors (SIC 1500s - 1700s)
Transportation/Sales/Services	Economy.com projections for corresponding SIC groups
Bore/Drill Rigs, Cranes, Rough Terrain Forklifts, Trenchers	Economy.com projections for all construction sectors (SIC 1500s - 1700s)
Special Trades Construction	Economy.com projections for SIC 1700 series
Manufacturing	Economy.com projections for corresponding SIC series
Brick and Stone	Economy.com projections for corresponding SIC series
Concrete Operations	Economy.com projections for corresponding SIC series
Landscaping	TX REMI data and regression between 1999 and 2013, forecast and back-cast based on census population growth rates
Municipal and County Fleets, City and County Roads, Landfills	Based on Texas State Data Center census population projections through 2040, linear interpolation to 2050
Utility Contractors	Economy.com projections for corresponding SIC codes
TxDOT Equipment	No growth assumed, all years, based on TxDOT purchasing cycles

The following discusses how these growth factor surrogates were identified, selected, and processed for each of the 24 non-road equipment sectors. The resulting county-level growth factors have been provided to the TCEQ in electronic form for the 2004 base year for each of the sectors developed for this task.

NONROAD Default Categories

The NONROAD model contains default growth factors covering the entire period from 1970 through 2050. These default factors were kept intact in the TexN model for two equipment sectors – "Non-DCE" equipment and "Other DCE" equipment. Non-DCE equipment refers to all equipment categories other than diesel construction. These include industrial, commercial, recreational, and other equipment categories. Alternative growth factors have not been developed for the TCEQ under previous studies.

Other DCE equipment includes those equipment categories for which non-default profiles have not been developed under other studies. These equipment types are not used in earthwork activities, and were not included in previous sales data purchases. They include off-highway tractors, crushing and processing equipment, signal boards and light plants, concrete/industrial saws, cement and mortar mixers, plate compactors, dumpers/tenders, tampers/rammers, "other" construction equipment, as well as all DCE less than 25 hp. While the list is extensive, most of these categories are very low hp applications, and/or specialty pieces with low population numbers. As such, these equipment categories are responsible for a very small part of the DCE inventory (estimated to be 1% or less of NO_X); therefore, default population, activity, and associated growth factors from NONROAD have been retained in the TexN model for this equipment.

Agricultural DCE Applications

DCE such as crawler tractors and loaders are used to a limited extent in agricultural applications. In the previous version of TexN, growth for agricultural other industry groups was based on historical and projected dollar outputs at the state level, from the Texas REMI model, for the period 1999 through 2013. Alternative growth surrogates for agricultural activity at the county level were developed from the reported amount of land in farms from the 2002 Texas Agricultural Census [15]. Given the volatile nature of crop yields and prices, it was deemed that the amount of land in production was a better surrogate for equipment activity than agriculture sector economic output. However, land in agricultural production was only available every five years, from 1987 through 2002.

Linear regressions were performed using the Excel's Forecast function and above data to estimate land in farms at the county level for the entire modeling period. In the case of decreasing acreage, trend projections were capped at zero acres. This was occasionally the case for highly urban counties. Increasing acreage trends were possible for highly rural counties, and projections were capped at the total available county size [17]. The forecast acreage values for each year were then divided by the 2004 value for each county to obtain county-level growth factors for a 2004 base year.

Single Family Housing Construction

In the previous version of TexN, growth for single family housing construction activity was based on statewide housing permit totals from 1999 through 2004, and projected through 2013 using linear regression. However, given the extreme downturn in the housing market over the last two years, alternative data sources were developed for this sector.

County-level housing permit data was determined to be the best source of data for this sector, available from the Texas A&M Real Estate Center for the years 1980 through 2006 [16]. This data set contained permit information for all but 23 of the 254 counties in the state, all of which were rural counties. Accordingly, ERG assumed zero single family housing development for these counties for all years. The 23 rural counties without permit data are listed below.

Borden	Edwards	Jeff Davis	McMullen	Terrell
Briscoe	Glasscock	Jim Hogg	Mills	Throckmorton
Concho	Hartley	Kenedy	Roberts	Zapata
Crocket	Hudspeth	King	Sterling	
Duval	Irion	Loving	Stonewall	

Data were missing from one or more years for 17 counties in the data set (again, all rural counties with very low housing construction activity). Gap filling for the missing years was performed by taking the county average for the years with actual data. Housing permits prior to 1980 were based on housing start totals for the southern region of the country obtained from the U.S. Census Bureau. County level permit totals from 1980 were therefore back-cast to earlier years using annual ratios from these data.

Growth for the 2007 through 2009 period was based on state level forecasts for housing starts from the Texas Comptrollers Fall 2007 Forecast [18]. The housing start data for 2007, 2008, and 2009 from this source were 129,729; 108,056; and 129,393 respectively.[10]

Housing construction growth for 2010 and beyond was assumed to stabilize and follow long-term population projections. County level census projections were obtained from Texas State Data Center for the years 2010 through 2040 [19].[11] (The associated data file is quite large and is available from the TCEQ in electronic format.) 2009 housing permit estimates were projected forward using the annual county level population growth rates from this data set. Lacking other data sources, housing activity was assumed to equal 2040 estimates from 2041 through 2050. Single family housing growth factors were developed for each county for the 2004 base year by dividing permit estimates for each year by the associated 2004 total.

Heavy-Highway Activity

The previous version of TexN used a combination of county level highway construction and maintenance budgets from the Texas Comptroller's Office and projected contract dollar values from McGraw Hill Construction to estimate the growth in highway construction activity. In order to expand the growth estimates for this sector to cover the target period, ERG first obtained an updated list of annual highway expenditures from the Texas Comptroller's Office, for the period 1998 through 2006 [20]. Expenditures were normalized to 1998 dollars using the Consumer Price Index (CPI) obtained from the Bureau of Labor Statistics. Attempts to extrapolate the comptroller data using linear regression resulted in highly erratic, negative trends in key urban areas; therefore, highway construction activity prior to 1998 and after 2006 was obtained by TCEQ staff using the Economy.com database [22]. Growth factors were derived at the county level for the 1978 – 2037 period using economic output (in real dollars) for NAICS code 2373, Highway Street and Bridge Construction.[12] Activity levels outside this period were assumed constant. Growth factors for the entire modeling period were then calculated as with the other sectors for the 2004 base year.

[10] It was determined that Economy.com, a potential alternative source of surrogate data, showed essentially no downturn for this sector during the 2006 – 2008 time period. Therefore the Comptroller data was deemed more appropriate for this sector.

[11] Growth Scenario 0.5 was used based on Demographer recommendations from the web site.

[12] Data from the Economy.com database are considered confidential and are not presented here. All manipulation and processing of the Economy.com data were performed by authorized TCEQ personnel.

After development of these factors, it was brought to ERG's attention that highway construction and maintenance budgets have been significantly influenced by rapidly rising materials costs over the past few years [23]. Accordingly, using total budget dollars without adjusting for material cost increases will substantially overestimate highway activity growth in recent years. As such, ERG will provide an adjustment to the current growth factors for this sector to account for material cost inflation, using the TxDOT Highway Cost Index Report for May 2008, including the adjustments in the final iteration of the TexN model (by August 2008).

Skid Steer Loaders

In the previous version of the TexN model, growth for skid steer loaders (and all other specialty equipment) was based on historical and projected dollar outputs at the state level, from the TX REMI model. However, a review of skid steer loader sales in the Dallas/Fort Worth area indicate that these equipment underwent a dramatic increase in popularity through the 1990s, with the increase in new sales leveling off only around 2002, as shown in Figure A-1 below [24].

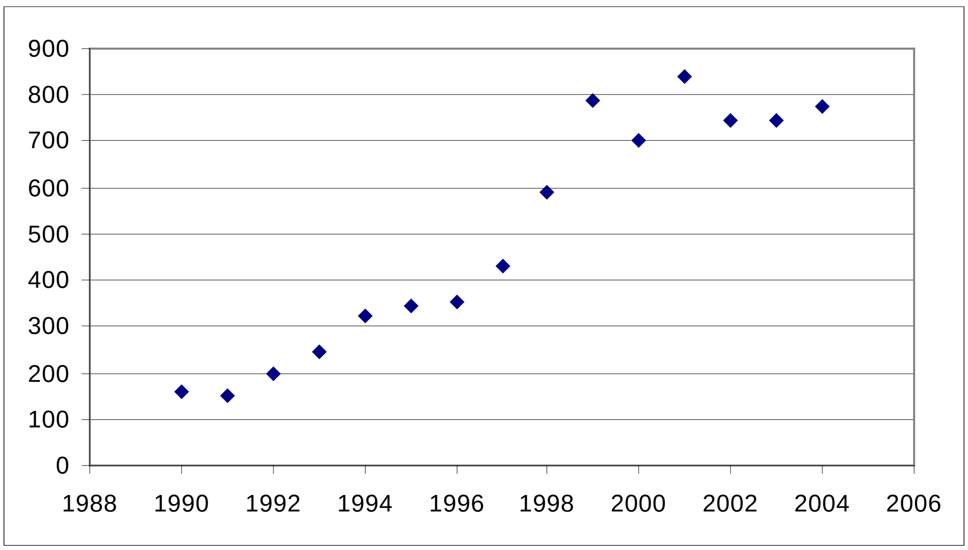

Figure A-1: Annual Skid Steer Loader Sales, 9-County DFW Area (1990-2004)*

*Source: Equipment Data Associates [24]

ERG used the above sales data as a surrogate for skid steer loader activity for the state as a whole for the 1990 – 2004 time period. Given the unique surge in popularity of these equipment, this surrogate was deemed preferable to other options such as economic output in associated industries during this time. Since skid steer loaders were uncommon before this time, ERG assumed earlier activity was equal to 1990 levels. Activity after 2004 was assumed to follow gross output for all construction sectors. These data were obtained at the county level through 2037 by the TCEQ using the Economy.com database. County level output projections for each year through 2037 were summed across the NAICS industry codes shown in Table A-13 (representing common users of this equipment type):

Table A-13: Construction Sector NAICS Codes

Sector	NAICS
Highway Construction	2373
Residential Building Construction	2361

Sector	NAICS
Non-residential Building Construction	2362
Special Trades Contractors	238B
Utility System Construction	2371

Skid steer loader activity beyond 2037 was assumed to equal 2037 levels. Growth factors relative to the 2004 base year were calculated based on these data as described for other sectors above.

Other Specialty Equipment – Bore/Drill Rigs, Cranes, Rough Terrain Forklifts, and Trenchers
In the previous version of the TexN model, growth for other specialty equipment was based on historical and projected dollar outputs at the state level, from the TX REMI model. Unlike the skid steer loaders, the sales data available for the nine-county DFW area for these equipment types did not show a definitive trend. Therefore it was decided to use gross economic output for all construction sectors, for all available years in the Economy.com database (1978 – 2037). TCEQ staff obtained and processed the associated data for these NAICS codes for all Texas counties during this period, which was then converted to growth factors with a 2004 base year. No growth was assumed prior to 1978 or after 2037.

Municipal and County Fleets, City/County Road Construction, and Landfills

County-level census population projections were used in the previous version of TexN to forecast and back-cast DCE activity for these sectors for the 1999-2013 period. ERG concluded that census population continues to be the best available surrogate for these sectors. ERG used the county-level census population estimates from the Texas State Data Center to develop growth factors for the period of interest [19]. Historical population was provided for decade years from 1970-2000. Population estimates for non-decade years were estimated using linear interpolation.

Census population estimates for 2000-2040 were based on the State Data Center's 0.5 Scenario, and have been provided to the TCEQ in electronic format. Populations for 2041-2050 were estimated by ERG by interpolation from 2039 and 2040 values.

Other Construction Applications

The previous version of TexN utilized project dollar values from different sources, such as the TX REMI model and McGraw-Hill Construction to forecast and back-cast equipment activity for a number of different DCE sectors, for the 1999-2013 period. For this effort, gross economic output data from Economy.com was identified as the best, most consistent growth surrogate for these sectors, considering the broad range of projection years (1978-2037), and the geographic specificity (county level estimates). Table A-14 lists the DCE sectors and associated NAICS codes for which Economy.com data were used.

Table A-14: DCE Sectors Utilizing Economy.com Growth Surrogates

Sector	NAICS
Commercial Building Construction	2362
Utility System Construction	2371
Special Trades Contractors	238X
Manufacturing	31XX – 33XX*
Cement and Concrete Product Manufacturing	3273

Sector	NAICS
Clay Product and Refractory Manufacturing	3271
Transportation/Sales/Services	42XX (wholesale), 44XX – 45XX (retail), 48 XX – 49XX (transportation and warehousing), 81XX (other services)

* Less cement, concrete, and clay product manufacturing

TCEQ staff obtained and processed the county level gross output data from Economy.com for the above NAICS codes, and provided the associated growth factors for the 2004 base year.

Landscaping Services / Scrap and Recycling Facilities
The previous TexN model utilized gross output for these sectors obtained from the TX REMI model for the 1999 through 2013 period. Landscaping services correspond to NAICS code 56173, and scrap-related activities to NAICS code 562920. Unlike the "Other Construction Applications," listed above, it was not possible to extend these sectors beyond this time period using the Economy.com data since queries of the database could only be performed for 4-digit NAICS codes (or higher levels of aggregation). For this reason ERG used the TX REMI model outputs for the 1999-2013 period, extended by linear regression using Excel's Forecast function for the scrap/recycling sector. However, linear regression resulted in unreasonable historical activity projections for the landscaping sector (e.g., negative activity for certain counties in the 1970s and 1980s). Census population was used for the remaining years, to develop growth factors for these sectors.

<u>TxDOT Equipment</u>

TxDOT maintains a constant inventory of their non-road equipment fleet. As such, no growth (i.e., a constant equipment population) is assumed across all years for this DCE sector.

Once growth factors were obtained for all the equipment sectors, ERG applied these factors to the base year equipment populations for each sector/county combination in the TexN model. This calculation provided forecast and back-cast equipment population totals for every calendar year, from 1970 through 2050. The TexN model was then modified to store the population data for every possible analysis year, bypassing the need to modify growth factors in the future. The revised model will look up the correct population based on the analysis year directly input by the user, thereby avoiding recurring problems with SCCs that experience rapid fluctuations in their population levels.[13]

DATA PROCESSING

Given the large number of model years, hp bins, and SCCs included in the NONROAD output files, emissions estimation necessarily includes a large amount of data processing and post-processing. Therefore, a set of data management tools have been developed, including the GUI, a database for data table storage and retrieval, and a modified Access Reporting Utility. The following clearly documents the steps used to aggregate and combine the emission and activity data for each equipment category and fuel type within TexN.

---

[13] The NONROAD model's scrappage algorithm is not capable of accurately modeling equipment populations with highly negative growth from year to year. This situation is common with certain types of transient activities, such as heavy-highway projects and boring/drilling activities.

TexN Data Management Tools and Processes

The TexN GUI was designed to incorporate more user-friendly features than the NONROAD model, accommodating the need for a finer level of emissions processing, and allowing for more detailed documentation of each run. The GUI interacts with a MySQL database, which enhances the user's ability to manage data, group runs, and document scenarios. The database was populated with all of the population and related activity data described above. The database is also utilized to automatically apply post-processing adjustments as appropriate, and create output files that can be imported into the modified Reporting Utility. A brief overview of the data management and emissions calculation process is discussed below.

The TexN GUI allows the user to group a large number of NONROAD input files and save them to the MySQL database as a single "scenario." For example, the modified GUI builds a NONROAD OPT file for each county the user selects. Should the user choose to estimate emissions for DCE, an OPT file is built for each county-DCE sector combination. By performing a separate NONROAD model run for each county and DCE sector combination, it is possible to apply activity and post-processing adjustments at the county and DCE sector level to emissions estimates. However, this approach has substantial implications for the number of OPT files required to estimate emissions, as is discussed in the next section. The GUI, however, greatly facilitates building the numerous OPT files required for regional and statewide modeling tasks.

The GUI interacts with the MySQL database to dynamically generate an OPT file for each run required by a scenario. For example, by specifying a particular county, analysis year, and season, an OPT file can be constructed containing county specific fuel and temperature data (which are stored in the database). Similarly, data are pulled from the database to generate county and sector specific population and activity files as well. In this way the GUI populates the OPT and supporting files with the region specific data necessary for the NONROAD model to execute. Once the OPT and related files are generated, the interface executes the NONROAD model for each OPT file contained within the scenario. Once the NONROAD model is launched, the interface tracks the progress of the current run and launches the next run sequentially. The GUI also checks for error messages generated by the NONROAD model. If a "warning" is reported, it is recorded in the message file, but does not affect processing. However, if an "error" is reported, the entire scenario is stopped and the user is presented with information on the error that occurred. All output files created by the NONROAD model are retained regardless of any warning or error messages generated.

Executing NONROAD to account for county and SCC specific data and post-processing adjustments can require a multitude of runs. Each county requires its own OPT file. In addition, DCE requires emission calculations at a sector level. There are 24 DCE sectors, each corresponding to a unique equipment activity profile. (As noted above, DCE sectors include commercial building construction, utility project work, and residential construction, among others.) Each county-DCE sector combination also requires its own OPT file. Furthermore, in order to appropriately apply temperature, humidity, and fuel property adjustments, seasonal emissions must be calculated separately and summed together to estimate annual emissions. A summary of the number of the OPT files necessary for each model run within a scenario is presented in Table A-15.

Table 1-15. Required Number of NONROAD OPT Files and Model Runs for Selected Modeling Scenarios

Period*	Region*	Equipment*	Number of Runs**	How the Number of Runs are Calculated
OSD^ or One Season	One County	Non-Diesel Construction Equipment (Non-DCE)	1	One for the selected county [1 segment x 1 county]
Annual	One County	Non-DCE	4	One for each County and Season [1 segment x 1 county x 4 seasons]
OSD^ or One Season	Three Counties	Non-DCE	3	One for each selected county [1 segment x 3 counties]
OSD^ or One Season	One County	DCE	24	One for each of the 24 DCE sectors for the selected county [24 segments x 1 county]
Annual	One County	DCE	96	One for each of the 4 seasons and each of the 24 DCE sectors for the selected county [24 segments x 1 county x 4 seasons]
OSD^ or One Season	Three Counties	DCE	72	One for each of the 24 DCE sectors for each of the selected counties [24 segments x 3 counties]
Annual	Statewide	All	25,400	One for each of the DCE sectors and one for Non-DCE equipment for each county for each season [(24 + 1) SCC segments x 254 counties x 4 seasons]

*User selections

**Each run requires one option file and each of the associated input files (e.g., population, activity, etc.)

^Ozone season day

To give an idea of run times, using a Dell Optiplex GX280 Intel® Computer with a Pentium® 4 CPU 3.00GHz with 512 MB of RAM, each run takes approximately 8 to 10 minutes to complete.

Once all of the runs for a scenario have executed successfully, the interface calls the post-processing driver. The post-processing driver imports all of the NONROAD output files into the MySQL database. The database then post-processes of all of the data, applying adjustment factors to the emissions estimates in the output file to generate the final criteria pollutant and ammonia emissions values. Post-processing applies county specific altitude, ground cover, and soil adjustments to emissions estimates for the appropriate SCCs. County and year specific temperature and humidity adjustments are also applied, along with adjustments to account for TxLED impacts in the appropriate counties, for diesel-fueled equipment. Once the post-processing adjustments are made, the database performs county-level aggregation of data by SCC and hp bin, summing population, activity, fuel-consumption, and emissions fields. Once completed, the database creates a single output file.

This output file is then ready to be imported into the modified Reporting Utility. The TexN Reporting Utility has all of the basic functionality of the NONROAD Reporting Utility, but has been modified to accommodate ammonia emissions estimates. In addition, the TexN Reporting Utility allows the user to generate more reports than the NONROAD version, including emission totals by county and SCC, as well as totals by hp bin and SCC.

Post-Processing Adjustments

Once all of the data edits have been completed and saved by the user, TexN will create the necessary option and supporting data files for NONROAD, and batch the runs needed to model the prescribed scenario. Once the runs for a scenario have executed successfully, the GUI automatically calls the post-processing driver. The post-processing driver imports all of the NONROAD output files generated at the model year level of detail into the MySQL database. The database then post-processes all of the data, applying adjustment factors to the emissions estimates in the output files to generate the final criteria pollutant and ammonia emissions values. Post-processing applies county specific adjustments to emissions estimates for the appropriate SCCs. Depending upon the SCC and county, the following adjustments may be applied within the database:

- County and year specific temperature and humidity adjustments for NO_X emissions;
- Adjustments for Texas Low Emission Diesel (TxLED) impacts;
- Altitude, correcting for decreased engine efficiency at increasing elevation;
- Soil compaction, reflecting relative ease or difficulty digging; and
- Ground cover, reflecting relative ease or difficulty in land-clearing activity.

Once post-processing adjustments are made to the NONROAD output files, the database performs county-level aggregation of the data by SCC and hp range, summing population, activity, fuel-consumption, and emissions fields. Once completed, the database creates a single output file. The output file contained in the database is then ready to be imported into the Reporting Utility. The TexN Reporting Utility has all of the basic functionality of the original NONROAD utility, but has been modified to accommodate ammonia emissions estimates. In addition, the TexN Reporting Utility allows the user to generate more reports than the NONROAD utility, including emission totals by county and SCC, as well as emission totals by hp and SCC.

ALTITUDE ADJUSTMENTS

Altitude adjustments are applied to all pollutants, as well as equipment activity estimates (in hours per year), for all diesel powered equipment. In general, diesel engines are assumed to suffer a 1% penalty in power output, and therefore productivity, per 1,000 feet in altitude. In other words, an activity requiring 100 hours at sea level would require 101 hours at 1,000 in elevation. Representative altitudes for each county were determined from GIS data containing altitude for each county seat [8]. For example, Anderson County has an altitude of 470 feet, and a corresponding adjustment factor of 0.47%, so all diesel equipment pollutant estimates for this county are multiplied by 1.0047 to reflect the altitude-induced increase in diesel equipment activity.

Given that the vast majority of the state is at relatively low altitude, TexN emission estimates are generally not sensitive to county altitude.

SOIL AND GROUND COVER ADJUSTMENTS

Substantial variations in construction equipment productivity, thus activity, can arise depending on soil and ground cover conditions in a given county. In a previous study, industry experts were consulted to develop activity adjustment factors to be applied to the DCE activity profiles, accounting for county-specific conditions [8]. Adjustments for standard soil and ground cover conditions were based on field experience and engineering judgment, and are summarized in Table A-16. (Note these factors are only applied to DCE earthwork categories within TexN.)

Table A-15: Site Condition Activity Adjustments

Ground Cover	Adjustment Factor (1.0=base conditions)
Wooded lot (dense/moderate)	1.5
Small trees, shrubs, and weed	1.3
Weed and Grass	1.0
Other	Varies
Soil Type: Good common earth (loam)	1.0
Soil Type: Sand/Gravel	1.0
Soil Type: Easy digging (moist silt/clay)	1.0
Soil Type: Hard digging (dry clay)	1.1
Soil Type: Fragmented Rock	1.2
Soil Type: Intact Rock	1.7
Soil Type: Other	Varies

The above factors represent the increase in the time required to complete a certain task, relative to base case conditions (equivalent to an increase in work time, since engine load factors are assumed constant under all conditions). Ground cover adjustments are applicable to the Commercial and Residential DCE profiles, but only for equipment involved in land clearing activities (assumed to be crawler dozers). U.S. Geological Survey (USGS) data were used for determining ground cover characteristics [8, 26]. The ground cover categories provided in the USGS data for Texas were mapped to one of the four standard classifications shown in Table A-15.

Average values for ground cover characteristics were developed for each county and weighted by relative area. Areas designated as having water or impermeable/existing structures were excluded, and the relative areal extent of the remaining categories was renormalized. Weighted average adjustment factors specific to each county are then applied to the base case DCE profiles within TexN to account for area-specific conditions.

Soil type adjustments for productivity are applicable to equipment involved in earthwork operations as well as boring/drilling tasks. For example, excavation work in areas with fragmented rock will require an additional 20% increase in hp-hours compared to “easy digging” soil conditions. In order to characterize soil conditions across the State, the Soil Survey Geographic Database (SSURGO) was obtained from the U.S. Natural Resource Conservation Service [25]. Three soil layers were extracted from this database, including the surface layer, the layer found at 90 cm, and the layer found at 150 cm, near or at the maximum depth of the dataset, to provide a cross-section for analysis. The classifications of these layers were then correlated with the standard soil classifications shown in Table A-15.

Both the spatial extent and depth of each layer were used to develop weights for the DCE adjustments. The productivity adjustment for each layer was weighted by the relative thickness of the layers, and summed to provide a weighted average adjustment for the soil as a whole. The inverse of the resulting county-level soil adjustment factors is shown in Figure A-2. The resulting countywide activity adjustment factors are applied to the Commercial, Residential and Utility sector DCE profiles, as well as the Trencher and Boring/Drilling profiles.

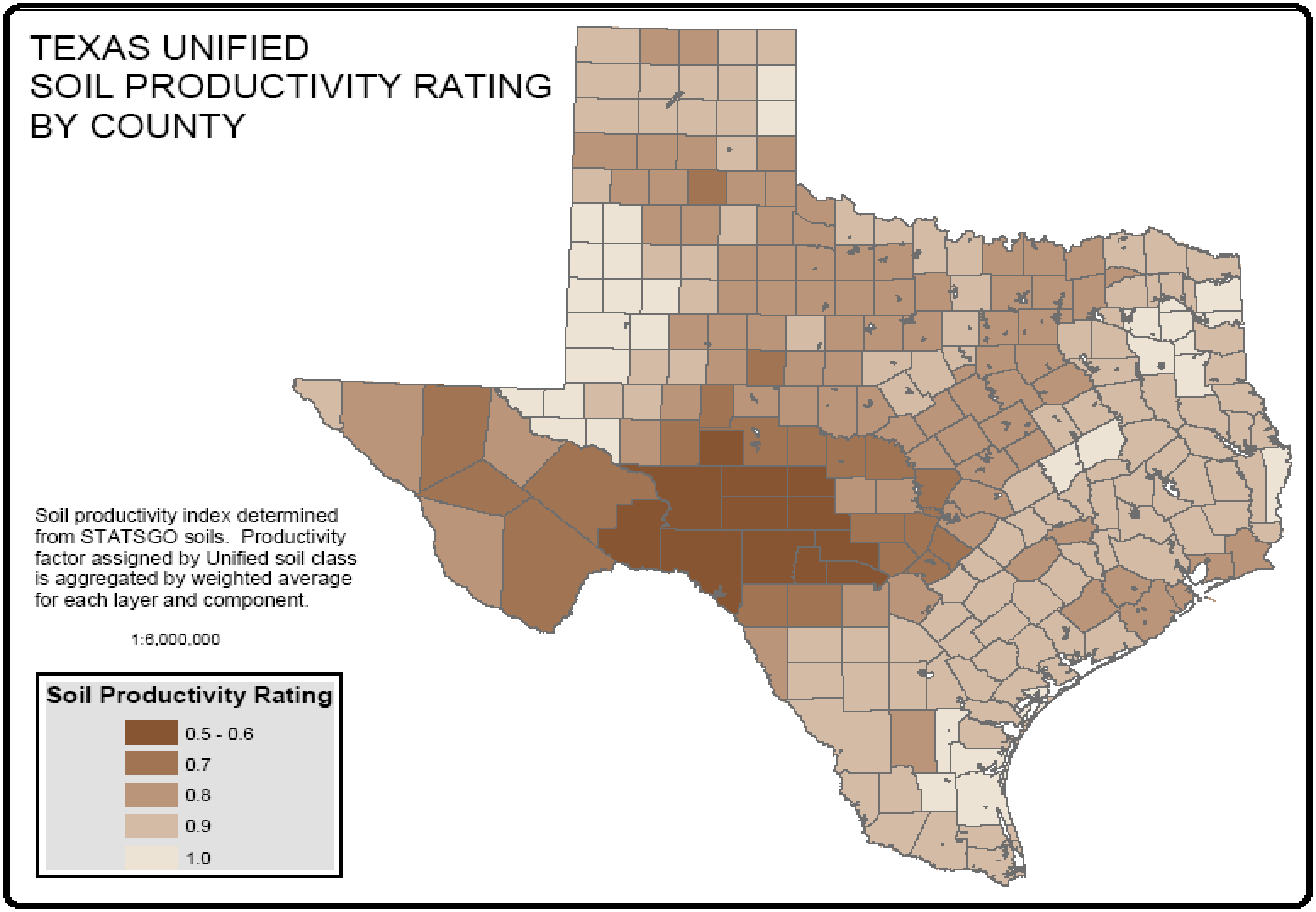

Figure A-2: County Level Weighted Average Soil Adjustment Factors

The DCE equipment profiles were evaluated to establish what portion of equipment activity should be subject to the soil productivity adjustments. The fraction of time each equipment type spends performing earthwork is summarized below in Table A-17.

Table A-16: Earthwork Weighting Factors for Soil Adjustments

DCE Sector	Equipment Type	Earthwork Fraction (% of time, weighted by hp-hrs)
All	Trencher	100%
All	Boring/Drilling	100%
Commercial	Excavator	100%
Commercial	Backhoe	100%
Commercial	Grader	49%
Commercial	Crawler Dozer	40%
Utility	Excavator	100%
Residential	Excavator	100%
Residential	Crawler Dozer	41%

Soil adjustments specific to each county and DCE sector were calculated as follows:

SCCs	2270002030, 2270002033, 2270002036, 2270002048, 2270002066, 2270002069
DCE Sub sectors	Commercial, Utility, Boring and Drilling, Residential, Trenchers
Application	Varies by sector and SCC –

Commercial (2270002036, 2270002066) = Pollutant / Adj. Factor
Commercial (2270002048) = Pollutant * (0.51 + 0.49/ Adj. Factor)
Commercial (2270002069) = Pollutant * (0.60 + 0.40/ Adj. Factor)
Residential (2270002036) = Pollutant / Adj. Factor
Residential (2270002069) = Pollutant * (0.59 + 0.41 / Adj. Factor)
Utility (2270002036) = Pollutant / Adj. Factor
Boring and Drilling (2270002033) = Pollutant / Adj. Factor
Trenchers (2270002030) = Pollutant / Adj. Factor

The weighting factors applied to the different SCCs above reflect the percent of hp-hrs a specific equipment type is involved in earthwork activities, as shown in Table A-17 above.

As seen in Figure A-2, although the largest soil adjustments occur in West Texas near the Edwards Plateau, substantial adjustments (> 10%) are applied in all non-attainment regions across the state. However, these adjustments are only applied to a small number of SCCs in a few DCE sectors. Therefore, while the activity adjustments can be substantial for any particular county/SCC/DCE sector combination, the overall impact on emissions is relatively small.

Ground cover adjustments were only applied to crawler tractors operating in the Commercial and Residential DCE sectors. In this case each pollutant is multiplied by (0.955 + 0.045 x county specific ground cover adjustment). While the ground cover adjustments can be substantial for crawler tractors operating in heavily wooded areas such as East Texas, the adjustment is only this one equipment type operating within two of the DCE sectors. Accordingly, overall emissions are not particularly sensitive to these cover adjustments.

TEMPERATURE AND HUMIDITY NO_X ADJUSTMENTS FOR DIESEL ENGINES

TCEQ identified additional temperature and humidity correction factors for adjustment of NO_X emissions from diesel engines [14]. The NO_X adjustment equations developed in this study are a function of temperature, humidity, and atmospheric pressure. Using the climate data previously discussed, temperature and humidity adjustment factors were calculated for diesel equipment operating in each county in the State, for each season and meteorological year. The application of these adjustment factors is summarized below.

1. Adjustments are applied to all diesel engines (SCC = 227XXXXXXX).
2. Adjustments are only applied to NO_X emissions.
3. Adjustments also depend upon technology type distributions, as determined by Analysis Year.
4. Inputs to the adjustment equations include the following:

    - County Average Temperature (T – season and meteorological year-specific, from Climate Data – in degrees Fahrenheit)
    - County Relative Humidity (RH – season and meteorological year-specific, from Climate Data – in percent)
    - County Atmospheric Pressure (P – in mill bars, or mb)14

5. Adjustments utilize absolute humidity (H), which is calculated as follows:

$H = [RH \times 38.017 \times ea] / [P - 6.112 \times ea]$
where $a = [9.8245 \times (T - 32)] / [0.556 \times (T - 32) + 243.5]$

6. There are two adjustment equations – one equation is used for naturally-aspirated engines, another for turbocharged engines.

    - Naturally-Aspirated Engine Adjustment:

$$1 + 0.001368 \times (0.556 \times (T - 32) - 29.444) - 0.01512 \times (H - 10.71)$$

    - Turbo-charged Engine Adjustment:

$$1 + 0.00446 \times (0.556 \times (T - 32) - 25) - 0.018708 \times (H - 10.71)$$

7. The fraction of naturally-aspirated and turbocharged engines depends upon engine model year and hp bin. Relative fractions were estimated based on the number of engine entries in EPA's certification database. Data were available electronically from EPA for model years 1998-2006.[15] The weighting factors applied to the two different adjustment equations correspond to the relative fraction of naturally-aspirated to turbocharged engines for a given model year, summarized in Table A-18 below:

[14] Average station pressure was found to vary by insignificant amounts over time. For the purposes of this calculation, annual average pressure for each station was calculated for the 2000 meteorological year.

[15] Data from EPA's certification records are not sales-weighted, and therefore may not represent the actual in-use distribution of naturally-aspirated and turbocharged engines. However, sales data is considered proprietary by manufacturers, and was not available for this analysis.

Table A-17: Ratio of Turbo to Naturally-Aspirated Models for Diesel Engines by hp and Model Year

hp Range	Model Year (MY) 1999 (and older)	MY 2000	MY 2001	MY 2002	MY 2003	MY 2004	MY 2005+
< 25	0%	0%	0%	0%	0%	0%	0%
25 – 50	10%	14%	15%	17%	15%	14%	18%
50 - 100	28%	28%	28%	28%	47%	55%	55%
100 – 175	63%	84%	84%	84%	98%	98%	98%
175+	100%	100%	100%	100%	100%	100%	100%

8. Given this information, TexN first calculates the naturally-aspirated and turbocharged factors for each county and season, then weights and sums the factors using the relative fractions given above for each hp bin and model year, and applies the final weighted factors to the NO_X emissions value by the appropriate hp bin and model year in the by model year exhaust file (BMX file).[16]

The above adjustments can result in substantial changes to diesel NO_X emission estimates. For example, for a 2005 Analysis Year, from a baseline of 80 degrees F and 50% relative humidity, a 10% increase in humidity results in a 4% reduction in NO_X emissions. However, although increasing temperature and decreasing relative humidity will tend to increase NO_X emissions from diesel engines, this effect is offset by NONROAD's downward adjustment of NO_X emissions from gasoline 4-stroke engines.

ADJUSTMENTS FOR EMISSION CONTROLS

Various control programs have been implemented to reduce emissions from non-road engines. Federal controls, such as the introduction of new emission standards, are accounted for by the NONROAD model. While evaporative refueling (Stage II) VOC emission controls can be modeled by NONROAD, these emissions are categorized as area sources by the TCEQ. For this reason, any Stage II emission control benefits associated with non-road engine refueling are excluded from TexN to avoid double counting.

The introduction of TxLED in certain Texas counties is not accounted for by the NONROAD model, and is addressed during TexN post-processing. Specifically, NO_X emissions from diesel engines were reduced by 6.2% beginning in February of the 2006 calendar year, for the 110 counties affected by the TxLED program. TxLED was implemented January 31, 2006. TexN has refined the dates for application of TxLED credits to emissions estimates beginning in February 2006 and beyond, as described below.

1. The TxLED "flag" is now activated for 2006 and later analysis years, for the 110 counties.
2. Annual modeling scenarios for 2007 and beyond receive the full credit of 6.2% NO_X reduction applied to all diesel emissions in TxLED counties.

[16] The fraction of naturally-aspirated and turbocharged engines depends upon engine model year and hp bin, so adjustments must be applied to NONROAD's by model year exhaust (BMX) output file. This file provides emission estimates for each SCC and hp bin combination, as well as by model year and engine technology type. Since there are no NOx emissions in the by model year evaporative emissions (BMV) file, no adjustments applied there.

3. If an annual modeling scenario is selected for the 2006 calendar year, the full 6.2% diesel NO_X reduction is applied to the spring, summer, and fall season calculations.
4. Winter season diesel NO_X emissions for 2006 are reduced by 4.1%, assuming adjustments for 2 of the 3 winter months (Jan, Feb, and Dec of 2006).
5. Ozone-season daily scenarios for the 2006 calendar year receive the full 6.2% diesel NO_X reduction adjustment.

A detailed example showing the steps involved in the TexN emission calculation process is provided in Attachment C.

Other rules and regulations that affect non-road engines include multiple Memoranda of Understanding and other agreements with specific fleets in different nonattainment areas, such as airport ground support equipment (GSE) and Port activities. Texas Emission Reduction Program (TERP) projects also fall under this category. However, these fleet level control initiatives have to be modeled using fleet-specific equipment and activity profiles. Similarly, emissions from unusual construction projects that have been profiled on an individual basis previously (such as the construction of three large liquid natural gas depots on the Gulf Coast), must also be modeled on a fleet-specific basis to account for their inventory impacts. As such the effects of these programs and initiatives are not reflected in TexN outputs.

Calculation of Ammonia Emissions

The NONROAD model does not provide estimates for ammonia emissions. In order to provide ammonia estimates using TexN, a list of available ammonia emission factors for the different non-road mobile engine fuel types, including diesel, gasoline, and gaseous fuels (propane and natural gas), were identified and documented [14]. A literature review was performed, and contacts were made with air quality researchers from EPA's Office of Transportation and Air Quality (OTAQ), the California Air Resources Board (ARB) and others to identify available data sources. A detailed web search was also conducted to identify additional sources of emissions test data and analysis. Available data were evaluated for applicability to non-road engine applications, and emission factors were processed and adjusted to account for the impact of future engine technology impacts to the extent possible. Emission factors in TexN are expressed in terms of grams per hp-hour of engine use, and/or grams per gallon of fuel consumption.

Only a limited amount of information was identified regarding ammonia emissions from non-road engines. An attempt was made to identify the most representative data, considering fuel and engine types, as well as the influence of future emission standards on control technologies. The ammonia emission factors identified can be combined with activity data outputs from NONROAD to estimate mass emissions for each SCC and county in Texas. Ammonia is estimated within TexN in tons for all SCCs.

There are four ammonia emission factors in TexN: one for diesel engines, one for spark ignition engines (gasoline and gaseous fuel) without three-way catalysts (TWCs), one for gasoline engines with TWCs, and one for natural gas/LPG engines with TWCs. The emission factors and corresponding technology types are presented in Table A-19 below.

Table A-18: Ammonia Emission Factors Used in TexN

Engine Type	Emission Factor	Units
Diesel	0.00162	g/hp-hr
Gasoline w/ TWC	0.0690	g/hp-hr
CNG/LPG w/ TWC	0.1030	g/hp-hr
Spark Ignition w/out TWC	0.15	g/gal

Note that all emission factors are in g/hp-hr except for spark ignition engines without TWCs, which is in g/gal. Emissions for SCC/technology type combinations with emission factors in g/hp-hr are calculated in TexN by multiplying the factor by the average hp value, the load factor, and the activity value in the BMX file. Results are then converted from grams to tons for output. For those SCC/Technology Type combinations expressed in g/gal, emissions are calculated by multiplying the emission factor by the fuel consumption value in the BMX file, then multiplying by 1.1023e-6 to convert from grams to tons.

REFERENCES

1. User's Guide for the Final NONROAD2005 Model, EPA420-R-05-013, December 2005, http://www.epa.gov/otaq/nonrdmdl.htm
2. NONROAD2005 Emission Factor Model, available from http://www.epa.gov/otaq/nonrdmdl.htm, last validated 11-18-2006.
3. Eastern Research Group, Sampling and Laboratory Analysis of Retail Fuel for Selected Texas Cities, prepared for Peter Ogbeide, Texas Commission on Environmental Quality, August 29, 2003.
4. Eastern Research Group, Sampling and Laboratory Analysis of Retail Fuel for Selected Texas Cities – Summer 2004, prepared for Peter Ogbeide, Texas Commission on Environmental Quality, August 31, 2004.
5. Eastern Research Group, Sampling and Laboratory Analysis of Retail Fuel for Selected Texas Cities – Summer 2005, prepared for Peter Ogbeide, Texas Commission on Environmental Quality, August 31, 2005.
6. Eastern Research Group, Sampling and Laboratory Analysis of Retail Fuel for Selected Texas Cities – Winter 2006, prepared for Peter Ogbeide, Texas Commission on Environmental Quality, April 30, 2006.
7. Texas A&M University Energy Systems Laboratory, http://energysystems.tamu.edu/sb5/data.html, last validated 11-22-06.
8. Eastern Research Group, Ozone Science and Air Modeling Research Project H43T163: Diesel Construction Equipment Activity and Emissions Estimates for the Dallas/Ft. Worth Region, prepared for The Houston Advanced Research Center, August 31, 2005.
9. Eastern Research Group, Statewide Diesel Construction Equipment Inventory, prepared for the Texas Commission on Environmental Quality, August 31, 2005.
10. Eastern Research Group, Nonroad Mobile Source Emissions Inventory Development for the Houston-Galveston-Brazoria Area, submitted to the Houston-Galveston Area Council, July 28, 2006.
11. Eastern Research Group, Data Collection, Sampling and Emissions Inventory Preparation Plan for Selected Commercial and Industrial Equipment: Phase II, Final Report, prepared for the Texas Commission on Environmental Quality, August 31, 2005.
12. Eastern Research Group, Development of Commercial Lawn and Garden Emissions Estimates for the State of Texas and Selected Metropolitan Areas, prepared for Texas Commission on Environmental Quality, November 24, 2003.

13. Eastern Research Group, Recreational Marine Emissions Inventory, prepared for the Texas Commission on Environmental Quality, August 28, 2002.
14. Eastern Research Group, Nonroad Ammonia Emissions Inventory Development, prepared for Texas Commission on Environmental Quality, November 24, 2006
15. EPA Office of Transportation and Air Quality, User's Guide to MOBILE6.1 and 6.2, http://www.epa.gov/otaq/models/mobile6/420r03010.pdf, last validated 11-22-06.
16. Texas A&M Real Estate Center, Texas County Building Permit Activity Data, from http://recenter.tamu.edu/data/bpc/.
17. U.S. Census Bureau, New Privately Owned Housing Units Started: Annual Data, http://www.census.gov/const/startsan.pdf.
18. Texas Comptroller of Public Accounts, Fall 2007 Economic Forecast, Texas Economic Detail, from http://www.window.state.tx.us/ecodata/fcst07fall/fall07economiccalendar.html.
19. Texas State Data Center, 0.5 Growth Scenario, http://txsdc.utsa.edu/tpepp/2004projections/.
20. Texas Comptroller of Public Accounts, Texas State Expenditures by County, from http://www.window.state.tx.us/taxbud/expbyco/.
21. Bureau of Labor Statistics, Consumer Price Index, All Urban Consumers, South Region, from http://data.bls.gov/PDQ/servlet/SurveyOutputServlet?data_tool=dropmap&series_id=CUUR0300SA0,CUUS0300SA0 - all consumers, South Region.
22. Personal communication with Anusuya Iyer, TCEQ, April 25, 2008.
23. Bob Lanham, Vice President Williams Brothers Construction, Houston Texas, personal communication May 23, 2008.
24. Equipment Data Associates, Skid Steer Loader Sales Records through 2005, taken from Eastern Research Group, "Statewide Diesel Construction Equipment Inventory", prepared for the Texas Commission on Environmental Quality, August 31, 2005, p. 3-36.
25. Natural Resource Conservation Service, http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/description.html.
26. U.S. Geological Survey, http://edc.usgs.gov/geodata/.
27. Environmental Protection Agency, http://www.epa.gov/fedrgstr/EPA-AIR/2004/January/Day-12/a458.pdf
28. Environmental Protection Agency, 40 CFR 89.1003(a)(1)(i) and http://www.epa.gov/nonroad-diesel/regulations.htm
29. Environmental Protection Agency, http://www.epa.gov/nonroad-diesel/frm1998/nr-fr.pdf
30. Environmental Protection Agency, http://www.epa.gov/otaq/regs/nonroad/equip-ld/hhsfrm/f00007.pdf
31. Environmental Protection Agency, http://www.epa.gov/otaq/largesi.htm
32. Environmental Protection Agency, http://www.epa.gov/nonroad-diesel/2004fr.htm
33. Environmental Protection Agency, http://www.epa.gov/otaq/models/nonrdmdl/nonrdmdl2005/420r05019.pdf
34. Environmental Protection Agency, http://www.epa.gov/otaq/models/nonrdmdl/nonrdmdl2004/420p04009.pdf

ATTACHMENT B

COUNTY LEVEL FUEL SPECIFICATIONS

Table B-1: 2002 Summertime Gasoline

County	RVP	Sulfur %	Oxy Wt %
Brazoria	6.80	0.0162	1.75
Chambers	6.80	0.0162	1.75
Fort Bend	6.80	0.0162	1.75
Galveston	6.80	0.0162	1.75
Harris	6.80	0.0162	1.75
Liberty	6.80	0.0162	1.75
Montgomery	6.80	0.0162	1.75
Waller	6.80	0.0162	1.75

Table B-2: 2008 Summertime Gasoline

County	RVP	Sulfur %	Oxy Wt %
Brazoria	6.8	0.00330	2.1
Chambers	6.8	0.00330	2.1
Fort Bend	6.8	0.00330	2.1
Galveston	6.8	0.00330	2.1
Harris	6.8	0.00330	2.1
Liberty	6.8	0.00330	2.1
Montgomery	6.8	0.00330	2.1
Waller	6.8	0.00330	2.1

Table B-3: 2002 Wintertime Gasoline

County	RVP	Sulfur %	Oxy Wt %
Brazoria	11.3	0.0259	3.5
Chambers	11.3	0.0259	3.5
Fort Bend	11.3	0.0259	3.5
Galveston	11.3	0.0259	3.5
Harris	11.3	0.0259	3.5
Liberty	11.3	0.0259	3.5
Montgomery	11.3	0.0259	3.5
Waller	11.3	0.0259	3.5

Table B-4: 2008 Wintertime Gasoline

County	RVP	Sulfur %	Oxy Wt %
Brazoria	11.3	0.00300	3.5
Chambers	11.3	0.00300	3.5
Fort Bend	11.3	0.00300	3.5
Galveston	11.3	0.00300	3.5
Harris	11.3	0.00300	3.5
Liberty	11.3	0.00300	3.5
Montgomery	11.3	0.00300	3.5
Waller	11.3	0.00300	3.5

Table B-5: Diesel Fuel Sulfur Levels (weight %)

County	1999-2003	2004	2005	2006-2009	2010+
Brazoria	0.0307	0.0402	0.0351	0.0351	0.0015
Chambers	0.0307	0.0402	0.0412	0.0412	0.0015
Fort Bend	0.0307	0.0402	0.0351	0.0351	0.0015
Galveston	0.0307	0.0402	0.0351	0.0351	0.0015
Harris	0.0307	0.0402	0.0351	0.0351	0.0015
Liberty	0.0307	0.0402	0.0412	0.0412	0.0015
Montgomery	0.0307	0.0402	0.0351	0.0351	0.0015
Waller	0.0307	0.0402	0.0351	0.0351	0.0015

Table B-6: Historical Census Population by County for 8-County HGB Area (1970/80/90/2000)

County	1970	1980	1990	2000
Brazoria	108,312	169,587	191,707	241,767
Chambers	12,187	18,538	20,088	26,031
Fort Bend	52,314	130,846	225,421	354,452
Galveston	169,812	195,940	217,399	250,158
Harris	1,741,912	2,409,547	2,818,199	3,400,578
Liberty	33,014	47,088	52,726	70,154
Montgomery	49,479	128,487	182,201	293,768
Waller	14,285	19,798	23,390	32,663

Source: Texas State Data Center

ATTACHMENT C

TEXN EMISSION CALCULATION EXAMPLE

The following provides an example illustrating the detailed calculation steps within the NONROAD model, as well as the post-processing adjustments applied by TexN. The derivation and use of each parameter in the fundamental emission equation (shown below) are discussed, as well as the application of the appropriate locality specific adjustments.

Fundamental Emissions Equation:

$$\text{Emissions}_{p/yr} = \sum(MYR) \sum(HP)\ Pop * Power * LF * A * EF_p$$

Where: Pop = Number of engines

Power = Average hp (for specific hp group)

LF = Load factor (% of rated power)

A = Activity (hr/year)

EF_p = Emissions for pollutant p (grams/bhp-hr)

∑(HP) = summation over each equipment hp group

∑(MYR) = summation over each equipment model year

The example calculation is conducted for NO_X emissions for the following scenario:

- County – Harris
- Equipment Type – Diesel Trenchers (SCC = 2270002030)
- Analysis Year – 2050
- Period – Ozone Season Weekday

In order to walk through the example calculation, we recommend you run a TexN scenario for these conditions.

Step 1 – Identify NONROAD Input and TexN Adjustment Parameters. First, open the TexN scenario you developed for the above conditions. This will allow you to identify the default input and adjustment parameters used within the model. From the Population Tab, identify average hp, useful life (in hrs), and population for each hp bin with non-zero populations. From the Activity Tab, identify the load factor and activity in hours per year. From the Fuel and Climate Tab, identify the average summertime temperature in degrees Fahrenheit and relative humidity (typical meteorological year assumed). These input parameters are listed below:

Table C-1: Population Tab

hp bin	avg. hp	useful life	population (2050)[17]
25 – 50 hp	34.1	2,500 hrs	2,172.64
50 – 75 hp	61.02	4,667 hrs	491.01
75 – 100 hp	86.75	4,667 hrs	610.22

[17] These figures correspond to 2050 population projections.

Table C-2: Activity Tab

load factor	activity
0.59	1,308 hrs/yr

Table C-3: Fuel and Climate

average temperature	relative humidity	atmospheric pressure (mb)[18]
81.1 °F	75%	1,013.21

Step 2 – Determine the Model Year Distribution for Each HP Bin. NONROAD applies its default scrappage and growth curves in order to allocate the population totals for each hp bin across model years. To develop these distributions, first calculate the median life in years for diesel trenchers as shown below.

Median Life in years (< 50 hp) = Median life in hours / (activity in hours/yr x load factor) = 2,500 / (1,306 x 0.59) = 3.24 years

Median Life in years (> 50 hp) = 4,667 / (1,306 x 0.59) = 6.05 years

Next, the default scrappage curve must be modified to provide the fraction of median life expressed in terms of engine age, as shown in Table C-4 below. The age distributions shown in the table are calculated by simply multiplying the fraction of median life value by the median life expressed in years (3.24 years for engines < 50 hp, and 6.05 years for engines >= 50 hp).

Table C-4: Default Scrappage Curve Expressed in Years of Age (Trenchers)

Fraction of Median Life	Cumulative % Scrapped	Incremental % Scrapped	Age Distribution (<50 hp)	Age Distribution (>50 hp)
0	0	0	0	0
0.0294	0.5	0.5	0.095	0.178
0.0588	1	0.5	0.190	0.356
0.08705	1.5	0.5	0.282	0.526
0.1153	2	0.5	0.374	0.697
0.14235	2.5	0.5	0.461	0.861
0.1694	3	0.5	0.549	1.024
0.19535	3.5	0.5	0.633	1.181
0.2213	4	0.5	0.717	1.338
0.24615	4.5	0.5	0.797	1.489
0.271	5	0.5	0.878	1.639
0.29475	5.5	0.5	0.955	1.783
0.3185	6	0.5	1.032	1.926
0.3412	6.5	0.5	1.105	2.063

[18] Atmospheric pressure is not displayed on the Fuel and Climate Tab, but is maintained in one of the TexN lookup tables accessible by the TexN database administrator.

Fraction of Median Life	Cumulative % Scrapped	Incremental % Scrapped	Age Distribution (<50 hp)	Age Distribution (>50 hp)
0.3639	7	0.5	1.179	2.201
0.3856	7.5	0.5	1.249	2.332
0.4073	8	0.5	1.319	2.463
0.42795	8.5	0.5	1.386	2.588
0.4486	9	0.5	1.453	2.713
0.4683	9.5	0.5	1.517	2.832
0.488	10	0.5	1.581	2.951
0.5067	10.5	0.5	1.641	3.064
0.5254	11	0.5	1.702	3.177
0.5432	11.5	0.5	1.760	3.285
0.561	12	0.5	1.817	3.393
0.5779	12.5	0.5	1.872	3.495
0.5948	13	0.5	1.927	3.597
0.6108	13.5	0.5	1.979	3.694
0.6268	14	0.5	2.031	3.791
0.6419	14.5	0.5	2.079	3.882
0.657	15	0.5	2.128	3.973
0.6713	15.5	0.5	2.175	4.060
0.6856	16	0.5	2.221	4.146
0.69905	16.5	0.5	2.265	4.228
0.7125	17	0.5	2.308	4.309
0.7252	17.5	0.5	2.349	4.386
0.7379	18	0.5	2.390	4.462
0.7498	18.5	0.5	2.429	4.534
0.7617	19	0.5	2.468	4.606
0.77285	19.5	0.5	2.504	4.674
0.784	20	0.5	2.540	4.741
0.79445	20.5	0.5	2.574	4.804
0.8049	21	0.5	2.607	4.868
0.81465	21.5	0.5	2.639	4.927
0.8244	22	0.5	2.671	4.986
0.83345	22.5	0.5	2.700	5.040
0.8425	23	0.5	2.729	5.095
0.85095	23.5	0.5	2.757	5.146
0.8594	24	0.5	2.784	5.197
0.8672	24.5	0.5	2.809	5.244

Fraction of Median Life	Cumulative % Scrapped	Incremental % Scrapped	Age Distribution (<50 hp)	Age Distribution (>50 hp)
0.875	25	0.5	2.835	5.292
0.8822	25.5	0.5	2.858	5.335
0.8894	26	0.5	2.881	5.379
0.89605	26.5	0.5	2.903	5.419
0.9027	27	0.5	2.924	5.459
0.90875	27.5	0.5	2.944	5.496
0.9148	28	0.5	2.964	5.532
0.92035	28.5	0.5	2.981	5.566
0.9259	29	0.5	2.999	5.599
0.93095	29.5	0.5	3.016	5.630
0.936	30	0.5	3.032	5.660
0.94055	30.5	0.5	3.047	5.688
0.9451	31	0.5	3.062	5.716
0.9492	31.5	0.5	3.075	5.740
0.9533	32	0.5	3.088	5.765
0.957	32.5	0.5	3.100	5.787
0.9607	33	0.5	3.112	5.810
0.96395	33.5	0.5	3.123	5.830
0.9672	34	0.5	3.133	5.849
0.9701	34.5	0.5	3.143	5.867
0.973	35	0.5	3.152	5.884
0.9755	35.5	0.5	3.160	5.899
0.978	36	0.5	3.168	5.914
0.9802	36.5	0.5	3.175	5.928
0.9824	37	0.5	3.183	5.941
0.9843	37.5	0.5	3.189	5.953
0.9862	38	0.5	3.195	5.964
0.9878	38.5	0.5	3.200	5.974
0.9894	39	0.5	3.205	5.983
0.9907	39.5	0.5	3.209	5.991
0.992	40	0.5	3.214	5.999
0.9931	40.5	0.5	3.217	6.006
0.9942	41	0.5	3.221	6.012
0.99505	41.5	0.5	3.223	6.018
0.9959	42	0.5	3.226	6.023
0.9966	42.5	0.5	3.229	6.027

Fraction of Median Life	Cumulative % Scrapped	Incremental % Scrapped	Age Distribution (<50 hp)	Age Distribution (>50 hp)
0.9973	43	0.5	3.231	6.031
0.9978	43.5	0.5	3.232	6.034
0.9983	44	0.5	3.234	6.037
0.99865	44.5	0.5	3.235	6.039
0.999	45	0.5	3.236	6.041
0.99925	45.5	0.5	3.237	6.043
0.9995	46	0.5	3.238	6.045
0.99965	46.5	0.5	3.238	6.045
0.9998	47	0.5	3.239	6.046
0.99985	47.5	0.5	3.239	6.047
0.9999	48	0.5	3.239	6.047
0.99995	49	1	3.239	6.047
1	50	1	3.240	6.048
1.00005	51	1	3.240	6.048
1.0001	52	1	3.240	6.048
1.00015	52.5	0.5	3.240	6.048
1.0002	53	0.5	3.240	6.049
1.00035	53.5	0.5	3.241	6.050
1.0005	54	0.5	3.241	6.051
1.00075	54.5	0.5	3.242	6.052
1.001	55	0.5	3.243	6.054
1.00135	55.5	0.5	3.244	6.056
1.0017	56	0.5	3.245	6.058
1.0022	56.5	0.5	3.247	6.061
1.0027	57	0.5	3.248	6.064
1.0034	57.5	0.5	3.251	6.068
1.0041	58	0.5	3.253	6.072
1.00495	58.5	0.5	3.256	6.077
1.0058	59	0.5	3.258	6.083
1.0069	59.5	0.5	3.262	6.089
1.008	60	0.5	3.265	6.096
1.0093	60.5	0.5	3.270	6.104
1.0106	61	0.5	3.274	6.112
1.0122	61.5	0.5	3.279	6.121
1.0138	62	0.5	3.284	6.131
1.0157	62.5	0.5	3.290	6.142

Fraction of Median Life	Cumulative % Scrapped	Incremental % Scrapped	Age Distribution (<50 hp)	Age Distribution (>50 hp)
1.0176	63	0.5	3.297	6.154
1.0198	63.5	0.5	3.304	6.167
1.022	64	0.5	3.311	6.181
1.0245	64.5	0.5	3.319	6.196
1.027	65	0.5	3.327	6.211
1.0299	65.5	0.5	3.336	6.228
1.0328	66	0.5	3.346	6.246
1.03605	66.5	0.5	3.356	6.266
1.0393	67	0.5	3.367	6.285
1.043	67.5	0.5	3.379	6.308
1.0467	68	0.5	3.391	6.330
1.0508	68.5	0.5	3.404	6.355
1.0549	69	0.5	3.417	6.380
1.05945	69.5	0.5	3.432	6.407
1.064	70	0.5	3.447	6.435
1.06905	70.5	0.5	3.463	6.465
1.0741	71	0.5	3.480	6.496
1.07965	71.5	0.5	3.498	6.529
1.0852	72	0.5	3.516	6.563
1.09125	72.5	0.5	3.535	6.599
1.0973	73	0.5	3.555	6.636
1.10395	73.5	0.5	3.576	6.676
1.1106	74	0.5	3.598	6.716
1.1178	74.5	0.5	3.621	6.760
1.125	75	0.5	3.644	6.803
1.1328	75.5	0.5	3.670	6.851
1.1406	76	0.5	3.695	6.898
1.14905	76.5	0.5	3.722	6.949
1.1575	77	0.5	3.750	7.000
1.16655	77.5	0.5	3.779	7.055
1.1756	78	0.5	3.808	7.109
1.18535	78.5	0.5	3.840	7.168
1.1951	79	0.5	3.872	7.227
1.20555	79.5	0.5	3.905	7.291
1.216	80	0.5	3.939	7.354
1.22715	80.5	0.5	3.975	7.421

Fraction of Median Life	Cumulative % Scrapped	Incremental % Scrapped	Age Distribution (<50 hp)	Age Distribution (>50 hp)
1.2383	81	0.5	4.011	7.489
1.2502	81.5	0.5	4.050	7.561
1.2621	82	0.5	4.089	7.633
1.2748	82.5	0.5	4.130	7.709
1.2875	83	0.5	4.171	7.786
1.30095	83.5	0.5	4.214	7.868
1.3144	84	0.5	4.258	7.949
1.3287	84.5	0.5	4.304	8.035
1.343	85	0.5	4.351	8.122
1.3581	85.5	0.5	4.400	8.213
1.3732	86	0.5	4.449	8.304
1.3892	86.5	0.5	4.500	8.401
1.4052	87	0.5	4.552	8.498
1.4221	87.5	0.5	4.607	8.600
1.439	88	0.5	4.662	8.702
1.4568	88.5	0.5	4.719	8.810
1.4746	89	0.5	4.777	8.918
1.4933	89.5	0.5	4.838	9.031
1.512	90	0.5	4.898	9.144
1.5317	90.5	0.5	4.962	9.263
1.5514	91	0.5	5.026	9.382
1.57205	91.5	0.5	5.093	9.507
1.5927	92	0.5	5.160	9.632
1.6144	92.5	0.5	5.230	9.763
1.6361	93	0.5	5.300	9.894
1.6588	93.5	0.5	5.374	10.032
1.6815	94	0.5	5.447	10.169
1.70525	94.5	0.5	5.524	10.313
1.729	95	0.5	5.601	10.456
1.75385	95.5	0.5	5.682	10.606
1.7787	96	0.5	5.762	10.757
1.80465	96.5	0.5	5.846	10.914
1.8306	97	0.5	5.930	11.071
1.85765	97.5	0.5	6.018	11.234
1.8847	98	0.5	6.106	11.398
1.91295	98.5	0.5	6.197	11.569

Fraction of Median Life	Cumulative % Scrapped	Incremental % Scrapped	Age Distribution (<50 hp)	Age Distribution (>50 hp)
1.9412	99	0.5	6.289	11.739
1.9706	99.5	0.5	6.384	11.917
2	100	0.5	6.479	12.095

The above fractions were then aggregated by engine age in year increments to determine the fraction of engines in each year (see Table C-5 below).

Table C-5: Remaining Fraction of Engines by Age

Age	< 50 hp	> 50 hp
1	0.95	0.98
2	0.87	0.94
3	0.71	0.90
4	0.20	0.85
5	0.10	0.78
6	0.03	0.60
7	0.00	0.24
8	0.00	0.16
9	0.00	0.11
10	0.00	0.07
11	0.00	0.04
12	0.00	0.01

In order to determine the 2050 model year distribution, the fractions presented in Table Y must be combined with annual equipment sales estimates over the previous 6 years, in the case of engines < 50 hp, and over the previous 12 years, in the case of engines >= 50 hp. The annual growth in sales can be calculated from NONROAD's default growth file, *nation.grw*. From this file, we identify the last two indicator values for the diesel construction indicator code (021), as show below.

2025 – 1,927
2045 – 2,569

The NONROAD model uses these two data points to linearly extrapolate annual sales growth rates up to 2050. Annual growth rates for the period from 2025-2050 are calculated as [(2,569 – 1,927) / (2045 – 2025)] / 1,000 = 3.21%.[19] Therefore, equipment sales totals for units of age X are related to sales totals in the year 2050 (age 1) by the following equation:

$Sales_{age\ x} = Sales_{age\ 1} / [1 + (x - 1)(0.0321)] = Sales_{age\ x} / a_x$

[19] The difference between the indicator code values are divided by the 1996 base year value of 1,000 – also obtained from the *nation.grw* file.

The values for ax are shown below in Table C-6.

Table C-6: Sales Adjustment Factors by Age

Age	a (x)
1	1.000
2	1.032
3	1.064
4	1.096
5	1.128
6	1.161
7	1.193
8	1.225
9	1.257
10	1.289
11	1.321
12	1.353

Dividing the total equipment population for each hp bin by the sum of the ratios of the remaining equipment fraction (Table C-5) and the sales adjustment factors (Table C-6) allows us to calculate the equipment sales totals for units sold in 2050 (age 1) for each hp bin. The general equation for a given hp bin is shown below, with the summation over all equipment ages with non-zero remaining fractions.

$\text{Sales}_{\text{age 1}} = \text{Total Pop} \,/\, \sum (\text{Remaining Fraction}_x \,/\, a_x)$

The resulting 2050 sales totals (age = 1) are shown in Table C-7 below.

Table C-7: 2050 (Age 1) Sales Totals by HP Bin

HP Bin	Sales Total
< 50 hp	793.4623
50-75 hp	94.15786
75-100 hp	117.0177

These age 1 sales totals are then divided by the product of the sales adjustment factor and the remaining fraction by year to obtain the model year distribution for each hp bin, as shown in Table C-8.

Table C-8: Model Year Distribution by HP Bin

Yr	< 50 hp	50 - 75 hp	75-100 hp
1	749.82	91.80	114.09
2	665.00	85.76	106.58

Yr	< 50 hp	50 - 75 hp	75-100 hp
3	529.37	79.63	98.96
4	141.13	73.00	90.73
5	66.80	65.09	80.89
6	20.51	48.68	60.50
7	0.00	18.55	23.06
8	0.00	12.30	15.29
9	0.00	8.24	10.24
10	0.00	5.11	6.36
11	0.00	2.49	3.10
12	0.00	0.35	0.43
Total	**2,172.64**	**491.01**	**610.22**

Step 3 – Determine Emission Factors by HP Bin and Age. First, determine the technology mix for trenchers in 2050. In the *tech-exh.dat* file we see that diesel engine sales (SCC 227XXXXXXX) in the 25-50, and 50-75 hp bins are designated 100% "T4" starting shortly after 2010. Therefore, by 2050 100% of all in-use trencher engines are assumed to be T4. Similarly, all in-use trenchers in the 75-100 hp range are assumed to be T4N by 2050. Next, identify the zero-hour NO_X emission factors in the *exhnox.emf* file for the appropriate hp bin and technology type. These factors are shown below in Table C-9.

Table C-9: Zero-Hour NO_X Diesel Emission Factors (2050)

HP Bin	g/hp-hr	Tech Type
< 50 hp	3.00	100% T4
50-75 hp	3.00	100% T4
75-100 hp	0.28	100% T4N

Next, identify the associated NO_X deterioration factors by technology type. These values are provided in the *exhnox.det* file. Deterioration factors are multiplicative to the zero-hour factors, and are calculated as follows:

$DF = 1 + A \times \text{engine age}^b$

In the above equation, engine age is expressed as a fraction of median life.

For technology types T4 and T4N, A = 0.008 and b = 1, translating to a very low deterioration rate for these engines. In addition, deterioration is capped once the engine age equals the median life of the engine. By calculating engine age in terms of the fraction of median life (hrs/yr x yrs x load factor / median life in hours), and substituting this value into the above equation, a separate deterioration factor can be calculated for each engine age of interest (in years), as shown in Table C-10.

Table C-10: NO_X Deterioration Factors by Model Year (2050 Scenario)

Model Yr	< 50 hp	>= 50 hp
2050	1.0025	1.0013
2049	1.0049	1.0026
2048	1.0074	1.0040
2047	1.0080	1.0053
2046	1.0080	1.0066
2045	1.0080	1.0079
2044	1.0080	1.0080
2043	1.0080	1.0080
2042	1.0080	1.0080
2041	1.0080	1.0080
2040	1.0080	1.0080
2039	1.0080	1.0080

By multiplying the zero-hour factors in Table C-9 by the deterioration factors above, we obtain the age-dependent emission factors, shown in Table C-11.

Table C-11: NO_X Emission Factors by Model Year (g/hp-hr)

Model Yr	< 50 hp	50-75 hp	75-100 hp
2050	3.007	3.004	0.280
2049	3.015	3.008	0.281
2048	3.022	3.012	0.281
2047	3.024	3.016	0.281
2046	3.024	3.020	0.282
2045	3.024	3.024	0.282
2044	3.024	3.024	0.282
2043	3.024	3.024	0.282
2042	3.024	3.024	0.282
2041	3.024	3.024	0.282
2040	3.024	3.024	0.282
2039	3.024	3.024	0.282

Step 4 – Determine Activity Hours per Ozone-Season Weekday. The MONTHLY packet within the *season.dat* file indicates that construction equipment in the Southwest U.S. ("SW", which includes Texas), are operated 9.1% of their annual total during each summer month. Equivalently, 27.3% (3 summer months x 9.1%/month) of total hours per year occur during the summer. This corresponds to 1,306 x 0.273 = 357 hours of trencher activity per summer. From the Scenario output file we see that a summer NONROAD run is assumed to include 92 days in the entire season, or 92 / 7 = 13.14 weeks. In turn, this corresponds to 357 hrs/season / 13.14 weeks/season = 27.17 hours per week.

Finally, the DAILY packet of the *season.dat* file shows that construction equipment is assumed to have 16.7% of its weekly activity occur on a weekday. This corresponds to 27.17 hrs/week x 0.167 = **4.53 hours/summer weekday**. This daily activity level can be multiplied using the following equation to estimate tons of NO_X per ozone season day, with the summation occurring over engine model years.

Tons/Ozone-Season Weekday = ∑ Emission Factor (g/hp-hr) x Engine Population x Hours/Ozone Season Weekday x Average hp x Load Factor x 1.1023 x 10-6 short tons/gram

The resulting emissions estimates are provided in Table C-12 below. These estimates correspond to the values output from the NONROAD model before TexN adjustments are applied.

Table C-12: NO_X Emissions from Diesel Trenchers (Tons per Ozone-Season Weekday, 2050 Scenario)

Equipment Age (Yrs)	< 50 hp	50 - 75 hp	75-100 hp
1	0.227	0.050	0.008
2	0.201	0.046	0.008
3	0.161	0.043	0.007
4	0.043	0.040	0.007
5	0.020	0.035	0.006
6	0.006	0.026	0.004
7	0.000	0.010	0.002
8	0.000	0.007	0.001
9	0.000	0.004	0.001
10	0.000	0.003	0.000
11	0.000	0.001	0.000
12	0.000	0.000	0.000
Total	**0.658**	**0.266**	**0.044**

Step 5 – Apply Post-Processing Adjustments. Several adjustments are applied to the NONROAD outputs. First, temperature and humidity adjustments are applied to all diesel engines. Adjustments utilize absolute humidity (H), which is calculated as follows:

H = [RH x 38.017 x ea] / [P – 6.112 x e^a]
where a = [9.8245 x (T – 32)] / [0.556 x (T – 32) + 243.5]

Inserting the parameters specific to typical meteorological year conditions in Harris County identified under Step 1, a = 1.781 and H = 17.330.

There are two adjustment equations – one equation is used for naturally-aspirated engines, another for turbocharged engines.

Naturally-Aspirated (N-A) Engine Adjustment:
1 + 0.001368 x (0.556 x (T - 32) – 29.444) – 0.01512 x (H – 10.71)

Turbo-charged Engine Adjustment:
1 + 0.00446 x (0.556 x (T – 32) - 25) – 0.018708 x (H – 10.71)

Inserting the values for T (81.1) and H from above, the **N-A adjustment = 0.897**, and the **turbo adjustment = 0.886**.

Next, the estimated fraction of N-A and turbocharged engines is shown below for model years beyond 2005.

Table C-13: Engine Adjustment Estimated Fractions for Model Years Beyond 2005

	N-A	Turbo
< 50 hp	0.82	0.18
> 50 hp	0.45	0.55

Applying these weights to the engine adjustments results in a net adjustment of **0.895 for engines less than 50 hp, and 0.891 for engines greater than or equal to 50 hp**. Applying these factors directly to the NONROAD output emissions estimates, we obtain the following adjusted NO_X values.

Table C-14: Adjusted NO_X Values Based on Engine Adjustments and HP

HP	TPD
< 50 hp	0.5889 TPD
50 – 75 hp	0.2370 TPD
75 – 100 hp	0.0391 TPD
Total	0.8650 TPD

Next, altitude adjustments are applied directly to NO_X emission estimates to reflect the slight increase in hp-hrs needed to accomplish a task at a higher altitude. Multiplying the 0.865 figure by the altitude adjustment factor for Harris County (1.00032) yields a miniscule adjustment of 0.0003 TPD (0.8653).

The soil adjustment factor for Harris County of 1.222 is applied to all trencher activity, resulting in a one-to-one increase in hp-hrs and NO_X emissions. The resulting adjustment applied to the 0.8653 figure results in a revised NO_X estimate of 1.0578 TPD.

Finally, Harris County is within the TxLED region, so a further adjustment of (1-.062) = 0.938 is applied to the 1.0578 value, yielding a final adjusted emission estimate of **0.992 TPD for all trenchers operating in Harris County in 2050**. The difference from the actual TexN output of 0.991 TPD is attributable to rounding error.

ATTACHMENT D

APPLICABLE RULES AND REASONABLE FURTHER PROGRESS (RFP) ANALYSES

RATE OF FURTHER PROGRESS (RFP) ANALYSES

The TexN model can be used to evaluate the effects of individual federal rules impacting non-road emissions for the RFP analyses. The applicable rules are:

- Rule #1: Emission Standards for New Nonroad Spark-ignition Engines at or below 19 Kilowatts - "Phase I Small SI Rule" [27]
- Rule #2: Federal Emission Standards for Heavy-Duty and Nonroad Engines - "1998 HD and Nonroad Rule" [28]
- Rule #3: Tier 1, 2 and Tier 3 Emission Standards: Control of Emissions of Air Pollution from Nonroad Diesel Engines - "Tier 1, 2 and 3 Rule" [29]
- Rule #4: Final Phase II Standards for Small Nonroad SI Handheld Engines - "Phase II Small SI Rule" [30]
- Rule #5: Emission Standards for New Nonroad Engines: Large Industrial SI Engines, Recreational Vehicles, and Diesel Recreational Marine Engines - "Large SI Rule" [31]
- Rule #6: Clean Air Nonroad Diesel - Tier 4 Final Rule – "Tier 4 Rule" [32]

In an RFP evaluation, the ozone season daily emission reduction impact must be determined and reported for each rule for the given region and evaluation year. Table D-1 below shows the phase-in dates, equipment types and hp ranges for each rule. Each of these rules is discussed in more detail below.

In order to evaluate individual rule impacts, the technology type files were modified to reflect the phase-in of individual rules. There is a separate set of technology type files for each federal rule that is evaluated. Each rule has a technology type file that reflects the uncontrolled conditions and the controlled conditions. To create the uncontrolled technology type files, the technology type phase-in that was available immediately prior to the rule of evaluation was carried forward to future years, effectively zeroing out the effects of the rule of evaluation. The controlled technology type files were created by carrying forward the phase-in that was available at the conclusion of the phase-in of the rule of evaluation, effectively zeroing out the effect of subsequent rules.

Note: In some cases, a technology would begin phase-in one year prior to the rule requirements. In these instances, this phase-in year is considered to be a direct consequence of the pending rule. Therefore, any benefits seen by an early phase-in is attributed to the pending rule.

Table D-1: Phase-in Dates by Rule

Rule Reference #	Rule	Sub-categories	Spark Ignition (Gasoline, LPG, CNG) < 25 hp	Spark Ignition (Gasoline, LPG, CNG) > 25 hp	Spark Ignition (Gasoline, LPG, CNG) MARINE < 25 hp	Spark Ignition (Gasoline, LPG, CNG) MARINE > 25 hp	Compression Ignition (Diesel) < 50 hp	Compression Ignition (Diesel) > 50 hp	Compression Ignition (Diesel) MARINE < 50 hp	Compression Ignition (Diesel) MARINE > 50 hp
1	Phase I Small SI		1997-							
2	1998 HD and Nonroad				1998-2006			1998-2000		
3	Tiers 1, 2, and 3	Tier 1					1999-2000			
3	Tiers 1, 2, and 3	Tier 2					2001-2006	2001-2006	2001-2006	
3	Tiers 1, 2, and 3	Tier 3						2006-2008	2006-2008	
4	Phase II Small SI		2002-2007							
5	Large SI	Large Industrial Spark-Ignition Engines (Tier 1)		2004		2004				

Rule Reference #	Rule	Sub-categories	Spark Ignition (Gasoline, LPG, CNG) < 25 hp	Spark Ignition (Gasoline, LPG, CNG) > 25 hp	Spark Ignition (Gasoline, LPG, CNG) MARINE < 25 hp	Spark Ignition (Gasoline, LPG, CNG) MARINE > 25 hp	Compression Ignition (Diesel) < 50 hp	Compression Ignition (Diesel) > 50 hp	Compression Ignition (Diesel) MARINE < 50 hp	Compression Ignition (Diesel) MARINE > 50 hp
5	Large SI	Large Industrial Spark-Ignition Engines (Tier 2)		2007		2007				
5	Large SI	Recreational Vehicles		2006						
5	Large SI	Diesel Recreational Marine Engines								2006
6	Tier 4						2008	2008-2013		

Rule #1: Emission Standards for New Non-road Spark-ignition (SI) Engines At or Below 19 kW (~25 hp)

This rule is applicable to new non-road SI engines at or below 19 kW (~ 25 hp) and manufactured during or after the 1997 model year, including farm and construction equipment, lawnmowers, string trimmers, edgers, chainsaws, commercial turf equipment, small construction equipment, and lawn and garden tractors. Exempt vehicles and equipment include competition or combat vehicles, research, training, investigations, demonstrations, and national security vehicles and equipment, engines used to propel marine vessels, engines used in underground mining equipment, motorcycles, aircraft, and recreational vehicles. The standards for this rule are presented in Table D-2 below.

Table D-2: Phase I Small SI Rule Standards (g/bhp-hr)

Class	Year	CO	HC	HC + NOx	NOx	Class Description
I	1997+	387	N/A	12	N/A	Nonhandheld < 225 cc
II	1997+	387	N/A	10	N/A	Nonhandheld > ~225 cc
III	1997+	600	220	N/A	4	Handheld < 20 cc
IV	1997+	600	180	N/A	4	Handheld > ~20 < 50 cc
V	1997+	450	120	N/A	4	Handheld > ~50 cc

Rule #2: Federal Emission Standards for Heavy-Duty and Non-road Engines

This rule is applicable to non-road compression ignition (CI – diesel) engines greater than 50 hp, and marine SI outboard engines manufactured as early as 1998, and personal watercraft and jet boat engines manufactured as early as 1999. This rule does not include standards for non-road SI engines greater than 25 hp or marine CI engines. The standards are presented below in Tables D-3 and D-4.

Table D-3: 1998 Non-road CI Engine Standards in g/bhp-hr

Rated Power	Year	CO	HC	NO_X	PM_{10}	Smoke (%) acceleration/lug/ peak modes
50 ≤hp< 100	1998+	N/A	N/A	6.9	N/A	20/15/50
100 ≤hp< 175	1997+	N/A	N/A	6.9	N/A	20/15/50
175 ≤hp< 750	1996+	8.5	1	6.9	0.4	20/15/50
hp = 750+	2000+	8.5	1	6.9	0.4	20/15/50

Table D-4: 1998 Marine SI Engine Standards ($HC+NO_X$)

Year	g/kW-hr (P* < 4.3)	g/hp-hr (P* < 4.3)	g/kW-hr (P* ≥ 4.3)	g/hp-hr (P* ≥ 4.3)
1998	278	207.3	(0.917 x (151+ 557/P^0.9)) + 2.44	[(0.917 x (151+ 557/P^0.9)) + 2.44] x 0.7457
1999	253	188.7	(0.833 x (151+ 557/P^0.9)) + 2.89	[(0.833 x (151+ 557/P^0.9)) + 2.89] x 0.7457
2000	208	155.1	(0.750 x (151+ 557/P^0.9)) + 3.33	[(0.750 x (151+ 557/P^0.9)) + 3.33] x 0.7457
2001	204	152.1	(0.667 x (151+ 557/P^0.9)) + 3.78	[(0.667 x (151+ 557/P^0.9)) + 3.78] x 0.7457
2002	179	133.5	(0.583 x (151+ 557/P^0.9)) + 4.22	[(0.583 x (151+ 557/P^0.9)) + 4.22] x 0.7457
2003	155	115.6	(0.500 x (151+ 557/P^0.9)) + 4.67	[(0.500 x (151+ 557/P^0.9)) + 4.67] x 0.7457
2004	130	96.9	(0.417 x (151+ 557/P^0.9)) + 5.11	[(0.417 x (151+ 557/P^0.9)) + 5.11] x 0.7457
2005	105	78.3	(0.333 x (151+ 557/P^0.9)) + 5.56	[(0.333 x (151+ 557/P^0.9)) + 5.56] x 0.7457
2006+	81	60.4	(0.250 x (151+ 557/P^0.9)) + 6.00	[(0.250 x (151+ 557/P^0.9)) + 6.00] x 0.7457

*P = power rating in kilowatts

Rule #3: Tier 1, 2 and 3 Diesel Engine Emission Standards

These emission standards apply to all non-road mobile diesel engines and equipment of all sizes, except for locomotives, marine engines above 50 hp, underground mining equipment, and engines with less than 50 cc that are typically used in model airplanes. The standards are presented in Table D-5 below.

Table D-5: Tier 1, 2 and 3 Diesel Engine Standards in g/kW-hr (g/hp-hr)

Engine Size	Tier	Model year	$NMHC + NO_X$	CO	PM_{10}
kW < 8 (hp < 11)	Tier 1	2000	10.5 (7.8)	8.0 (6.0)	1.0 (0.75)
kW < 8 (hp < 11)	Tier 2	2005	7.5 (5.6)	8.0 (6.0)	0.8 (0.6)
8 ≤ kW < 19 (11≤hp< 25)	Tier 1	2000	9.5 (7.1)	6.6 (4.9)	0.8 (0.6)
8 ≤ kW < 19 (11≤hp< 25)	Tier 2	2005	7.5 (5.6)	6.6 (4.9)	0.8 (0.6)
19 ≤kW< 37 (25 ≤hp< 50)	Tier 1	1999	9.5 (7.1)	5.5 (4.1)	0.8 (0.6)
19 ≤kW< 37 (25 ≤hp< 50)	Tier 2	2004	7.5 (5.6)	5.5 (4.1)	0.6 (0.45)
37≤kW< 75 (50 ≤hp< 100)	Tier 2	2004	7.5 (5.6)	5.0 (3.7)	0.4 (0.3)
37≤kW< 75 (50 ≤hp< 100)	Tier 3	2008	4.7 (3.5)	5.0 (3.7)	0.4 (0.3)
75 ≤kW< 130 (100 ≤hp< 175)	Tier 2	2003	6.6 (4.9)	5.0 (3.7)	0.3 (0.22)
75 ≤kW< 130 (100 ≤hp< 175)	Tier 3	2007	4 (3.0)	5.0 (3.7)	0.3 (0.22)
130 ≤kW< 225 (175 ≤hp< 300)	Tier 2	2003	6.6 (4.9)	3.5 (2.6)	0.2 (0.15)

Engine Size	Tier	Model year	NMHC + NO_X	CO	PM_{10}
130 ≤kW< 225 (175 ≤hp< 300)	Tier 3	2006	4 (3.0)	3.5 (2.6)	0.2 (0.15)
225 ≤kW < 450 (300 ≤hp < 600)	Tier 2	2001	6.4 (4.8)	3.5 (2.6)	0.2 (0.15)
225 ≤kW < 450 (300 ≤hp < 600)	Tier 3	2006	4 (3.0)	3.5 (2.6)	0.2 (0.15)
450 ≤kW < 560 (600 ≤hp< 750)	Tier 2	2002	6.4 (4.8)	3.5 (2.6)	0.2 (0.15)
450 ≤kW < 560 (600 ≤hp< 750)	Tier 3	2006	4 (3.0)	3.5 (2.6)	0.2 (0.15)
kW ≥ 560 (hp ≥ 750)	Tier 2	2006	6.4 (4.8)	3.5 (2.6)	0.2 (0.15)

Rule #4: Phase II Standards for Small Non-road SI Handheld Engines

The Phase II standards for small handheld non-road spark-ignition engines apply to the following classes of engines shown in Table D-6. Phase II standards are presented in Table D-7.

Table D-6: Phase II Small Non-road SI Engine Categories

Class	Type	cc*
I-A	Nonhandheld	cc < 66
I-B	Nonhandheld	66 to 100 cc
I	Nonhandheld	100 to 225 c
II	Nonhandheld	> ~225 cc
III	Handheld	< 20 cc
IV	Handheld	20 to 50 cc
V	Handheld	> ~50 cc

* Displacement in cubic centimeters

Table D-7: Phase II HC+NO_X Standards for Handheld Engines in g/kW-hr (g/hp-hr)

Model Year	Class III	Class IV	Class V
2002	238 (177)	196 (146)	N/A
2003	175 (130)	148 (110)	N/A
2004	113 (84)	99 (74)	143 (107)
2005	50 (37)	50 (37)	119 (89)
2006	50 (37)	50 (37)	96 (72)
2007+	50 (37)	50 (37)	72 (54)

Rule #5: Large Industrial SI Engines, Recreational Vehicles, and Diesel Recreational Marine Engines

This rule applies to large industrial spark-ignition engines powered by gasoline, natural gas, or propane gas, rated over 19 kW (25 hp). The rule also applies to diesel marine engines over 37 kW (50 hp) used in recreational boats, such as yachts and cruisers. This rule does not apply to spark-ignition recreational marine vessels. The standards are presented in Tables D-8 through D-11.

Table D-8: Large SI Engine Standards in g/kW-hr (g/hp-hr)

Tier/Year	HC+NOx	CO
Tier I Starting in 2004	4 (3.0)	50 (37.3)
Tier 2 Starting in 2007	2.7 (2.0)	4.4 (3.3)

Table D-9: Recreational Vehicles Standards in g/kW-hr (g/hp-hr)

Vehicle	Model Year	HC	CO	Phase-in %
Snowmobiles	2006	100 (74.6)	275 (205.1)	50
Snowmobiles	2007-2009	100 (74.6)	275 (205.1)	100
Snowmobiles	2010	75 (55.9)	275 (205.1)	100
Snowmobiles	2012	75 (55.9)	200 (149.1)	100
Off-highway Motorcycles	2006	2 (1.5)	25 (18.6)	50
Off-highway Motorcycles	2007+	2 (1.5)	25 (18.6)	100
ATVs	2006	1.5 (1.1)	35 (26.1)	50
ATVs	2007+	1.5 (1.1)	35 (26.1)	100

Table D-10: Permeation Standards for Recreational Vehicles

Emission Component	Implementation Date	Standard	Test Temperature
Fuel Tank Permeation	2008	1.5 g/sq meters/day	28 Degrees C (82 degrees F)
Fuel Hose Permeation	2008	15 g/sq meters/day	23 Degrees C (73 degrees F)

Table D-11: Recreational Diesel Marine Standards in g/kW-hr (g/hp-hr)

Engine size	Implementation Date	HC + NOx	PM_{10}	CO
0.5 L/cyl ≤Displacement< 0.9 L/cyl	2007	7.5 (5.59)	0.4 (0.30)	5 (3.73)
0.9 L/cyl ≤Displacement< 1.2 L/cyl	2006	7.2 (5.37)	0.3 (0.22)	5 (3.73)
1.2 L/cyl ≤Displacement< 2.5 L/cyl	2006	7.2 (5.37)	0.2 (0.15)	5 (3.73)
Displacement ≥ 2.5 L/cyl	2009	7.2 (5.37)	0.2 (0.15)	5 (3.73)

Rule #6: Tier 4 Diesel Rule

This rule introduces new emission standards for non-road diesel engines and sulfur reductions for non-road diesel fuel. This rule will reduce PM emissions by 95% and NO_X emissions by 90% and virtually eliminate SO_X. The sulfur level in non-road diesel fuel will be reduced from 3,000 ppm to 500 ppm starting in 2007, and then to 15 ppm starting in 2010. The sulfur reductions make it possible for manufacturers to use clean engine technologies to reduce pollution, similar to those being introduced in on-road vehicles. These new engine standards took effect, based on engine hp, beginning in 2008. This rule applies to diesel engines is used primarily in most construction, agricultural, industrial, and airport support equipment. The standards will be fully phased in by 2014, though engines greater than 750 hp will have an additional year (2015) to comply. The Tier 4 standards are presented in Table D-12.

Table D-12: Tier 4 Emissions Standards (g/bhp-hr)

Rated Power	First year the standards apply	PM10	NO_X
hp < 25	2008	0.3	-
25 ≤hp < 75	2013	0.02	3.5
75 ≤hp < 175	2012-2013	0.01	0.3
175 ≤hp <750	2011-2013	0.01	0.3
hp ≥750	2011-2014	0.075	0.5 (gensets greater than 1,200 hp); 2.6 (all other)
hp ≥750	2015	0.02 (gensets); 0.03 (all other engines)	0.5 (gensets only)

To use TexN to evaluate the effects of individual federal rules, after selecting the region and analysis year of interest, go to the *Period and Controls* tab (as seen in Figure D-1) of the application and select the rule you are interested in evaluating.

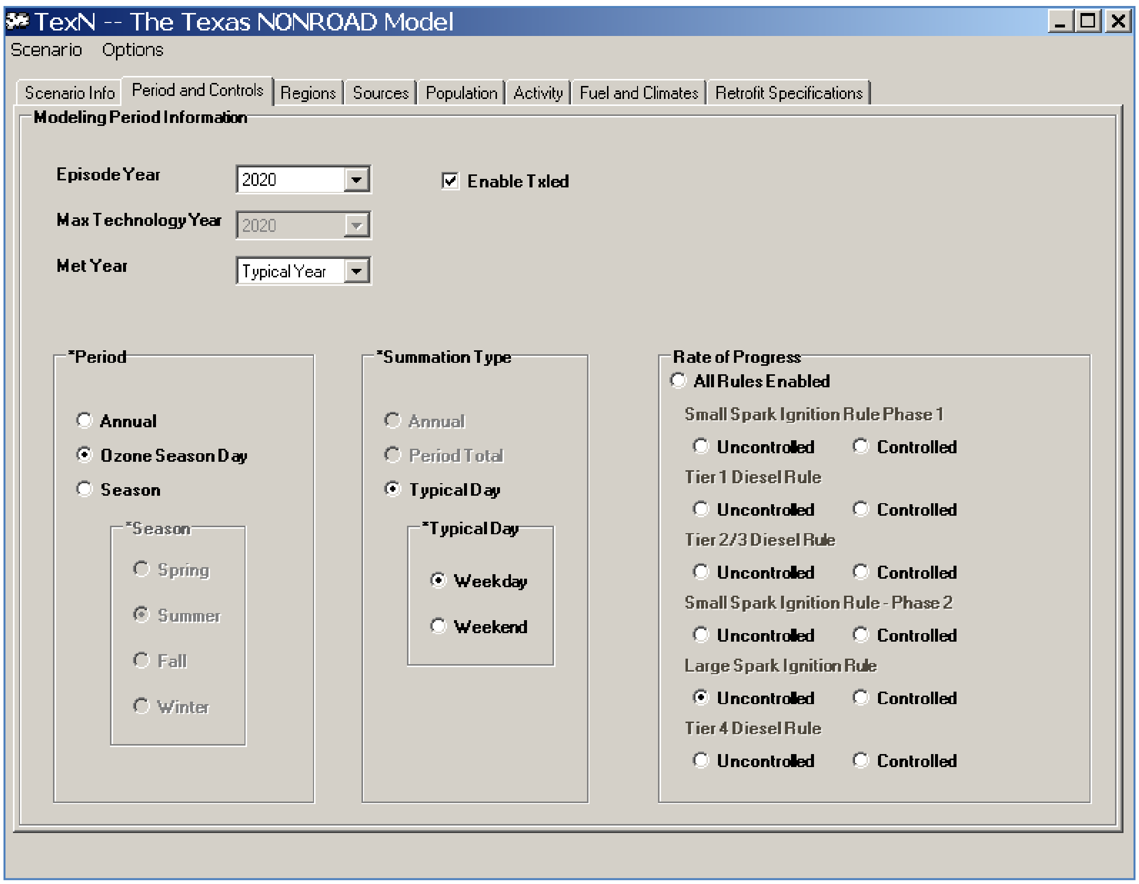

Figure D-1: Period and Controls Tab

When the scenario is executed, the NONROAD model must be executed twice by the user for each rule evaluation. The first run will use technology type files reflecting the controls up to, but not including the rule of interest. These are the uncontrolled, or baseline, runs. The second run will use technology type files reflecting the controls enacted by the rule of interest, but does not include any rules subsequent to the rule of interest. These are the controlled runs. The rule impacts are calculated by subtracting the controlled run emissions from the uncontrolled run emissions for each rule, and then summing the differences across all rules for each SCC.

FEDERAL NON-ROAD RULE / SCC CROSSWALK

Rule #1

226X002XXX (hp < 25)
226X003XXX (hp < 25)
226X004XXX (hp < 25)
226X005XXX (hp < 25)
226X006XXX (hp < 25)
226X007XXX (hp < 25)
226X008XXX (hp < 25)
226X010010 (hp < 25)
2285004XXX (hp < 25)
2285006XXX (hp < 25)

Rule #2

227XXXXXXX (hp > 50)
2285002XXX (hp > 50)
22820050XX (hp < 25)
2282010005 (hp < 25)

Rule #3

2270001XXX
2270002XXX
2270003XXX
2270004XXX
2270005XXX
2270006XXX
2270007XXX
2270008XXX
2270010010
22820200XX (hp < 50)

Rule #4

226XXXXXXX (hp < 25)
2285004XXX (hp < 25)

Rule # 5

226XXXXXXX (hp > 25)
22820050XX (hp > 25)
2282010005 (hp > 25)
2285004XXX (hp > 25)
2285006XXX (hp > 25)
22820200XX (hp > 50)

Rule #6

227XXXXXXX
2285002XXX
22820200XX