

ERG No.: 0245.03.402.001  
Contract No.: EP-D-07-097

**Documentation for Locomotive Component of the National Emissions  
Inventory Methodology**

Prepared by:

Eastern Research Group  
1600 Perimeter Park Drive  
Morrisville, North Carolina 27560

Under Contract to:  
E.H. Pechan & Associates, Inc.  
3622 Lyckan Parkway  
Suite 2002  
Durham, North Carolina 27707

For Submittal to:

Laurel Driver  
Emissions, Monitoring and Analysis Division  
U.S. Environmental Protection Agency  
Research Triangle Park, North Carolina 27711

May 3, 2011

## TABLE OF CONTENTS

Section	Page No.
1.0 INTRODUCTION.....	1-1
1.1 What are Locomotive Sources? .....	1-1
2.0 DEVELOPMENT OF THE LOCOMOTIVE COMPONENT FOR THE NEI .....	2-1
2.1 What Pollutants are Included in the National Emission Estimates for Locomotives? .....	2-1
3.0 HOW WERE LOCOMOTIVE EMISSIONS ESTIMATED? .....	3-1
3.1 Line Haul Criteria Emissions Estimates .....	3-1
3.2 Rail Yard Criteria Emissions Estimates.....	3-1
3.3 Hazardous Air Pollutant Emissions Estimates.....	3-2
4.0 HOW WERE COUNTY LINE HAUL EMISSIONS REALLOCATED TO INDIVIDUAL RAIL SEGMENTS?.....	4-1
4.1 Class I Line Haul Emissions Allocation .....	4-1
4.2 Class II/III Line Haul Emissions Allocation.....	4-2
4.3 Rail Yard Emissions Allocation.....	4-3
4.4 State Provided Data.....	4-3
4.5 What are the Results?.....	4-3
5.0 REFERENCES .....	5-1

Appendix A – ERTAC Class I Line Haul Documentation

Appendix B – ERTAC Class II/III Line Haul Documentation

Appendix C – ERTAC Rail Yard Documentation

## LIST OF TABLES AND FIGURES

Tables	Page No.
Table 2-1. Locomotive Pollutant List .....	2-1
Table 2-2. Methods Used to Develop Annual Emission Estimates for Nonroad Mobile Sources .....	2-2
Table 3-1. Hazardous Air Pollutant Speciation Profile for 2008 Locomotive Emission Estimation .....	3-2
Table 4-1. Line Haul Segment Activity (MGTM/Mi) Categories .....	4-1

## **1.0 INTRODUCTION**

### **1.1 What are Locomotive Sources?**

The locomotive source category includes railroad locomotives powered by diesel-electric engines. A diesel-electric locomotive uses 2-stroke or 4-stroke diesel engines and an alternator or a generator to produce the electricity required to power its traction motors. The locomotive source category does not include locomotives powered by electricity or steam. Emissions associated with the operation of electric locomotives would be included in the point source utility emission estimate. It is believed that the number of wood or coal driven steam locomotives is currently very small; therefore, these types of locomotives are not included in this inventory.

The locomotive source category is further divided up into three categories: Class I line haul, Class II/III line haul, and Class I yard. The national rail estimates were developed by the Eastern Regional Technical Advisory Committee hereafter referenced as ERTAC Rail. This group is comprised of eastern states' regulatory agencies in collaboration with the rail industry. ERTAC Rail developed emissions estimates based on fuel data obtained from the American Association of Railroads for each subcategory. California locomotive emission estimates were handled separately from the rest of the United States because of their use of low sulfur locomotive diesel fuels.

## 2.0 DEVELOPMENT OF THE LOCOMOTIVE COMPONENT FOR THE NEI

### 2.1 What Pollutants are Included in the National Emission Estimates for Locomotives?

All of the criteria pollutants, VOC, CO, NO<sub>x</sub>, SO<sub>x</sub>, PM, and PM<sub>2.5</sub>, are included in the locomotive component of the NEI. OTAQ identified the HAPs for which data were available to develop inventory estimates (Scarbro, 2001). The hazardous air pollutants (HAPs), listed below, were identified based on available test data and accepted emission estimation procedures. Emission estimation methods have changed over the history of the NEI, as outlined briefly in Table 2-2 for nonroad sources.

**Table 2-1. Locomotive Pollutant List**

1,3-Butadiene	Beryllium	Napthalene
2,2,4-Trimethylpentane	Cadmium	n-Hexane
Acenaphthene	Chromium (Hexavalent)	Nickel
Acenaphthylene	Chromium (Trivalent)	Phenanthrene
Acetaldehyde	Chrysene	PAH Propionaldehyde
Acrolein	Dibenz(a,h) anthracene	Pyrene
Anthracene	Ethyl Benzene	Styrene
Arsenic	Fluoranthene	Toluene
Benzene	Fluorene	Xylene
Benzo(a)anthracene	Formaldehyde	
Benzo[a]pyrene	Indeno(1,2,3-cd) pyrene	
Benzo[b]fluoranthene	Lead	
Benzo[g,h,i]perylene	Manganese	
Benzo[k]fluoranthene	Mercury	

**Table 2-2. Methods Used to Develop Annual Emission Estimates for  
Nonroad Mobile Sources**

(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
<b>NONROAD Categories</b>			
Nonroad Gasoline, Diesel, LPG, CNG	2008	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub> , NH <sub>3</sub> , & HAPs	Emission estimates for NONROAD model engines were developed using EPA's National Mobile Inventory Model (NMIM), which incorporates NONROAD2008. Where states provided alternate NMIM nonroad inputs, these data replaced EPA default inputs.
	2005	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub> , NH <sub>3</sub> , & HAPs	Emission estimates for NONROAD model engines were developed using EPA's NMIM, which incorporates NONROAD2005. Where States provided alternate nonroad inputs, these data replaced EPA default inputs.
	2002	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub> , NH <sub>3</sub> , & HAPs	Emission estimates for NONROAD model engines were developed using EPA's NMIM, which incorporates NONROAD2004. Where states provided alternate nonroad inputs, these data replaced EPA default inputs. State-supplied emissions data also replaced default EPA emission estimates.
	1999	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Using emission estimates from two emission inventories including: 1) a 1996 county-level inventory, developed using EPA's October 2001 draft NONROAD model; and 2) an updated 1999 national inventory, based on EPA's draft Lockdown C NONROAD model (dated May 2002). Using the 1996 county-level emission estimates, seasonal and daily county-to-national ratios were then developed for application to updated national estimates per season estimated from the Lockdown C model. Replaced State-submitted data for California for all NONROAD model categories; Pennsylvania for recreational marine and aircraft ground support equipment, and Texas for select equipment categories.
	1996, 1997, 1998, 2000 & 2001	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Using emission estimates from two emission inventories including: 1) a 1996 county-level inventory, developed using EPA's October 2001 draft NONROAD model; and 2) updated year-specific national and California inventories, based on EPA's draft Lockdown C NONROAD model (dated May 2002). Using the 1996 county-level emission estimates, seasonal and daily county-to-national ratios and California county-to-state ratios were then developed for application to updated national estimates per season estimated from the Lockdown C model. California results replace the diesel equipment emissions generated from prior application of county-to-national ratios.

**Table 2-2. Methods Used to Develop Annual Emission Estimates for  
Nonroad Mobile Sources (Continued)**  
(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
Nonroad Gasoline, Diesel, LPG, and CNG (Continued)	1991-1995	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub> , NH <sub>3</sub>	Using 1990 and 1996 county-level emissions inventories, estimated emissions using linear interpolation of national emissions between 1990 and 1996. From these emissions, calculated the average annual growth rate for each pollutant/SCC combination for each year, and then applied the growth factors to 1990 county-level emissions to estimate 1991-1995 emissions.
	1990	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Using emission estimates from two emission inventories including: 1) a 1996 county-level inventory, developed using EPA's October 2001 draft NONROAD model; and 2) updated 1990 national inventory, based on EPA's draft Lockdown C NONROAD model (dated May 2002). Using the 1996 county-level emission estimates, seasonal and daily county-to-national ratios were then developed for application to updated national estimates per season estimated from the Lockdown C model.
	1986, 1988, & 1989	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub> , NH <sub>3</sub>	Using 1985 and 1990 county-level emissions inventories, estimated emissions using linear interpolation of national emissions between 1985 and 1990. From these emissions, calculated the average annual growth rate for each pollutant/SCC combination for each year, and then applied the growth factors to 1985 county-level emissions to estimate 1986-1989 emissions.
	1987	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Using EPA's draft Lockdown C NONROAD model (dated May 2002), developed updated national emissions for 1987 by running 4 seasonal NONROAD model runs to estimate annual criteria pollutant emissions. Also performed national NONROAD model runs to estimate typical summer weekday emissions.
	1985	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Using emission estimates from two emission inventories including: 1) a 1996 county-level inventory, developed using EPA's October 2001 draft NONROAD model; and 2) updated 1985 national inventory, based on EPA's draft Lockdown C NONROAD model (dated May 2002). Using the 1996 county-level emission estimates, seasonal and daily county-to-national ratios were then developed for application to updated national estimates per season estimated from the Lockdown C model.
	1970, 1975, 1978, & 1980	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Using EPA's draft Lockdown C NONROAD model (dated May 2002), developed updated national emissions for all years by running 4 seasonal NONROAD model runs to estimate annual criteria pollutant emissions. Also performed national NONROAD model runs to estimate typical summer weekday emissions.

**Table 2-2. Methods Used to Develop Annual Emission Estimates for  
Nonroad Mobile Sources (Continued)**

(Categories included in this report are noted in bold print)

<b>Category</b>	<b>Base Year</b>	<b>Pollutant(s)</b>	<b>Estimation Method*</b>
Nonroad Gasoline, Diesel, LPG, and CNG (Continued)	1996, 1997, 1998, 1999, 2000, & 2001	NH <sub>3</sub>	Obtaining national fuel consumption estimates from the Lockdown C NONROAD model, multiplying by NH <sub>3</sub> emission factors, and distributing to counties using 1996 inventory, based on October 2001 draft NONROAD. NH <sub>3</sub> emissions for California were also recalculated using updated diesel fuel consumption values generated for California-specific runs, and assuming the 1996 county-level distribution.
	1985 & 1990	NH <sub>3</sub>	Obtaining national fuel consumption estimates from the Lockdown C NONROAD model, multiplying by NH <sub>3</sub> emission factors, and distributing to counties using 1996 inventory, based on October 2001 draft NONROAD.
	1987	NH <sub>3</sub>	Obtaining 1987 national fuel consumption estimates from Lockdown C NONROAD model and multiplying by NH <sub>3</sub> emission factors.
	1970, 1975, 1978, & 1980	NH <sub>3</sub>	Obtaining national fuel consumption estimates from the Lockdown C NONROAD model and multiplying by NH <sub>3</sub> emission factors.
	1990, 1996, & 1999	HAPs	Speciation profiles applied to county VOC and PM estimates. Metal HAPs were calculated using fuel and activity-based emission factors. Some state data were provided and replaced national estimates. (2003)
<b>Aircraft</b>			
Commercial Aircraft	2008	Criteria and HAPs	Federal Aviation Administration (FAA) Emissions and Dispersion Modeling System (EDMS) - Version 5.1.was run using BTS T-100 LTO data. (2009)
	2002 and 2005	Criteria and HAPs	Federal Aviation Administration (FAA) Emissions and Dispersion and Modeling System (EDMS) was run for criteria pollutants, VOC and PM emissions were speciated into HAP components. (2004)
	1990, 1996, 1999, 2000, 2001	VOC, NO <sub>x</sub> , CO, SO <sub>x</sub>	Input landing and take-off (LTO) data into FAA EDMS. National emissions were assigned to airports based on airport specific LTO data and BTS GIS data. State data replaced national estimates. (2003)
	1970-1998	VOC, NO <sub>x</sub> , CO, SO <sub>x</sub>	Estimated emissions for interim years using linear interpolation between available base years. (2003)
	1990, 1996, 1999	HAPs	Speciation profiles were applied to VOC estimates to get national HAP estimates. State data replaced national estimates. (2003)
General Aviation, Air Taxis	2008	Criteria and HAPs	Federal Aviation Administration (FAA) Emissions and Dispersion Modeling System (EDMS) - Version 5.1.was run using BTS T-100 LTO for aircraft identified as Air taxis. (2010)  Used FAA LTO data from TAF and OTAQ provided activity data for smaller airports derived from FAA 5010 master plans. EPA approved generic emission factors for criteria estimates. Speciation profiles were applied to VOC and PM estimates to get national HAP estimates. (2010)



**Table 2-2. Methods Used to Develop Annual Emission Estimates for  
Nonroad Mobile Sources (Continued)**  
(Categories included in this report are noted in bold print)

<b>Category</b>	<b>Base Year</b>	<b>Pollutant(s)</b>	<b>Estimation Method*</b>
General Aviation, Air Taxis (Continued)	2005	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	2002 emissions for approximately 4,000 largest airports were calculated via EDMS and SIP guidance and included in the 2005 NEI as point sources. Only airports in FAA's T100 and TAF databases were included. State point source submittals were incorporated.
	1978, 1987, 1990, 1996, 1999, 2000, 2001, & 2002	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Used FAA LTO data and EPA approved emission factors for criteria estimates. Speciation profiles were applied to VOC estimates to get national HAP estimates. State data replaced national estimates. (2004)
	1970-1998	VOC, NO <sub>x</sub> , CO, SO <sub>x</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Estimated emissions for interim years using linear interpolation between available base years. (2003)
	1990, 1996, 1999, & 2002	HAPs	Used FAA LTO data and EPA approved emission factors for criteria estimates. Speciation profiles were applied to VOC estimates to develop national HAP estimates. (2004)
	1990, 1996, 1999, & 2002	Pb	Used Department of Energy (DOE) aviation gasoline usage data with lead concentration of aviation gasoline. (2004)
Military Aircraft	1996	NH <sub>3</sub>	Applied NH <sub>3</sub> emissions factors to 1996 national jet fuel and aviation gasoline consumption estimates.
	2008	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Used FAA LTO data as reported in TAF and EPA approved emission factors for criteria estimates. Representative HAP profiles were not readily available, therefore HAP estimates were not developed. (2010)
	2005	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	2002 emissions were included in the 2005 NEI as point sources similar to other TAF reported data.
	1978, 1987, 1990, 1996, 1999, 2000, 2001, 2002, 2008	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Used FAA LTO data as reported in TAF and EPA approved emission factors for criteria estimates. Representative HAP profiles were not readily available, therefore HAP estimates were not developed.
	1970-1998	VOC, NO <sub>x</sub> , CO, SO <sub>x</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Estimated emissions for interim years using linear interpolation between available base years. (2003)
Auxiliary Power Units and Ground Support Equipment	2008	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub> , HAPs	Federal Aviation Administration (FAA) Emissions and Dispersion and Modeling System (EDMS) - Version 5.1. was run using BTS T-100 LTO data. (2009)
	2002 and 2005	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub> , HAPs	Computed via NONROAD2005 model runs
	1985-2001	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Grew 1996 emissions to each year using LTO operations data from the FAA. Estimation methods prior to 1996 reported in EPA, 1998.

**Table 2-2. Methods Used to Develop Annual Emission Estimates for  
Nonroad Mobile Sources (Continued)**

(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
Unpaved Airstrips <sup>1</sup>	1985-2001	PM <sub>10</sub> , PM <sub>2.5</sub>	Grew 1996 emissions to each year using SIC 45-Air Transportation growth factors, consistent with the current draft version of EGAS. Estimation methods prior to 1996 reported in EPA, 1998.
Aircraft Refueling <sup>1</sup>	1985-2001	VOC	Grew 1996 emissions to each year using SIC 45-Air Transportation growth factors, consistent with the current draft version of EGAS. Estimation methods prior to 1996 reported in EPA, 1998.
<b>Commercial Marine Vessel (CMV)</b>			
All CMV Categories	2008	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	OTAQ provided CAP emission estimates for all CMV categories. Note that the SCCs for this category have changed such that the Diesel category refers to smaller vessels (Category 1 and 2) using distillate fuels and the Residual category refers to larger (Category 3) vessels using a blend of residual fuels. Emissions were allocated to segments using GIS shapefiles and adjusted based on limited state data (2010)
	2008	HAPs	OTAQ's 2008 estimates were speciated into HAP components using SEPA profiles (2009)
CMV Diesel	2002 and 2005	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	2001 Estimates carried over. Used state data when provided. (2004)
		HAPs	1999 Estimates carried over. Used state data when provided. (2004)
	1978, 1987, 1990, 1996, 1999, 2000, & 2001	VOC, NO <sub>x</sub> , CO, SO <sub>x</sub> , PM <sub>10</sub> , & PM <sub>2.5</sub>	Used criteria emission estimates in the background document for marine diesel regulations for 2000. Adjusted 2000 criteria emission estimates for other used based on fuel usage. Emissions were disaggregated into port traffic and underway activities. Port emissions were assigned to specific ports based on amount of cargo handled. Underway emissions were allocated based on Army Corp of Engineering waterway data. State data replaced national estimates. (2003)
	1970-1998	VOC, NO <sub>x</sub> , CO, SO <sub>x</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Estimated emissions for interim years using linear interpolation between available base years. (2003)
	1990, 1996, 1999	HAPs	VOC and PM emission estimates were speciated into HAP components. State data replaced national estimates. (2003)
	1996	NH <sub>3</sub>	Applied NH <sub>3</sub> emissions factors to 1996 distillate and residual fuel oil estimates (i.e., as reported in EIA, 1996).
	1990-1995	NH <sub>3</sub>	Estimation methods reported in EPA, 1998.

**Table 2-2. Methods Used to Develop Annual Emission Estimates for  
Nonroad Mobile Sources (Continued)**  
(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
CMV Steam Powered	2005	VOC, NO <sub>x</sub> , CO, SO <sub>x</sub> , PM <sub>10</sub> , & PM <sub>2.5</sub> , HAPs	2002 estimates grown to 2005 (2008).
	2002	VOC, NO <sub>x</sub> , CO, SO <sub>x</sub> , PM <sub>10</sub> , & PM <sub>2.5</sub> , HAPs	2002 based estimates were developed for port and underway category 3 (C3) vessels as part of a rulemaking effort. Emissions were developed separately for near port and underway emissions. For near port emissions, inventories for 2002 were developed for 89 deep water and 28 Great Lake ports in the U.S. The Waterway Network Ship Traffic, Energy, and Environmental Model (STEEM) was used to provide emissions from ships traveling in shipping lanes between and near individual ports (2008)
	1978, 1987, 1990, 1996, 1999, 2000, & 2001	VOC, NO <sub>x</sub> , CO, SO <sub>x</sub> , PM <sub>10</sub> , & PM <sub>2.5</sub>	Calculated criteria emissions based on EPA SIP guidance. Emissions were disaggregated into port traffic and under way activities. Port emissions were assigned to specific ports based on amount of cargo handled. Underway emissions were allocated based on Army Corp of Engineering waterway data. State data replaced national estimates. (2003)
	1970-1998	VOC, NO <sub>x</sub> , CO, SO <sub>x</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Estimated emissions for interim years using linear interpolation between available base years. (2003)
	1990, 1996, & 1999	HAPs	VOC and PM emission estimates were speciated into HAP components. State data replaced national estimates. (2003)
Military Marine	1997-2001	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Applied EGAS growth factors to 1996 emissions estimates for this category.
CMV Coal, <sup>2</sup> CMV, Steam powered, CMV Gasoline <sup>2</sup>	1997-1998	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Applied EGAS growth factors to 1996 emissions estimates for this category.
CM Coal, CMV, Steam powered, CMV Gasoline, Military Marine	1991-1995	VOC, NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Estimation methods reported in EPA, 1998.
<b>Locomotives</b>			
<b>Class I, II, III and Yard operations</b>	<b>2008</b>	<b>VOC, NO<sub>x</sub>, CO, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>x</sub> &amp; HAPs</b>	<b>Criteria emission estimates were provided to EPA by ERTAC. These data were assigned to individual railway segments using DOT shapefiles and guidance from ERTAC. HAP emissions were calculated by applying speciation profiles to VOC and PM estimates. (2010)</b>

**Table 2-2. Methods Used to Develop Annual Emission Estimates for  
Nonroad Mobile Sources (Continued)**

(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
Class I, Class II, Commuter, Passenger, and Yard Locomotives	1978, 1987, 1990, 1996, 1999, 2000, 2000, 2002, & 2005	VOC, NO <sub>x</sub> , CO, PM <sub>10</sub> , PM <sub>2.5</sub>	Criteria pollutants were estimated by using locomotive fuel use data from DOE EIA and available emission factors. County-level estimates were obtained by scaling the national estimates with the rail GIS data from DOT. State data replaced national estimates. (2004)
	1978, 1987, 1990, 1996, 1999, 2000, 2001, 2002, & 2005	SO <sub>2</sub>	SO <sub>x</sub> emissions were calculated by using locomotive fuel use and fuel sulfur concentration data from EIA. County-level estimates were obtained by scaling the national estimates with the county level rail activity data from DOT. State data replaced national estimates. (2004)
	1970-1998	VOC, NO <sub>x</sub> , CO, SO <sub>x</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	Estimated emissions for interim years using linear interpolation between available base years. (2003)
	1990, 1996, 1999, & 2002	HAPs	HAP emissions were calculated by applying speciation profiles to VOC and PM estimates. County-level estimates were obtained by scaling the national estimates with the county level rail activity from DOT. State data replaced national estimates. (2004)
	1997-1998	NH <sub>3</sub>	Grew 1996 base year emissions using EGAS growth indicators.
	1996	NH <sub>3</sub>	Applied NH <sub>3</sub> emissions factors to diesel consumption estimates for 1996.
	1990-1995	NH <sub>3</sub>	Estimation methods reported in EPA, 1998.

*Notes:*

\* Dates included at the end of Estimation Method represent the year that the section was revised.

1 Emission estimates for unpaved airstrips and aircraft refueling are included in the area source NEI, since they represent non-engine emissions.

2 National Emission estimates for CMV Coal and CMV Gasoline were not developed though states and local agencies may have submitted estimates for these source categories.

EPA, 1998. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emission Factors and Inventory Group, National Air Pollutant Emission Trends, Procedures Document, 1900–1996, EPA-454/R-98-008. May 1998.

### **3.0 HOW WERE LOCOMOTIVE EMISSIONS ESTIMATED?**

ERTAC Rail used confidential railroad-provided data to generate railroad-specific criteria emission estimates for line haul and rail yards at the rail segment and rail yard level, respectively. Appendices A-C provide more detail on how emissions were developed and includes critical data used in calculating these estimates. This section of the report describes the emission estimating methods used in general terms as well as the approach for reallocating the emissions to protect confidential data. The data and documentation provided with respect to ERTAC Rail's emission estimates pertain to the version that was incorporated into the NEI and does not reflect recent revisions.

#### **3.1 Line Haul Criteria Emissions Estimates**

Criteria pollutant emissions were estimated by applying emission factors to the total amount of distillate fuel oil used by line haul locomotives. Fuel usage was obtained from publically available Class I Railroad Annual Reports (Form R-1). The R-1 reports are submitted to the Surface Transportation Board annually and include financial and operations data to be used in monitoring rail industry health and identifying changes that may affect national transportation policy. Additionally, each railroad provided fleet mix information that allowed ERTAC Rail to calculate railroad-specific emission factors. Weighted Emission Factors (EF) per pollutant for each gallon of fuel used (gm/gal or lbs/gal) were calculated for each Class I railroad fleet based on its fraction of line haul locomotives at each regulated Tier level. EPA emission factors were used for PM<sub>2.5</sub>, SO<sub>2</sub>, and NH<sub>3</sub>.

The weighted emission factors were then applied to the link-specific fuel consumption to obtain emissions for each rail segment. Given the confidentiality of the activity data, emissions for criteria pollutants were provided to EPA by ERTAC Rail by county for Class I line haul. Class II/III rail was provided by railroad company and county. Appendices A and B provide more detail on the Class I and Class II/III line haul emission development, respectively.

#### **3.2 Rail Yard Criteria Emissions Estimates**

Rail yard locations were identified using a database from the Federal Railroad Administration. Criteria pollutant emissions were estimated by applying emission factors to the total amount of distillate fuel used by locomotives. Each railroad provided fleet mix information that allowed ERTAC to calculate railroad-specific emission factors. The company-specific, system wide fleet mix was used to calculate weighted average emissions factors for switchers operated by each Class I railroad. EPA emission factors were used for PM<sub>2.5</sub>, SO<sub>2</sub>, and NH<sub>3</sub>.

R-1 report-derived fuel use was allocated to rail yards using an approximation of line haul activity data within the yard; see Appendix C for more details. These fuel consumption values were further revised by direct input from the Class I railroads. The weighted emission factors were then applied to the yard-specific fuel consumption to obtain emissions for each yard. Since the rail yard inventory was based on publically-available data, the final criteria emission estimates were provided per rail yard.

### 3.3 Hazardous Air Pollutant Emissions Estimates

HAP emissions were estimated by applying speciation profiles to the VOC or PM estimates. The speciation profiles were derived from *Evaluation of Factors that Affect Diesel Exhaust Toxicity* (Truex and Norbeck, 1998), and data provided by OTAQ (Scarbro, 2001 and 2002). It should be noted that since California uses low sulfur diesel fuel and emission factors specific for California railroad fuels were available, calculations of the state's emissions were done separately from the other states. The HAP speciation profile used in this effort is shown in Table 3-1. HAP estimates were calculated at the yard and link level, after the criteria emissions had been allocated.

**Table 3-1. Hazardous Air Pollutant Speciation Profile for 2008 Locomotive Emission Estimation**

Pollutant Name	California	All Other States	Speciation Base
1,3 Butadiene	0.0000615	0.0047735	PM <sub>10</sub>
2-2-4 Trimethylpentane	0.0022425	0.0022425	VOC
Acenaphthene	0.0000080	0.0000306	PM <sub>10</sub>
Acenaphthylene	0.0002182	0.0004275	PM <sub>10</sub>
Acetaldehyde	0.0004492	0.0276274	PM <sub>10</sub>
Acrolein	0.0000855	0.0045943	PM <sub>10</sub>
Anthracene	0.0000535	0.0001009	PM <sub>10</sub>
Arsenic	0.0000004	0.0000004	PM <sub>10</sub>
Benzene	0.0000517	0.0038020	PM <sub>10</sub>
Benzo(a)anthracene	0.0000121	0.0000160	PM <sub>10</sub>
Benzo(a)pyrene	0.0000044	0.0000027	PM <sub>10</sub>
Benzo(b)fluoranthene	0.0000044	0.0000064	PM <sub>10</sub>
Benzo(ghi)perylene	0.0000044	0.0000031	PM <sub>10</sub>
Benzo(k)fluoranthene	0.0000044	0.0000052	PM <sub>10</sub>
Beryllium	0.0000280	0.0000280	PM <sub>10</sub>
Cadium	0.0000280	0.0000280	PM <sub>10</sub>
Chromium (III)	0.0000001	0.0000040	PM <sub>10</sub>
Chromium (VI)	0.0000000	0.0000021	PM <sub>10</sub>
Chrysene	0.0000092	0.0000119	PM <sub>10</sub>
Dibenz(a,h)anthracene	0.0000000	0.0000000	PM <sub>10</sub>
Ethylbenzene	0.0020000	0.0020000	VOC
Fluoranthene	0.0000601	0.0000746	PM <sub>10</sub>
Fluorene	0.0000619	0.0001407	PM <sub>10</sub>
Formaldehyde	0.0009451	0.0636582	PM <sub>10</sub>
Indeno(1,2,3-cd)pyrene	0.0000033	0.0000027	PM <sub>10</sub>
Lead	0.0000840	0.0000840	PM <sub>10</sub>
Manganese	0.0000020	0.0000020	PM <sub>10</sub>
Mercury	0.0000280	0.0000280	PM <sub>10</sub>
Napthalene	0.0018505	0.0025756	PM <sub>10</sub>
n-Hexane	0.0055000	0.0055000	VOC

**Table 3-1. Hazardous Air Pollutant Speciation Profile for 2008 Locomotive Emission Estimation (Cont.)**

<b>Pollutant Name</b>	<b>California</b>	<b>All Other States</b>	<b>Speciation Base</b>
Nickel	0.0000066	0.0000066	PM <sub>10</sub>
Phenanthrene	0.0002822	0.0005671	PM <sub>10</sub>
Propionaldehyde	0.0061000	0.0061000	VOC
Pyrene	0.0000771	0.0001054	PM <sub>10</sub>
Styrene	0.0021000	0.0021000	VOC
Toluene	0.0032000	0.0032000	VOC
Xylene	0.0048000	0.0048000	VOC

## 4.0 HOW WERE COUNTY LINE HAUL EMISSIONS REALLOCATED TO INDIVIDUAL RAIL SEGMENTS?

### 4.1 Class I Line Haul Emissions Allocation

Class I line haul emissions were allocated to rail segments based on segment-specific railroad traffic data (ton miles) obtained from the Department of Transportation (BTS, 2009). This dataset categorizes the segments' level of activity into ranges of MGTM and is populated by FRA. Emissions were divided between all mainline segments using these activity ranges as a proxy to allocate more emissions to segments with higher activity.

Since the activity data were provided as ranges, a single "allocation value", typically the midpoint of the range, was selected for use in the emissions allocation. The exception to this was the "0" activity category, which by definition had "unknown" activity. As a result, most mainline segments with the "0" activity category were not included in the emissions calculation/allocation. However, there was a small subset of segments that did have known activity values in the confidential data set but were labeled as "unknown" in the publically available data set. Those segment IDs were provided by ERTAC Rail for inclusion in the emission allocation; however, the activity of these segments was averaged to protect confidential data. Table 4-1 lists the activity categories along with their ranges in MGTM/mi and the allocation value used in the emissions spatial allocation.

**Table 4-1. Line Haul Segment Activity (MGTM/Mi) Categories**

Category	Range Minimum	Range Maximum	Allocation Value Used
0*	0.0003	0.09	0.01233
1	0.1	4.9	2.5
2	5	9.9	7.45
3	10	19.9	14.95
4	20	39.9	29.95
5	40	59.9	49.95
6	60	99.9	79.95
7	100	1000000	100

\* The "0" category has "unknown" activity in the publically available segment data. As a result, this table lists the minimum, maximum, and average of the confidential activity data greater than zero that were categorized as "unknown" in the public data.

The county emission sums were reallocated to the segments by multiplying the county emissions by the segment's allocation value divided by the sum of the allocation values for all links within the county.



$$E_{iL} = E_{iC} * \frac{A_L}{\sum_{C=1}^N A_{LC}}$$

Where:

$E_{iL}$  = Emissions of pollutant i per link L (tons/year).

$E_{iC}$  = Emissions of pollutant i per county C (tons/year).

$A_L$  = Allocation value for link L per activity category from public BTS dataset

$A_{LC}$  = Sum of allocation values for all links in county C from public BTS dataset

Note that rail line data for Puerto Rico, U.S. Virgin Islands, and Hawaii data were not included in ERTAC Rail's shapefile and were developed separately; however, since these areas have exclusively Class II/III railroads present, these efforts are discussed in the following section.

## 4.2 Class II/III Line Haul Emissions Allocation

ERTAC Rail created a shapefile of Class II/III mainline rail segments from their FRA-provided proprietary shapefile as described in Appendix B for the contiguous 48 states and Alaska. Raw rail line data for Puerto Rico were obtained from USGS (Scanlon and Briere, 2000), and rail line data for Hawaii was obtained from ESRI's Digital Chart of the World (ESRI 2010). The U.S. Virgin Islands have no rail lines. Because Class II/III railroads are less likely to use rail segments that are heavily traveled by Class I railroads, the activity-based approach used for Class I lines was not appropriate. Instead, Class II/III line haul emissions were allocated to rail segments using segment length as a proxy.

The county emission sums were reallocated to the segments by multiplying the county emissions by the segment's length divided by the sum of the length for all links within the county.

$$E_{iL} = E_{iC} * \frac{l_L}{\sum_{C=1}^N l_{LC}}$$

Where:

$E_{iL}$  = Emissions of pollutant i per link L (tons/year).

$E_{iC}$  = Emissions of pollutant i per county C (tons/year).

$l_L$  = Allocation value for link L per activity category from public BTS dataset

$l_{LC}$  = Sum of allocation values for all links in county C from public BTS dataset

Since ERTAC Rail used proprietary data to develop the shapefile, some segment IDs were not found in the EIS data set. These segments were manually identified, and their emissions were allocated to the nearest segment within the EIS data set.

### 4.3 Rail Yard Emissions Allocation

Rail yard emissions were developed based on yard name and ownership properties. As a result, unique yards needed to be identified and emissions summed. Unfortunately, the yard data lacked detail necessary for confident duplicate checks and yard matching such as address, detailed yard name, etc. As a result, a GIS was used to find the centroid of the yards based on the latest public BTS rail network, using the yard name and FIPS. The list of unique yards was further examined against ERTAC's data and within Google Earth to identify any yards that required further revision. A crosswalk of original ERTAC data to new, consolidated yard IDs facilitated the summing of activity and emissions. 753 unique yards were identified nationwide. This underestimate of the total number of yards is most likely due to using line-haul-focused data to identify locations and develop rail yard emissions.

Once the unique yards were identified and criteria emissions were summed at the yard, the PM and VOC-based HAP speciation profile was applied to estimate HAP emissions at each yard.

### 4.4 State Provided Data

In this version of NEI, state and local agencies were invited to provide locomotive data that replaced the estimates based on national fuel consumption. However, only a small rail yard dataset was received from Kentucky. Their rail yard list was compared with the ERTAC/ERG yard list, and 2 yards were found in both sets. These yards were merged so as to avoid duplication in activity or emissions.

### 4.5 What are the Results?

Table 3 summarizes the 2008 locomotive mobile source emission estimates.

**Table 3. 2008 Locomotive Emissions Data**

2008 Locomotive Criteria Emissions				
Pollutant Name	Class I Line Haul	Class II/III Line Haul	Rail Yard	TOTAL
CO	110,969	5,055	9,152	125,176
NH <sub>3</sub>	347	16	27	390
NO <sub>x</sub>	754,433	51,342	73,741	879,516
PM <sub>10</sub> -PRI	25,477	1,264	2,086	28,827
PM <sub>25</sub> -PRI	23,439	1,163	2,024	26,626
SO <sub>2</sub>	7,836	357	619	8,811
VOC	37,941	1,896	4,824	44,661
2008 Locomotive Hazardous Air Pollutant Emissions				
Pollutant Name	Class I Line Haul	Class II/III Line Haul	Rail Yard	TOTAL
1,3 Butadiene	116.7941	5.7969	9.3296	131.9206
2-2-4 Trimethylpentane	85.0832	4.2511	10.8178	100.1521
Acenaphthene	0.7569	0.0376	0.0609	0.8554

**Table 3. 2008 Locomotive Emissions Data (Cont.)**

<b>2008 Locomotive Hazardous Air Pollutant Emissions</b>				
<b>Pollutant Name</b>	<b>Class I Line Haul</b>	<b>Class II/III Line Haul</b>	<b>Rail Yard</b>	<b>TOTAL</b>
Acenaphthylene	10.6772	0.5298	0.8639	12.0709
Acetaldehyde	676.0572	33.5552	54.0089	763.6213
Acrolein	112.4351	5.5806	8.9828	126.9985
Anthracene	2.5231	0.1252	0.2042	2.8525
Arsenic	0.0091	0.0005	0.0007	0.0103
Benzene	93.0272	4.6173	7.4312	105.0757
Benzo(a)anthracene	0.4047	0.0201	0.0329	0.4577
Benzo(a)pyrene	0.0717	0.0036	0.0059	0.0812
Benzo(b)fluoranthene	0.1607	0.0079	0.0131	0.1817
Benzo(ghi)perylene	0.0798	0.0040	0.0066	0.0904
Benzo(k)fluoranthene	0.1312	0.0065	0.0107	0.1484
Beryllium	0.7138	0.0354	0.0584	0.8076
Cadium	0.7138	0.0354	0.0584	0.8076
Chromium (III)	0.0985	0.0049	0.0079	0.1113
Chromium (VI)	0.0508	0.0025	0.0041	0.0574
Chrysene	0.2998	0.0149	0.0244	0.3391
Ethylbenzene	75.8814	3.7914	9.6479	89.3207
Fluoranthene	1.8868	0.0936	0.1538	2.1342
Fluorene	3.5039	0.1739	0.2830	3.9608
Formaldehyde	1,557.66	77.3124	124.4335	1759.4059
Indeno(1,2,3-cd)pyrene	0.0684	0.0034	0.0056	0.0774
Lead	2.1413	0.1062	0.1753	2.4228
Manganese	0.0520	0.0026	0.0043	0.0589
Mercury	0.7138	0.0354	0.0584	0.8076
Napthalene	64.8766	3.2187	5.2765	73.3718
n-Hexane	208.6739	10.4263	26.5317	245.6319
Nickel	0.1669	0.00983	0.0137	0.19043
Phenanthrene	14.1555	0.7024	1.1450	16.0029
Propionaldehyde	231.4383	11.5637	29.4261	272.4281
Pyrene	2.6566	0.1318	0.2161	3.0045
Styrene	79.6755	3.9809	10.1303	93.7867
Toluene	121.4103	6.0662	15.4366	142.9131
Xylene	182.1154	9.0993	23.1549	214.3696

## 5.0 REFERENCES

Bureau of Transportation Statistics, 2009. National Transportation Atlas Databases - National Rail Network 1:2,000,000. Washington, DC, Publisher: Bureau of Transportation Statistics.

Energy Information Administration Form EIA-821, “Annual Fuel Oil and Kerosene Sales Report” for 1999. Table 23: Adjusted Sales for Transportation Use: Distillate Fuel Oil Residual Fuel Oil, 1999, U.S.

ESRI, Digital Chart of the World Hawaii Rail line dataset  
<http://data.geocomm.com/catalog/US/61094/group103.html> July 27, 2010

Fritz, Steve, *Diesel Fuel Effects on Locomotive Exhaust Emissions*, California Air Resource Board. SwRI 08.02062, October 2000.

Porter, Fred L., U.S. Environmental Protection Agency, Emission Standards Division. Note to Anne Pope, U.S. EPA/Emissions, Monitoring and Analysis Division. Comments on combustion source information in the *Baseline Emission Inventory of HAP Emissions from MACT Sources - Interim final Report* (September, 18, 1998. November 13, 1998)

Scanlon, Kathryn and Peter R. Briere, U.S. Geological Survey Open-File Report 00-006. Puerto Rico Marine Sediments, Terrestrial and Seafloor Imagery, and Tectonic Interpretations, 2000.  
<http://pubs.usgs.gov/of/2000/of00-006/htm/index.htm>

Scarbro, Carl, E-mail entitled *A Few Questions on the Rail Emissions - Reply*, to Richard Billings, and Roger Chang, Eastern Research Group, Inc., United States Environmental Protection Agency Office of Transport and Air Quality. July 19, 2001

Scarbro, Carl, E-mail entitled *Chromium in Loco's - Reply*, to Richard Billings, Eastern Research Group, Inc., United States Environmental Protection Agency Office of Transport and Air Quality. June 1, 2001

Scarbro, Carl, E-mail entitled *Better Railroad Numbers This Will Disaggregate Class I Work*, to Roger Chang, Eastern Research Group, Inc., United States Environmental Protection Agency Office of Transport and Air Quality. May 8, 2001

Scarbro, Carl, E-mail entitled *CMV SO<sub>x</sub> corrections - Reply*, to Richard Billings, Eastern Research Group, Inc., United States Environmental Protection Agency Office of Transport and Air Quality. May 28, 2002

Scarbro, Carl, E-mail entitled *2, 2, 4-trimethylpentane*, to Richard Billings, Eastern Research Group, Inc., United States Environmental Protection Agency Office of Transport and Air Quality. June 1, 2001

Scarbro, Carl, E-mail entitled *2, 2, 4-trimethylpentane*, to Roger Chang, Eastern Research Group, Inc., United States Environmental Protection Agency Office of Transport and Air Quality. March 26, 2002

Truex, Timothy J. and Joseph M. Norbeck. *Evaluation of Factors that Affect Diesel Exhaust Toxicity*. University of California-Riverside, Center for Environmental Research and Technology. Riverside, CA. March 16, 1998.

U.S. Environmental Protection Agency Form APR420-F-97-051, *Emission Factors for Locomotives*, for 1996 Table 9: Fleet Average Emission Factors for All Locomotives (Projected 1999), December 1997

U.S. Environmental Protection Agency, *Locomotive Emission Standards Regulatory Support Document*, page 109 April 1998.

U.S. Environmental Protection Agency, *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources*.1992.

U.S. Environmental Protection Agency. *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources*. Office of Air Quality Planning and Standards. Research Triangle Park, NC. 1989.

## **Appendix A**

### **ERTAC Class I Line Haul Documentation**

# **DRAFT**

## **ERTAC Rail Emissions Inventory**

### **Part 1: Class I Line-Haul Locomotives**

Michelle Bergin, GA Environmental Protection Division  
Matthew Harrell, IL Environmental Protection Agency  
Mark Janssen, Lake Michigan Air Directors Consortium

#### **Acknowledgments:**

Robert Fronczak, Association of American Railroads  
Raquel Wright, Federal Railroad Administration  
Julie McDill, Mid-Atlantic Regional Air Management Association  
Patrick Davis, Mid-Atlantic Regional Air Management Association  
Laurel Driver, US EPA, Office of Air Quality Planning and Support  
Byeong Kim, GA Environmental Protection Division

## **Introduction**

Air protection agencies from twenty-seven states, coordinated through the Eastern Regional Technical Advisory Committee (ERTAC) and headed by the Lake Michigan Air Directors Consortium (LADCO), identified a need to better quantify and characterize rail-related emissions inventories. Traditional locomotives largely utilize diesel engines, resulting in emissions of NO<sub>x</sub>, diesel PM, hydrocarbons, greenhouse gases, and other pollutants. These emissions are sometimes concentrated in areas exceeding National Ambient Air Quality Standards. No cohesive nationwide railroad emission estimates based on local operations are known to have been made previously. Inventory development methods for locomotive emissions estimates vary from state to state and, in general, lack the spatial or temporal resolution needed to support air quality modeling and planning<sup>1-5</sup>.

The ERTAC Rail Subcommittee (ERTAC Rail) was established with active representatives from twelve member states, three regional planning offices, and the US EPA. The subcommittee's goals are to (1) standardize agencies' inventory development methods through a collaborative effort, (2) improve the quality of data received and the resulting emission inventories, and (3) reduce the administrative burden on railroad companies of providing data.

With support from the Rail industry and assistance from the ERTAC Rail Data Workgroup (Appendix A), ERTAC Rail has developed 3 inventories of locomotive emissions (Table 1); from Class I line-haul, Shortline and Regional Railroads (Class II and III operations), and Class I railyard switchers. Because of the difficulty in obtaining data and differences in states' needs for inventory years, sources from both 2007 and 2008 were utilized (Appendix B.) Due to the variability and uncertainty in much of the data, the results are considered applicable for either 2007 or 2008.

The Surface Transportation Board (STB) defines Class I Railroads as having had minimum carrier operating revenues of \$401.4 million (USD) in 2008. There are 8 Class I Railroads operating in the United States (Table 2), about 12 Regional Railroads (Class II), and approximately 530 Class III Railroads (Shortlines). While categorized as a Class I Railroad, Amtrak was excluded from these inventories because of significant differences in equipment and operation characteristics. Line-haul locomotives travel long distances (e.g. between cities) while switcher locomotives largely operate in railyards, splitting and joining rail cars with varying destinations. Passenger and Commuter Rail (including Amtrak), industrial locomotives, and associated non-locomotive equipment are not included in these inventories.

This paper documents the data sources and methodologies used for calculating the Class I line-haul emissions inventory. Class I line-haul activities are the largest source of rail-related emissions, with estimates of Class I line-haul fuel consumption totals to be from 74 to 84% of all rail sources combined<sup>4, 5</sup>. For this reason, characterizing Class I line-haul emissions were a focal point of ERTAC Rail's inventory development efforts. Information on ERTAC Rail, Railroad participation, the Rail industry, and effects of rail on air quality are available elsewhere<sup>6</sup>.

**Table 1. Summary of ERTAC Rail Inventories: U.S. Locomotive Emissions and Fuel Use for either 2007 or 2008\*.**

	Fuel Use** (gal/yr)	Emissions (tons/yr)					
		NO <sub>x</sub>	PM <sub>2.5</sub>	HC	SO <sub>2</sub>	CO	NH <sub>3</sub>
Class I*** line-haul	3,770,914,002	754,443	23,439	37,941	7,836	110,969	347
Class I switcher	300,492,223	73,741	2,024	4,824	619	9,152	27
Class II and III	157,800,000	51,367	1,163	1,897	357	5,058	16

\*See Appendix B for a description of the year and source of data utilized for each inventory.

\*\*Locomotive grade diesel

\*\*\*Excluding Amtrak and including work train fuel use

**Table 2. Class I Railroads, Reported Locomotive Fuel Use, and Railroad Fuel Consumption Index (RFCI)<sup>7</sup>.**

Class I Railroads*	R-1 Reported Locomotive Fuel Use (gal/yr)		RFCI (ton-miles/gal)
	Line-Haul (2007)**	Switcher (2008)	
BNSF	1,393,874,954	52,497,057	883.14
Canadian National	93,830,751	12,290,022	1190.79
Canadian Pacific***	50,320,233	4,594,067	1096.28
CSX	514,687,186	53,717,674	963.81
Kansas City Southern	69,787,071	1,816,759	785.89
Norfolk Southern	463,267,278	32,317,375	865.75
Union Pacific	1,185,146,529	143,470,336	974.64
<b>Total</b>	<b>3,770,914,002</b>	<b>300,492,223</b>	<b>929.47</b>



\* Excluding Amtrak

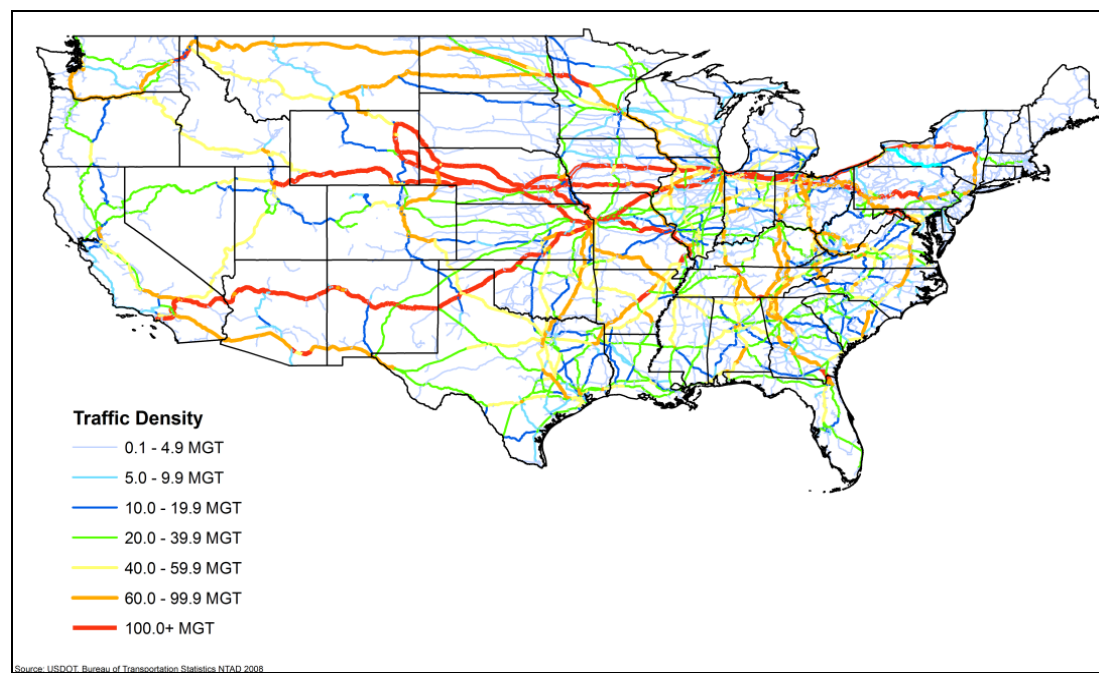
\*\* Includes work trains

\*\*\* CP's line-haul fuel use values include 2008 data (rather than 2007) for their Delaware and Hudson subsidiary.

## Method

Earlier efforts to characterize line-haul railroad emissions relied on highly aggregated activity data (Figure 1), and generally apportioned annual system-wide fuel use equally across all route miles of track operated by a Class I railroad. However, the majority of freight tonnage carried by Class I railroads is concentrated on a disproportionately small number of route miles. In addition, emissions calculations were previously based on an estimate of annual nationwide-average locomotive fleet mix to create one set of emissions factors.

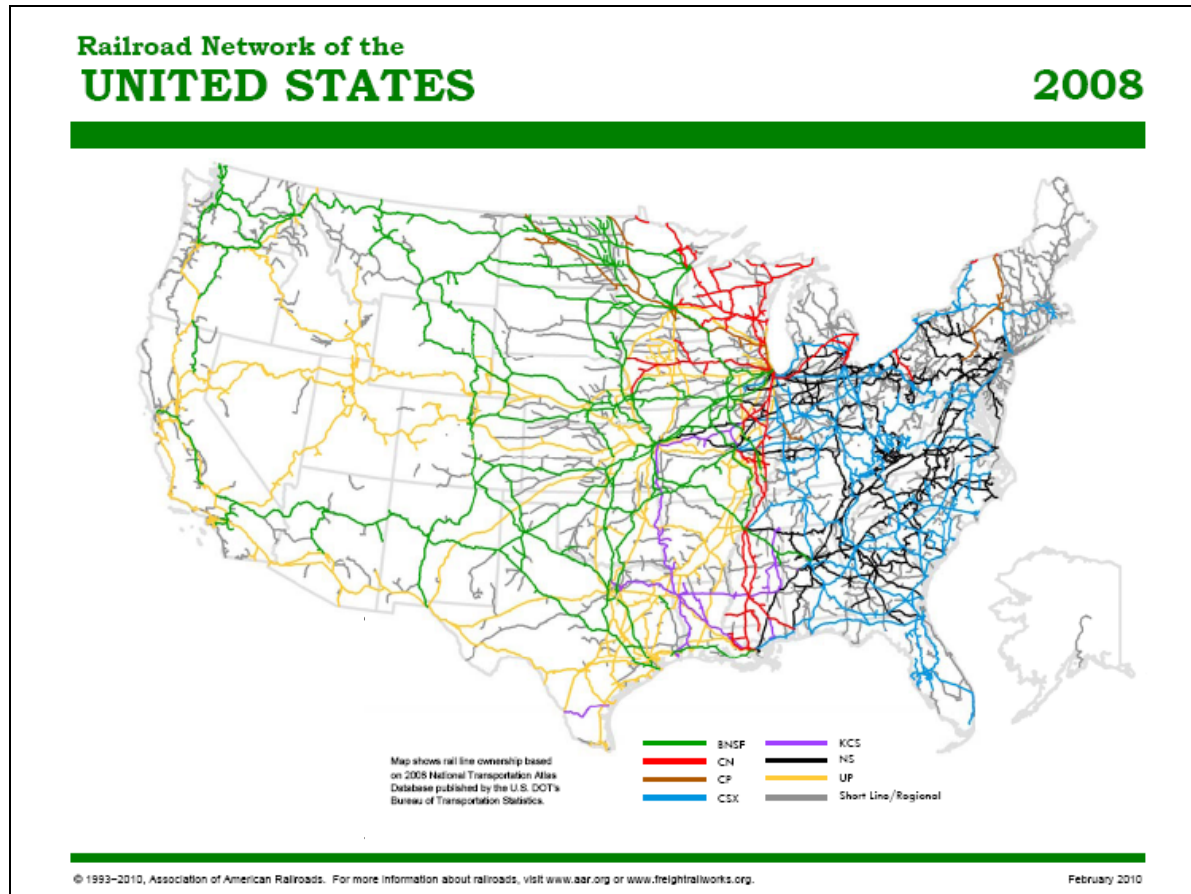
For this inventory, the Class I Railroads allowed ERTAC Rail access under a confidentiality agreement to a link-level (single lengths of track) line-haul GIS layer activity dataset managed by the Federal Railroad Administration<sup>9</sup>. Each railroad also provided fleet mix information that allowed ERTAC Rail to calculate weighted emission factors based on the fraction of their line-haul fleet meeting each Tier level category. The use of this data, largely following a line-haul inventory methodology recommended by Sierra Research<sup>2,3</sup>, resulted in a link-level line-haul locomotive emission inventory using railroad-specific emission factors. This segment-level inventory is nationwide, aggregated to state and county level files, and will be released as gridded emissions files for use in photochemical and dispersion modeling. Link-level emissions may be provided for special study requests pending approval of any Class I railroads operating in the study domain. The calculations are described below as a two-part process, calculating railroad-specific factors and emissions per rail link.



**Figure 1. US Railroad Traffic Density in 2006.<sup>8</sup> MGT is million gross tons.**

## 1. Calculate Railroad-Specific Factors.

The EPA provides annual default Emission Factors for locomotives based on characteristic operating cycles ('duty cycles') and the estimated nationwide fleet mixes for both switcher and line-haul locomotives. However, fleet mixes vary from railroad to railroad and, as can be seen in Figure 2, Class I railroad activity is highly regionalized in nature and subject to issues of local terrain such as operation on plains vs. mountainous areas, which can have a significant impact on fuel consumption and emissions.



**Figure 2. Class I Railroad Territories in the United States<sup>10</sup>.**

As an alternative approach to using a single nationwide set of emission factors, ERTAC Rail requested each Class I company to provide a description of their line-haul fleet mix based on Tier rating, which each company provided under a confidentiality agreement. An engine's Tier level is based on the year the engine was built and determines allowable emission limits (Table 3).

**Table 3. EPA line-haul locomotive Emission Factors by Tier, 1997 standards (grams/gal).**  
**Note that the new standards released in 2008 did not apply to fleets in the year 2008.** <sup>11</sup>

	<b>PM<sub>10</sub></b>	<b>HC</b>	<b>NO<sub>x</sub></b>	<b>CO</b>
Uncontrolled (pre-1973)	6.656	9.984	270.4	26.624
Tier 0 (1973-2001)	6.656	9.984	178.88	26.624
Tier 1 (2002-2004)	6.656	9.776	139.36	26.624
Tier 2 (2005 + )	3.744	5.408	102.96	26.624

Based on values in EPA Technical Highlights: Emission Factors for Locomotives, EPA Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009.

Weighted Emission Factors (EF) per pollutant for each gallon of fuel used (gm/gal or lbs/gal) were calculated for each Class I railroad fleet based on its fraction of line-haul locomotives at each regulated Tier level (Eqn 1; Table 3).

$$EF_{iRR} = \sum_{T=1}^4 (EF_{iT} * f_{TRR}) \quad \text{Equation 1}$$

$EF_{iRR}$  = Weighted Emission Factor for pollutant i for Class I railroad RR (gm/gal).  
 $EF_{iT}$  = Emission Factor for pollutant i for locomotives in Tier T (gm/gal) (Table 3).  
 There were 4 Tiers of locomotives in the 2008 fleets.  
 $f_{TRR}$  = Fraction of railroad RR fleet in Tier T.

While engine emissions are variable within Tier categories, this approach likely provides better regional estimates than uniformly applying the nationwide average emission factors. This approach likely provides conservative emission estimates as locomotive engines are certified to meet or exceed the emissions standard for each Tier, although emission levels may increase after certification.

Other emission factors are not engine specific. For locomotives, PM<sub>2.5</sub> is assumed to be 97% of PM<sub>10</sub> <sup>11</sup>, and emission factors applied for SO<sub>2</sub> and NH<sub>3</sub> are 1.88 g/gal <sup>11</sup> and 83.3 mg/gal <sup>12</sup> respectively. Greenhouse gases are estimated using emission factors shown in Table 4.

**Table 4. EPA greenhouse gas emission factors for locomotive diesel fuel (grams/gal).** <sup>13</sup>

	<b>CO<sub>2</sub></b>	<b>N<sub>2</sub>O</b>	<b>CH<sub>4</sub></b>
Locomotive diesel	1.015E4	0.26	0.80

A Railroad Fuel Consumption Index (RFCI) was also calculated for each Class I railroad using their system-wide line-haul fuel consumption (FC) and gross ton-mile (GTM) data reported in their annual R-1 reports submitted to the Surface Transportation Board<sup>7</sup> (Eqn 2). This value represents the average number of GTM produced per gallon of diesel fuel used over their system in a year, and varies between railroad carriers depending on factors such as fleet mix, system

terrain, speeds, loading/weight of cargo, train type (e.g., intermodal, unit, and manifest), and operating practices. (Table 2).

$$RFCI_{RR} = \frac{GTM_{RR}}{FC_{RR}} \quad \text{Equation 2}$$

$RFCI_{RR}$  = Railroad Fuel Consumption Index (gross ton-miles/gal) per Class I railroad (RR).  
 $GTM_{RR}$  = Gross Ton-Miles (GTM), annual system-wide gross ton miles of freight transported per RR. (R-1 Report Schedule 755, Line 104)  
 $FC_{RR}$  = Annual system-wide fuel consumption by line-haul and work trains per RR (gal) (R-1 Report Schedule 750, Lines 1 and 6).

## 2. Calculate Emissions per Link.

Emissions of pollutant *i* per link *L* ( $E_{iL}$ ) are then calculated by multiplying the gallons of diesel fuel consumed by each Class I railroad on the link by that railroad's weighted Emission Factor for the pollutant, and summed over all railroads operating on the link (Eqn 3). This approach splits the activity on each link (represented by MGT) evenly between all railroads operating on the link. Note that the weighted Emission Factors are converted to tons/gal for these calculations, and that variables with units in tons may represent tons of freight hauled (MGT, RFCI) or tons of pollutants (EF, E).

$$E_{iL} = \sum_{RR=1}^N \frac{\left( \frac{MGT_L * 10^6}{N} \right) * l_L}{RFCI_{RR}} * EF_{iRR} \quad \text{Equation 3}$$

$E_{iL}$  = Emissions of pollutant *i* per link *L* (tons/year).  
 $N$  = Number of Class I railroads operating on link *L*.  
 $MGT_L$  = Millions of Gross Tons hauled per link per year from the FRA database ( $10^6$  tons/yr)<sup>9</sup>.  
 $l_L$  = Link length from the FRA database (miles).  
 $EF_{iRR}$  = Weighted Emission Factor for pollutant *i* per railroad *RR* (Eqn 1; tons/gal).  
 $RFCI_{RR}$  = Railroad Fuel Consumption Index per railroad *RR* (Eqn 2; gross ton-miles/gal).

Note that approximately 36% of Class I route miles in the United States are shared by more than one Class I carrier, a fraction that drops to 26% when neglecting track only shared between one Class I freight railroad and Amtrak. Accurately apportioning the specific fractions of tonnage (MGT) per carrier per link was considered, but after comparing likely worst-case areas, the difficulty of merging carrier-specific MGT with the aggregated FRA MGT dataset was considered too great considering the potential gain in accuracy. Where warranted, MGT data may be apportioned more accurately in the future.

## **Limitations, Conclusions, and Future Work**

Rail-related emissions can be important components of emissions inventories used to support effective air quality management practices, at local, state, regional, and national levels. This line-haul inventory, as well as the companion Class I railyard inventory and Class II/III inventory, greatly improve our estimates of rail-related emissions. However, a systematic study of variability and uncertainty in line-haul locomotive emissions and activity, by fleets, locations, and through time, would give valuable information for identifying how to best improve this inventory as well provide an indication of how representative the inventory may be. An uncertainty study on the data used for this inventory, including the R-1 reported fuel use and the confidential link-level tonnage data, would also help in evaluating the quality of this inventory. Localized studies should also examine how shared tracks are apportioned between multiple carriers.

Early ERTAC Rail discussions concluded that link-level tonnage was the most important data to obtain, while other variables such as track grade and track speed could not be addressed at this time. ERTAC Rail calculated railroad-specific fleet-averaged emission factors rather than applying the estimated national average; however, it is recognized that emissions from individual engines are highly variable even within Tier categories depending on variables such as the specific locomotive model, operation cycle, and conditions of operation. Future evaluation of emission variability within Tiers and between certain types of operation and locations would also be valuable.

Emissions inventory preparation guidance from the U.S. EPA describes locomotive activity as relatively constant throughout the year (e.g. no daily, weekly, or seasonal variability); however, actual activity levels do vary seasonally and annual averaging may dilute or exaggerate concentrations during pollution episodes. ERTAC Rail and the Class I railroad community had some discussions addressing if incorporating more specific fleet mix or monthly or seasonal variation may be worthwhile, and these topics should be looked into further.

Finally, it is important to reiterate that the link-level MGT data maintained by the FRA is proprietary and can only be released to agencies/groups outside the FRA with the express permission of each Class I railroad. It is possible that one or more Class I railroads could withhold permission for access, but data for specialized studies may be provided if requested. This database can also be improved by better distinguishing between haulage and trackage rights, and by apportioning tonnage hauled on links to specific carriers.

We would like to thank the Class I Railroads and their representatives for their assistance and support in the development of this inventory.

## **References**

1. Eastern Research Group (ERG) for E.H. Pechan & Associates, Inc., "Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and Other Nonroad Components of the National Emissions Inventory, Volume I – Methodology"; EPA Contract No.: 68-D-02-063. Prepared for the US EPA Emissions, Monitoring and Analysis Division, Sept.

30, 2005.

[ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei\\_mobile\\_nonroad\\_methods.pdf](ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei_mobile_nonroad_methods.pdf). Related documents at

[ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei\\_mobile\\_nonroad\\_train.pdf](ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei_mobile_nonroad_train.pdf)

2. Sierra Research, Inc., "Revised Inventory Guidance For Locomotive Emissions"; Report No. SR2004-06-01. Prepared for Southeastern States Air Resource Managers (SESARM), June 2004. <http://www.metro4-sesarm.org/pubs/railroad/FinalGuidance.pdf>
3. Sierra Research, Inc., "Research Project: Development of Railroad Emission Inventory Methodologies"; Report No. SR2004-06-02. Prepared for Southeastern States Air Resource Managers (SESARM), June 2004. <http://www.metro4-sesarm.org/pubs/railroad/FinalMethodologies.pdf>
4. Environ, "Draft LADCO 2005 Locomotive Emissions". Prepared for Lake Michigan Air Director Consortium, Feb 2007.  
[http://www.ladco.org/reports/technical\\_support\\_document/references/ladco\\_2005\\_locomotive\\_emissions.021406.pdf](http://www.ladco.org/reports/technical_support_document/references/ladco_2005_locomotive_emissions.021406.pdf)
5. Southern Research Institute, "NYSERDA Clean Diesel Technology: Non-Road Field Demonstration Program, Development of the 2002 Locomotive Survey for New York State"; Agreement Number 8958. Prepared for the New York State Energy Research And Development Authority (NYSERDA), Feb. 09, 2007.  
<http://www.nyserda.org/publications/LocomotiveSurveyReportwithAppendices.pdf>
6. M. Bergin; M. Harrell; J. McDill; M. Janssen; L. Driver; R. Fronczak; R. Nath,; and D. Seep. "ERTAC Rail: A Collaborative Effort in Building a Railroad-Related Emissions Inventory Between Eastern States Air Protection Agencies and Participation with the Railroad Industry," 18th Annual International Emission Inventory Conference. Baltimore, MD. April 14 - 17, 2009. Paper and presentation available at:  
<http://www.epa.gov/ttn/chief/conference/ei18/session6/bergin.pdf>
7. Surface Transportation Board R-1 Reports, available at:  
[http://www.stb.dot.gov/stb/industry/econ\\_reports.html](http://www.stb.dot.gov/stb/industry/econ_reports.html).
8. US DOT Bureau of Transportation Statistics' 2008 National Transportation Atlas Database.
9. Confidential database was provided with assistance from Raquel Wright of the Federal Railroad Administration. Similar public data providing ranges of tonnage hauled rather than link-level tonnage is available from the Bureau of Transportation Statistics in the NTAD 2009 shapefile data (data is representative for the year 2007):  
[http://www.bts.gov/publications/national\\_transportation\\_atlas\\_database/2009](http://www.bts.gov/publications/national_transportation_atlas_database/2009).
10. Freight Railroads in the United States 2008. Association of American Railroads. Available at:  
[http://www.aar.org/~media/AAR/InCongress\\_RailroadsStates/2008unitedstates.ashx](http://www.aar.org/~media/AAR/InCongress_RailroadsStates/2008unitedstates.ashx).
11. EPA Technical Highlights: Emission Factors for Locomotives, EPA Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009.  
<http://www.epa.gov/otaq/regs/nonroad/locomotv/420f09025.pdf>

12. Estimating Ammonia Emissions From Anthropogenic Nonagricultural Sources - Draft Final Report by E.H. Pechan & Assoc. April 2004. Prepared for EPA/STAPPA-ALAPCO Emission Inventory Improvement Program. Supported by personal communication (5/6/2010) with Craig Harvey, US EPA, OTAQ, and Robert Wooten, NC DENR. [http://www.epa.gov/ttnchie1/eiip/techreport/volume03/eiip\\_areasourcesnh3.pdf](http://www.epa.gov/ttnchie1/eiip/techreport/volume03/eiip_areasourcesnh3.pdf)
13. U.S. Environmental Protection Agency. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005, EPA 430-R-07-002, Annex 3.2, (April 2007), web site: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

#### **Appendix A: ERTAC Rail Data Workgroup**

<b>REPRESENTATIVE</b>	<b>ORGANIZATION</b>
Matt Harrell	IL EPA
Michelle Bergin (Co-Chair) and Byeong Kim	GA EPD
Mark Janssen (Co-Chair)	LADCO
Julie McDill and Patrick Davis	MARAMA
Laurel Driver	US EPA OAQPS
Robert Fronczak	AAR
Steven Sullivan	ASLRRA
Rick Nath	CSX
David Seep and Lyle Staley	BNSF
Ken Roberge	CPR
Carl Akins and Peter Conlon	KCS
Erika Akkerman	CN
M. John Germer	UP
Brent Mason and Richard Russell	NS
Joanne Maxwell	Amtrak

## Appendix B: Source and Year of Data Utilized for Each Inventory

Data	Year	Source
<b>Class I Line-Haul</b>		
Annual Line-Haul Fuel Use and Gross Ton-Miles	2007	STB R-1 Reports (CP data for D&H is for 2008.)
Line-haul fleet mix for emission factors	2008	Each Class I railroad
Link-level tonnage	2007	FRA confidential database
<b>Class I Railyards (Switcher Locomotives)</b>		
Annual Switcher Fuel Use	2008	R-1 Reports
Switcher fleet mix for emission factors	2008	Each Class I railroad
Link-level tonnage or Density Code (for activity estimate)	2007	FRA confidential database
<b>Class II and III Locomotives</b>		
Annual Total Fuel Use	2008	ASLRRA Annual Report (2008)
Track length and railroad	2008	ASLRRA Annual Report (2008)
Estimated fleet mix for emission factors		Discussions with ASLRRA and Class II and III representatives.



## **Appendix B**

### **ERTAC Class II/III Line Haul Documentation**

# **DRAFT**

## **ERTAC – Class 2/3 Shapefile Documentation**

**13 Jul 2009**

### **Introduction**

This document outlines the methods and procedures used to compile a shapefile representing the links in the FRA 1:100,000 railroad dataset that are owned or operated by Class II and III railroad companies. It is important to note that there is a considerable amount of overlap between the Class II's and III's and the Class I and passenger railroads. Class II's and III's can operate on Class I or passenger rail links and vice versa. Although the final shapefile specifically represents Class II and III links, there are many Class I and passenger railroads represented as well.

### **Procedure**

1. Started with all proprietary FRA links where “NET = ‘M’ and “STCNTYFIPS” <> ‘ ‘ (this definition query selects all active mainline links located within the United States).
2. Ran 12 queries, one for each ownership and trackage rights field, to select all links not associated with a Class I freight railroad or Amtrak and not containing a null value (e.g., "RROWNER1" <> 'AMTK' AND "RROWNER1" <> 'BNSF' AND "RROWNER1" <> 'CN' AND "RROWNER1" <> 'CPRS' AND "RROWNER1" <> 'CSXT' AND "RROWNER1" <> 'KCS' AND "RROWNER1" <> 'NS' AND "RROWNER1" <> 'UP' AND "RROWNER1" <> ' '). The first query was setup as a new selection. Each of the 11 subsequent queries were setup to add records to initial set of records. 26,261 links were selected and exported to a new shapefile.
3. Due to the multitude of railroad codes used to represent commuter rail operations across the country, additional processing was required to remove any links that were not operated by a Class II or III freight railroad. Each commuter railroad was queried out of the new shapefile and the links analyzed to eliminate all links where no Class II or III operations were occurring. The following commuter rail operations were evaluated: NJT (New Jersey Transit), MNCW (Metro-North Commuter Railroad), LI (Long Island Railroad), CDOT (Connecticut DOT), MBTA (Massachusetts Bay Transportation Authority), SEPA (Southeastern Pennsylvania Transportation Authority), MARC (Maryland Area Rail Commuter), VRE (Virginia Railway Express), MTRA (Northeastern Illinois Regional Commuter Railroad), CSS (Northern Indiana Commuter Transportation District), DART (Dallas Area Rapid Transit), SCRA (Southern California Regional Rail Authority – including also SCAX, LACM, LAPT, and LATC), TCRA (South Florida Regional Transportation Authority), PJPB (Caltrain), and ACE (Altamont Commuter Express).

Approximately 1581 links were identified with no Class II or III operations and were deleted from the Class 2/3 shapefile.

4. The remaining Class II and III links were then compared to the regional maps contained in the July-August issue of The Official Railway Guide to assess the completeness of the Class 2/3 shapefile. Six specific edits were made to the shapefile to correct the most glaring errors: 1) BMLP links deleted (Black Mesa & Lake Powell, an electric coal hauling railway in Arizona); 2) DSNG links deleted (Durango & Silverton steam tourist railroad in Colorado); 3) CIC haulage rights links on CN from Chicago to Omaha deleted; 4) DMIR links deleted (Duluth, Missabe & Iron Range, now owned and operated by CN in Minnesota); 5) EVWR's ex-CSXT links coded from Evansville, IN to Okawville, IL (Evansville Western Railroad); 6) INRD ex-CP links coded from Chicago, IL to Louisville, IN (Indiana Rail Road).
5. During the course of reviewing the FRA dataset, 555 "active" links were found to have no ownership or trackage rights codes. 1005 links have no codes listed in the 3 ownership fields. In most cases these links are very short and scattered across the country. Only the links representing the EVWR and INRD spanned large distances and were fixed. The other problem links were deemed to be insignificant. A listing of these links will be provided back to the FRA to assist with their coding in 1:100K railway shapefile.

## **Appendix C**

### **ERTAC Rail Yard Documentation**

# **DRAFT**

## **ERTAC Rail Emissions Inventory**

### **Part 2: Class I Railyard Switcher Locomotives**

Michelle Bergin, GA Environmental Protection Division  
Matthew Harrell, IL Environmental Protection Agency  
Mark Janssen, Lake Michigan Air Directors Consortium

Acknowledgments: Robert Fronczak, Association of American Railroads  
Laurel Driver, US EPA, Office of Air Quality Planning and Support  
Byeong Kim, GA Environmental Protection Division

#### **Introduction**

Air protection agencies from twenty-seven states, coordinated through the Eastern Regional Technical Advisory Committee (ERTAC) and headed by the Lake Michigan Air Directors Consortium (LADCO), identified a need to better quantify and characterize rail-related emissions inventories. Traditional locomotives largely utilize diesel engines, resulting in emissions of NO<sub>x</sub>, diesel PM, hydrocarbons, greenhouse gases, and other pollutants. These emissions are sometimes concentrated in areas exceeding National Ambient Air Quality Standards. No cohesive nationwide railroad emission estimates are known to have been made previously. Inventory development methods for locomotive emissions estimates vary from state to state and, in general, lack the spatial or temporal resolution needed to support air quality modeling and planning<sup>1-5</sup>.

The ERTAC Rail Subcommittee (ERTAC Rail) was established with active representatives from twelve member states, three regional planning offices, and the US EPA. The subcommittee's goals are to (1) standardize agencies' inventory development methods through a collaborative effort, (2) improve the quality of data received and the resulting emission inventories, and (3) reduce the administrative burden on railroad companies of providing data. With support from the Rail industry and assistance from the ERTAC Rail Data Workgroup (Appendix), ERTAC Rail has developed 3 inventories of locomotive emissions; from Class I line-haul, Shortline and Regional Railroads, and Class I railyard switchers, for the year 2008 (Table 1).

The Surface Transportation Board (STB) defines Class I Railroads as having had minimum carrier operating revenues of \$401.4 million (USD) in 2008. There are 8 Class I Railroads operating in the United States (Table 2), about 12 Regional Railroads (Class II), and approximately 530 Class III Railroads (Shortlines). While categorized as a Class I Railroad, Amtrak was excluded from these inventories because of significant differences in equipment and operation characteristics. Line-haul locomotives travel long distances (e.g. between cities) while switcher locomotives largely operate in railyards, splitting and joining rail cars with varying destinations. Passenger and Commuter Rail (including Amtrak), industrial locomotives, and associated non-locomotive equipment are not included in these inventories.

Table 1. Summary of ERTAC Rail Inventories: U.S. Locomotive Emissions and Fuel Use for either 2007 or 2008\*.

	Fuel Use** (gal/yr)	Emissions (tons/yr)					
		NO <sub>x</sub>	PM <sub>2.5</sub>	HC	SO <sub>2</sub>	CO	NH <sub>3</sub>
Class I*** line-haul	3,770,914,002	754,443	23,439	37,941	7,836	110,969	347
Class I switcher	300,492,223	73,741	2,024	4,824	619	9,152	27
Class II and III	157,800,000	51,367	1,163	1,897	357	5,058	16

\*See Appendix B for a description of the year and source of data utilized for each inventory.

\*\*Locomotive grade diesel

\*\*\*Excluding Amtrak and including work train fuel use

Table 2. Class I Railroads and Reported Locomotive Fuel Use<sup>7</sup>.

Class I Railroads*	R-1 Reported Locomotive Fuel Use (gal/yr)	
	Line-Haul (2007)**	Switcher (2008)
BNSF	1,393,874,954	52,497,057
Canadian National	93,830,751	12,290,022
Canadian Pacific***	50,320,233	4,594,067
CSX	514,687,186	53,717,674
Kansas City Southern	69,787,071	1,816,759
Norfolk Southern	463,267,278	32,317,375
Union Pacific	1,185,146,529	143,470,336
<b>Total</b>	<b>3,770,914,002</b>	<b>300,492,223</b>

\* Excluding Amtrak

\*\* Includes work trains

\*\*\* CP's line-haul fuel use values include 2008 data (rather than 2007) for their Delaware and Hudson subsidiary.

This paper documents the data sources and methodologies used for calculating the Class I switcher ("Railyard") inventory. Information on ERTAC Rail, Railroad participation, the Rail industry, and effects of rail on air quality are available elsewhere<sup>6</sup>.

## Method

Switcher locomotives are expected to be the single largest source of air emissions in railyards. Therefore, as a starting point for a comprehensive railyard inventory, a Class I switcher emission inventory was developed. It is assumed that estimates for yards of interest, associated equipment and activity, and smaller railroads could be refined later.

While ERTAC Rail represents states east of the Mississippi River, the railroad companies specified they wanted this effort to result in a consistent nationwide inventory. ERTAC Rail agreed to calculate emissions for all states when the data was available and when additional

significant effort was not required. Because both the dataset of railyards and switcher fuel use was nationwide in scope, the resulting initial railyard inventory is a nationwide, ‘top-down’ derivation. However, railroad companies may have different levels and quality of data available, and may have interpreted some data requests differently. Also, states are requested to update yards they have detailed information on when possible, and a few states (i.e. California) have unique railroad operations and equipment. Therefore, data for some areas will be more accurate than for others, and locally-derived inventories may be more accurate.

This documentation describes development of the initial top-down inventory, which consisted of three main activities:

1. Locate Class I Railyards
2. Select/Calculate Emission Factors
3. Estimate Locomotive Activity
4. Improve Estimates

### **1. Locate Class I Railyards.**

Identification and correct placement of railyards was an important first step, requiring a comprehensive electronic dataset. A confidential database was obtained from the Federal Railroad Administration (FRA) with permission from the Class I Railroads (FRA database). A similar public database compiled by the Bureau of Transportation Statistics is also available<sup>7</sup>. Data from this source will not match the confidential data exactly, but will be very similar. The FRA database has rail links (track lengths) individually identified as parts of specific railyards. While there may be discrepancies in how each railroad defined railyard links, this dataset appears to identify most Class I railyards in the U.S., and shows a high density of yards in the eastern states (Figure 1). The database gives length, up to 3 owners and 3 operators, and a Federal Density Code (explained below) for each railyard link.

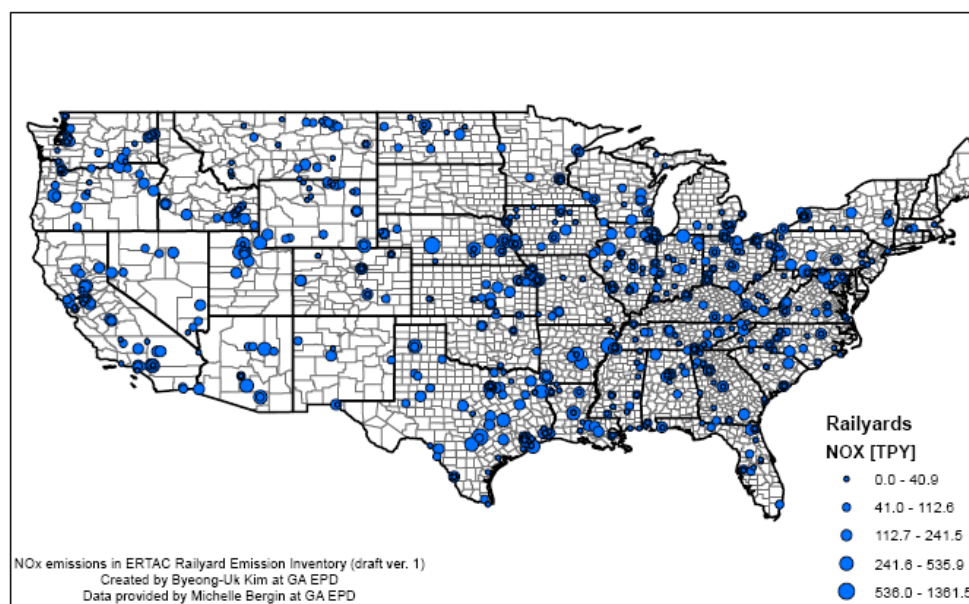


Figure 1. Class I Railyards in the United States and estimates of Annual NOx emissions from switcher locomotives (tons/yr in 2008).

## 2. Select/Calculate Emission Factors.

The EPA provides annual default emission factors based on characteristic operating cycles ('duty cycles') and the estimated nationwide fleet mix for both switcher and line-haul locomotives. However, switcher fleet mix is not uniform from company to company and, as can be seen in Figure 2, Class I railroad activity is highly regional.

As an alternative approach, ERTAC Rail requested each Class I rail company to provide a description of their switcher fleet mix based on Tier rating, which each company provided under a confidentiality agreement. An engine's Tier determines allowable emission limits based on the year the engine was built (Table 3). While engine emissions are variable within Tier categories, this estimate likely provides a better regional estimate than the nationwide average. The company-specific systemwide fleet mix was used to calculate weighted average emissions factors for switchers operated by each Class I railroad.

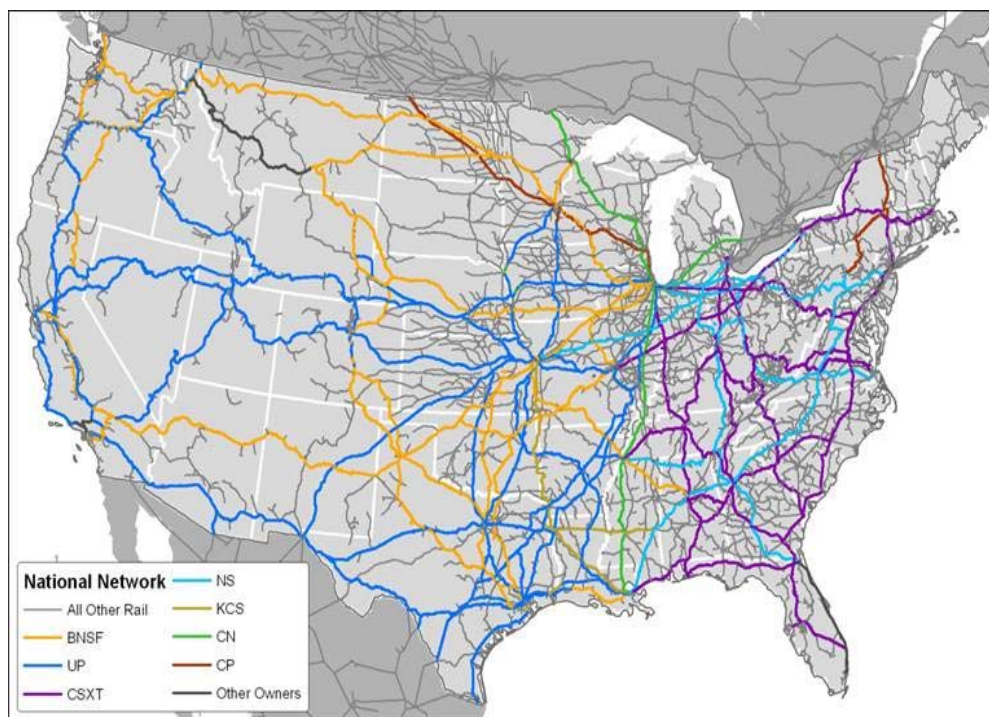


Figure 2. Class I Railroad Territories in the United States.

Table 3. EPA switcher locomotive emission factors by Tier, 1997 standards (grams/gal).

	<b>PM<sub>10</sub></b>	<b>HC</b>	<b>NO<sub>x</sub></b>	<b>CO</b>
Uncontrolled (pre-1973)	6.688	15.352	264.48	27.816
Tier 0 (1973-2001)	6.688	15.352	191.52	27.816
Tier 1 (2002-2004)	6.536	15.352	150.48	27.816
Tier 2 (2005 + )	2.888	7.752	110.96	27.816

Listed years apply to the year the engine was built. Table based on values from<sup>8</sup>. Note that the new standards released in 2008 did not apply to existing fleets in the year 2008.



For locomotives, PM<sub>2.5</sub> is assumed to be 97% of PM<sub>10</sub><sup>8</sup>, and emission factors for SO<sub>2</sub> and NH<sub>3</sub> are 1.88 g/gal and 83.3 mg/gal respectively (add cites). Greenhouse gases are also estimated using emission factors shown in Table 4.

Table 4. EPA greenhouse gas emission factors for locomotive diesel fuel (grams/gal).

	CO <sub>2</sub>	N <sub>2</sub> O	CH <sub>4</sub>
Locomotive diesel	1.015E4	0.26	0.80

**Source:** U.S. Environmental Protection Agency. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005, EPA 430-R-07-002, Annex 3.2, (April 2007), web site: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

These emission factors are based on a characteristic duty cycle for switchers which assumes operation over 24-hour per day 365 days per year. An evaluation of the effect of variability in railyards and switching duties on emissions would be useful for future inventories.

### **3. Estimate Locomotive Activity.**

Class I railroads report total annual switcher locomotive fuel use to the STB, which is reported in publicly available 'R-1' reports (Table 2). There may be inconsistencies between railroads in how fuel use is estimated to be apportioned between line-haul and switcher locomotive use, and possibly in the total locomotive fuel use, so these values may be adjusted in the future.

However, the use of these values provides a starting point for estimating total U.S. Class I locomotive-related emissions segregated by Class I carrier. The R-1 report was used by ERTAC for both the line-haul and switcher locomotive emissions inventories.

The next step for inventory development is to allocate switcher fuel use to each railyard. Two methods were applied, one that relies on publicly available line-haul activity (the 'Decode' method), and the other using confidential line-haul activity (the 'MGT' method.) At this time, Norfolk Southern and Kansas City Southern have provided input for use of the MGT method and the Decode method is applied for the other five railroads.

#### **The Decode Method – Publicly available data**

Each link in both the publicly available BTS database and the confidential FRA database has a 'Federal Density Code' (Decode) ranging from 1 to 7 assigned based on the cumulative annual freight tonnage hauled on the link (track). Total Switcher Fuel Use in each railyard Y (SFU<sub>Y</sub>) is estimated as follows:

First the Switcher Activity Indicator per yard (SAI<sub>Y</sub>) is estimated by multiplying the average decode of the links identified as part of the same railyard by the sum of the length of the links for that railyard (Eqn 1).

$$SAI_Y = \sum (l_{nY} * FDC_{nY}) \quad \text{Equation 1}$$

SAI<sub>Y</sub> = Switcher Activity Indicator in Railyard Y

$n_Y$  = number of links identified as part of railyard Y  
 $l_{nY}$  = length of link n in miles  
 $FDC_n$  = Federal Density Code (1 to 7) of link n

Next, this value is then weighted ( $SAI_Y'$ ) based on an ownership factor (OF) set between 0 and 1. The OF depends on the number of owners listed for each railyard: if there is one owner the OF is set to 1, if there are two owners the primary owner is set to 0.8 and the secondary is 0.2, and if there are 3 owners the primary is 0.6, the secondary is 0.2, and the tertiary is 0.1.

$$SAI_Y' = OF_Y * SAI_Y \quad \text{Equation 2}$$

Next, the  $SAI_Y'$  of all railyards belonging to a Class I railroad (RR) were summed, and the fraction of the railroads total SAI associated with each railyard was multiplied by the railroads total annual switcher fuel use reported in the R-1 ( $TFU_{RR}$ ), resulting in the total Switcher Fuel Use for each railyard Y (Eqn 2).

$$SFU_Y = \frac{SAI_Y'}{\sum_{RR} SAI_Y'} * TFU_{RR} \quad \text{Equation 3}$$

$SFU_Y$  = Switcher Fuel Use at railyard Y

Finally, the  $SFU_Y$  is multiplied by the emission factors described in the previous section to obtain annual switcher emissions at each railyard.

### **The MGT Method – Confidential data**

Two railroads, Norfolk Southern and Kansas City Southern, provided confidential link-level tonnage information and weighting factors to correct skewed estimates to improve estimated switcher activity at important yards. Other railroads may also allow the use of this technique for their inventories in the future.

The MGT Method also uses the FRA database for railyard identification and link lengths. However, rather than using the average dencode per link, confidential annual gross tonnage (MGT) hauled per link in the railyard was used to calculate the railyard switcher activity ( $SAI_Y$ ). This is calculated by replacing  $FDC_n$  in Equation 2 with link-specific tonnage  $MGT_n$  (Equation 4).

$$SAI_Y = \sum (l_{nY} * MGT_{nY}) \quad \text{Equation 4}$$

$SAI_Y$  = Switcher Activity Indicator in Railyard Y  
 $n_Y$  = number of links identified as part of railyard Y

$l_{nY}$  = length of link n in miles

$MGT_{nY}$  = million gross tons on link n

This method provides a more refined comparison between railyards than the use of the 7-category dencodes; however, is more susceptible to errors for yards where tonnage is not correlated to switching activity. For example, a yard with large coal trains pulling through used for crews to change over would be assigned an overly high level of emissions for switching activity. To account for this, a discretionary Switching Activity Factor (SAF) was introduced to allow railroads to roughly weight yards with clearly higher or lower levels of switching activity than what results from the mathematical allocation. Therefore,  $SAI_Y$  is weighted based on both the ownership factor (OF) as well as the SAF (Equation 5). For example, a yard used for crew changes and not switching may have an SAF of 0, while a yard at a major interchange between cities may have an SAF of 3.

$$SAI_Y' = OF_Y * SAF_Y * SAI_Y \quad \text{Equation 5}$$

Again, the  $SAI_Y'$  of all railyards belonging to a Class I railroad (RR) are summed, and the fraction of the railroads total SAI associated with each railyard was multiplied by the railroads total annual switcher fuel use reported in the R-1 ( $TFU_{RR}$ ), resulting in the total Switcher Fuel Use for each railyard Y (Eqn 6).

$$SFU_Y = \frac{SAI_Y'}{\sum_{RR} SAI_Y'} * TFU_{RR} \quad \text{Equation 6}$$

While the SAF allows estimates of yard-specific emissions to be adjusted, the total level of emissions for each railroad, which is based on systemwide fuel use and systemwide emission factors, remains unchanged. The MGT method  $SFU_Y$  is also later multiplied by the emission factors described in the previous section to obtain annual switcher emissions at each railyard.

#### **4. Improve estimates.**

In addition to the Switching Activity Factor described above, direct input was also used to improve emission estimates for important railyards. Each Class I railroad provided an estimate of annual average switcher fuel use (generally much lower than the EPA default of 82,490 gal/yr) as well as the name, location, and number of operating switchers for railyards with 8 or more switchers operating in ozone or PM2.5 nonattainment areas. This data was used to overwrite the dencode or MGT derived emissions estimates for those railyards.

The difference in estimated fuel use for those railyards was re-allocated (added or removed) between the remaining railyards belonging to that Class I railroad. It is important to note that there are some discrepancies in how this data was reported for the large railyards by each railroad. For example, some railroads reported all switchers located at a railyard while others reported 'full time equivalent' switchers, meaning the number of switchers normalized to a full working cycle (24-hours per day year-round.) This process should be standardized for future inventory versions.

States also have the option of updating specific railyard emissions estimates. Because this inventory is derived ‘top-down’, local studies and familiarity with specific railyards is expected to provide better estimates, which can be used to adjust this inventory. Care must be taken to ensure the other railyard estimates are adjusted to account for increases or decreases in estimated fuel use per yard.

## **Limitations, Conclusions, and Future Work**

What this ERTAC Rail railyard inventory does well is provide a comprehensive overview of where railyards are, who owns them, and gives a geographical allocation of switcher emissions bounded by what is reported as nationwide switcher fuel usage by the Class I railroads. These sources can be important for air quality management in nonattainment areas, as well as in regional analysis and for future transportation planning. This inventory will be useful for regional and some local modeling, helps identify where railyards need to be better characterized, and provides a strong foundation for future development of a meaningful nationwide Class I switcher emissions inventory.

There are important uncertainties associated with estimates from this method, including, but not limited to, the use of tonnage hauled as an indicator of the amount of switching activity, and, for a few of the railroads, how the amount of switcher fuel use was determined to be reported in the R-1. The R-1 reported values are currently under examination.

There is also likely significant variability in actual switching duty-cycles and, potentially, in the number of switchers operating at some railyards at different times of the year. ‘Road-switching’, or the use of what are considered switching locomotives to move between nearby yards, should be addressed in either this or the ERTAC line-haul inventory.

It must be noted that freight-related rail activity is not always routine and no annual emissions inventory will ever be able to capture the innate variability of the source. However, as other large emission sources are reduced, and if rail activity increases as expected, it is important to include our best estimates of these sources in air quality analysis. In the future, on-line data loggers and other tracking technologies, combined with ambient studies and detailed modeling, will hopefully provide more insight to the emissions of locomotives and other railyard sources.

## **References**

1. E.H. Pechan & Associates, Inc., “Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and Other Nonroad Components of the National Emissions Inventory, Volume I – Methodology”; EPA Contract No.: 68-D-02-063. Prepared for the US EPA Emissions, Monitoring and Analysis Division, Sept. 30, 2005.  
[ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei\\_mobile\\_nonroad\\_methods.pdf](ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei_mobile_nonroad_methods.pdf). Related documents at  
[ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei\\_mobile\\_nonroad\\_train.pdf](ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei_mobile_nonroad_train.pdf)

2. Sierra Research, Inc., "Revised Inventory Guidance For Locomotive Emissions"; Report No. SR2004-06-01. Prepared for Southeastern States Air Resource Managers (SESARM), June 2004. <http://www.metro4-sesarm.org/pubs/railroad/FinalGuidance.pdf>
3. Sierra Research, Inc., "Research Project: Development of Railroad Emission Inventory Methodologies"; Report No. SR2004-06-02. Prepared for Southeastern States Air Resource Managers (SESARM), June 2004. <http://www.metro4-sesarm.org/pubs/railroad/FinalMethodologies.pdf>
14. Environ, "Draft LADCO 2005 Locomotive Emissions". Prepared for Lake Michigan Air Director Consortium, Feb 2007.  
[http://www.ladco.org/reports/technical\\_support\\_document/references/ladco\\_2005\\_locomotive\\_emissions.021406.pdf](http://www.ladco.org/reports/technical_support_document/references/ladco_2005_locomotive_emissions.021406.pdf)
15. Southern Research Institute, "NYSERDA Clean Diesel Technology: Non-Road Field Demonstration Program, Development of the 2002 Locomotive Survey for New York State"; Agreement Number 8958. Prepared for the New York State Energy Research And Development Authority (NYSERDA), Feb. 09, 2007.  
<http://www.nyserda.org/publications/LocomotiveSurveyReportwithAppendices.pdf>
16. M. Bergin; M. Harrell; J. McDill; M. Janssen; L. Driver; R. Fronczak; R. Nath,; and D. Seep. "ERTAC Rail: A Collaborative Effort in Building a Railroad-Related Emissions Inventory Between Eastern States Air Protection Agencies and Participation with the Railroad Industry," 18th Annual International Emission Inventory Conference. Baltimore, MD. April 14 - 17, 2009. Paper and presentation available at:  
<http://www.epa.gov/ttn/chief/conference/ei18/session6/bergin.pdf>
17. Confidential database was provided with assistance from Raquel Wright of the Federal Railroad Administration. Similar public data is available from the Bureau of Transportation Statistics, in the NTAD 2009 shapefile data (data is representative for the year 2007): [http://www.bts.gov/publications/national\\_transportation\\_atlas\\_database/2009](http://www.bts.gov/publications/national_transportation_atlas_database/2009)  
.
18. EPA Technical Highlights: Emission Factors for Locomotives, EPA Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009.  
<http://www.epa.gov/otaq/regs/nonroad/locomotv/420f09025.pdf>

## **Appendix: ERTAC Rail Data Workgroup**

<b>REPRESENTATIVE</b>	<b>ORGANIZATION</b>
Matt Harrell	IL EPA
Michelle Bergin (Co-Chair) and Byeong Kim	GA EPD
Mark Janssen (Co-Chair)	LADCO
Julie McDill and Patrick Davis	MARAMA
Laurel Driver	US EPA OAQPS
Robert Fronczak	AAR
Steven Sullivan	ASLRRA
Rick Nath	CSX

David Seep and Lyle Staley	BNSF
Ken Roberge	CPR
Carl Akins and Peter Conlon	KCS
Erika Akkerman	CN
M. John Germer	UP
Brent Mason and Richard Russell	NS
Joanne Maxwell	Amtrak