Draft

LADCO 2005 LOCOMOTIVE EMISSIONS

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LOCOMOTIVE EMISSION SOURCES

INTRODUCTION

Locomotives are usually the most important source of NOx, PM, and SOx emissions from off-road engines. Rail activity is especially important in the LADCO states, because Chicago and other metropolitan areas in the LADCO states represent important rail centers.

Rail activity has been typically broken into five subcategories or Source Category Codes (SCC) shown in Table 1 from the National Emission Inventory (EPA, 2001). Class I railroad operations are the largest and most important railroads and have been split into two categories, which ENVIRON considered to be their line-haul (SCC 2285002006) and switching (SCC 2285002010) activity. Smaller rail (Class II and III; SCC 2285002007) include a large number of railroads and a wide variety of operations including line-haul and switching operations. It was useful to separate switching activity from line-haul activity for both Class I and II/III because the emissions are usually specific to a given yard and such engines have different operating profiles. Because EPA only provided one switching engine SCC, the Class I and II/III switchers were combined in the one SCC. AMTRAK operates the only continuous passenger rail system (SCC 2285002008), though there may be small (weekend) excursion lines operating sporadically and largely unidentified. The only commuter line (SCC 2285002009) that operates in the LADCO area is the METRA system in and around the Chicago metropolitan area.

Table 1. EPA NEI rail categories.

SCC	EPA Description	Railroad Descriptions for This Work	Relative Fuel Use
2285002006	Class I line-haul	Union Pacific (UP), Burlington Northern Santa Fe (BNSF), Norfolk Southern (NS), CSX, Kansas City Southern (KCS), Canadian National[1], Canadian Pacific (CP)[2]	84.3%
2285002007	Class II/III line-haul	Regional and local railroads line-haul	2.6%
2285002008	Passenger Trains	AMTRAK	1.5%
2285002009	Commuter lines	METRA[3]	4.2%
2285002010	Yard Operations	Class I yard rail and Class II/III switching railroads	7.4%

[1] Illinois and Wisconsin Central also included in Canadian National Grand Trunk (CNGT).

[2] Soo Line included.

[3] One other line operates an electric rail system only.

The primary activity unit used to determine emissions is gallons of fuel consumed. To provide a perspective on emissions from different categories, the fuel consumption estimates for different SCC groups are shown in Table 1. The switching engine activity (SCC 2285002010) includes Class I (about 65% of SCC total) and Class II/III (about 35%) outlined by unique yard activity. The passenger and commuter rail systems were easily identified for this study and provided activity data specific to the system.

Emission rates used in this work were derived from EPA documents provided as support documentation for the 1997 locomotive emission standards (EPA, 1997). The emission rates per gallon of fuel consumed are higher with switching engines because the duty cycle is on average

lower power and has a significant amount of idling time, so the engine does not operate as efficiently as possible. Emission rates are higher for smaller rail systems than Class I railroad operations because they have been expected to convert more slowly to lower emissions engines (EPA, 2004a). EPA (2004b) provided the ammonia emission rates using the latest available data. The emission rates used in this work are shown in Table 2. The different emission rates do not match the SCC definitions exactly. The primary differences are that Class II/III switching has been treated with distinct emission factors compared to the Class II/III line-haul because of duty cycle differences, and commuter rail has the same emission factors as other passenger rail.

Table 2. Emission factor estimates used in this work (in grams per gallon). (Emission reduction due to fleet turnover to engines meeting lower emission standards.)

Engine Type	HC	CO	NOx	PM	SOx[1]	NH3[2]
Precontrolled 1999 Line-haul	10	26.6	270	6.7	16.7	0.116
Precontrolled 1999 Switching	21	38.1	362	9.2	16.7	0.116
Including emission reductions expected with the EPA rulemaking (% Reduction)						
2005 Class I Line-haul	9.59 (4.1%)	26.6	184.1 (31.8%)	6.43 (4.0%)	16.7	0.116
2005 Class I Switching	20.88 (0.6%)	38.1	336.7 (7.0%)	9.14 (0.7%)	16.7	0.116
2005 Class II/III Line-haul	10	26.6	265.6 (1.6%)	6.70	16.7	0.116
2005 Class II/III Switching	21	38.1	356.1 (1.6%)	9.20	16.7	0.116
2005 Passenger	9.79 (2.1%)	26.6	200.8 (25.6%)	6.57 (1.9%)	16.7	0.116

[1] Reported as SO_2 and derived from an average sulfur level of 2600 ppm (EPA, 2004c).

[2] EPA (2004b).

CLASS I RAILROADS

Because the Class I railroads were expected and indeed had the most significant rail operations in the LADCO states, every Class I railroad was petitioned for information about their rail operations.

Union Pacific (UP, 2007), Burlington Northern Santa Fe (BNSF, 2006), and CSX (2007) provided the most favorable responses providing county summaries of line-haul and switching engine fuel consumption. Norfolk Southern provided county level activity for their line-haul freight movements in 2002 (NS, 2004) and State totals for 2005 (NS, 2006), and detailed their switching rail activity for Cook County yards in the 2002 data but did not update those estimates for 2005. Canadian National (CN, 2007) and Canadian Pacific (CP, 2006) railroads provided State-level total activity though CP could not detail their switching engines. Kansas City Southern, which operates primarily in western Illinois and to Chicago, did not provide activity data. Table 3 summarizes the data provided by the railroads for this work.

Table 3. Class I Railroad fuel consumption submittals.

Railroad	Railroad ID	Line-Haul Activity Submittal	Switching Activity Submittal
Burlington Northern Santa Fe	BNSF	By county line-haul activity	By county switching activity
Canadian National	CNGT	State total fuel consumption	State total fuel consumption
Canadian Pacific	CP	State total gross ton-mile	No data submitted
CSX (Chessie System)	CSX	By county line-haul activity	By county switching activity
Kansas City Southern	KCS	No data submitted	No data submitted
Norfolk Southern	NS	By county line-haul activity in 2002 and State totals for 2005	By county switching activity for Cook Co. in 2002 only.
Union Pacific	UP	By county line-haul activity	By county switching activity

For Kansas City Southern (KCS), which did not provide estimates of relative activity in the LADCO states, an alternative method was used to estimate state fuel consumption. The US national fuel consumption for the railroad was prorated against the relative system mileage within Illinois as a fraction of the railroad's reported US national system (AAR, 2006).

For Canadian Pacific, switching engine activity was estimated as a fraction of line-haul fuel consumption from their line-haul activity. ENVIRON estimated this to be 7.25% of line-haul fuel consumption as derived from the CP fuel consumption submittals (AAR, 2006). Likewise, Norfolk Southern provided only the Cook Co. activity, so ENVIRON multiplied the line-haul activity by 8.95% for NS specifically to estimate the overall fraction of NS switching engine activity.

Class I railroad fuel consumption is presented in Tables 4 and 5; these estimates are primarily the railways' submittals.

Table 4. Class I Railroad line-haul 2005 fuel consumption estimates.

Railroad/State	Illinois	Indiana	Michigan	Ohio	Wisconsin
BNSF	109,809,384	0	0	0	30,285,369
CNGT	26,370,193	4,799,739	19,491,428	187,760	20,546,552
CP	2,715,644	2,086,920	3,084,322	84,666	9,368,715
CSX	14,637,848	43,189,477	6,541,787	78,198,981	0
KCS	3,028,496	0	0	0	0
NS	22,607,541	53,609,405	3,546,979	78,884,760	0
UP	78,854,338	0	0	0	7,323,114
Total	**258,023,444**	**103,685,542**	**32,664,516**	**157,356,168**	**67,523,751**

Table 5. Class I Railroad switching 2005 fuel consumption estimates.

Railroad/State	Illinois	Indiana	Michigan	Ohio	Wisconsin
BNSF	550,000	0	0	0	500,000
CNGT	2,743,600	0	1,584,145	91,323	1,711,510
CP	196,926	151,334	223,660	6,140	679,375
CSX	2,040,000	1,440,000	1,080,000	4,440,000	0
KCS	131,360	0	0	0	0
NS	2,023,203	4,797,633	317,428	7,059,585	0
UP	2,559,434	0	0	0	971,067
Total	**10,244,522**	**6,388,967**	**3,205,233**	**11,597,047**	**3,861,951**

CLASS II/III REGIONAL, SHORTLINE, AND SWITCHING RAILROADS

In order to estimate potentially important small rail activity, the national fuel consumption per railroad employee was used and associated with local employment information. Benson (2004) prepared the national estimates of fuel consumption and employees shown in Table 6 from annual surveys conducted by ASLRRA (1999). Nationally, Class II/III rail is of lesser importance than the Class I rail, which consumed nearly 20 times the fuel that these smaller rail systems consume nationwide. Table 6 provides the national summary estimates for Class II/III fuel consumption and employees; on average about 10,000 gallons of fuel are consumed per year per employee. By contrast, the Class I railroad fuel consumption per employee averages about 25,000 gallons per employee, possibly due to longer haul trips where fewer employees are required per ton-mile of operation. The ASLRRA (2007) was consulted for estimates for 2005, but ASLRRA indicated that, in the absence of a formal survey, they expect that the level of employment and activity has been relatively flat for many years. Based on that assessment, ENVIRON assumed the same level of activity for 2005 as 2002.

Table 6. Class II/III national summary activity rates.

Year	Employees	Fuel Consumption (gallons)
1993	24,000	200,000,000
1994	25,000	225,000,000
1995	24,000	225,000,000
1996	24,000	200,000,000
1997	No data available	
1998	23,000	210,000,000
1999	23,000	220,000,000
2000	22,000	220,000,000
2001	22,000	220,000,000

The results for estimating fuel consumption in 2002 were used as identical for 2005 within the scope of this project. ENVIRON estimated 2002 fuel consumption using the fuel consumption per employee where the number of employees for each company was provided from a purchased database of Dun & Bradstreet (D&B). The number of employees multiplied by the fuel consumption per employee as calculated from 2001 in Table 6 provided the fuel consumption of each railroad in each state. The D&B data supplemented by AAR also indicated whether the

railroad was considered a typical (line-haul) railroad or only provided switching services to determine the appropriate emission factors for line-haul or switching operations by railroad.

PASSENGER RAIL

AMTRAK provided an estimate of 2.35 gallons per train-mile of travel. AMTRAK (www.amtrak.com) provides the weekly schedules for all trains in the Midwest including track mileage on their web site. ENVIRON used the AMTRAK schedules to estimate the number of trains and mileage for each train (both ways). These trains are shown in Table 7. The 2.35 gallons per train-mile fuel consumption figure was applied to the weekly mileage multiplied by 52 for an annual estimate in Table 8.

Table 7. AMTRAK Midwest operations in 2005.

Train (number)	Weekly Trains (Both Ways)	Route to Terminus or Exit of LADCO	Route Miles				
			IL	IN	MI	OH	WI
Chicago Zephyr (5 & 6)	14	Chicago – Burlington IA	205	0	0	0	0
Cardinal / Hoosier State (51 & 50)	6	Chicago – Cincinnati OH	9	266	0	24	0
Cardinal / Hoosier State (850 & 851)	14	Chicago – Indianapolis IN	9	187	0	0	0
City of New Orleans (58 & 59)	14	Chicago – Cairo IL	365	0	0	0	0
Empire Builder (7 & 8)	14	Chicago – La Crosse WI	18	0	0	0	263
Hiawatha (329 – 342)	96	Chicago – Milwaukee WI	18	0	0	0	68
Illinois routes (300 – 307, 311, 313. 314. 316)	56	Chicago – St. Louis	284	0	0	0	0
Illinois routes (380 – 383) Carl Sandberg	28	Chicago – Quincy IL	258	0	0	0	0
Illinois routes (390 & 393)	28	Chicago – beyond Carbondale IL	310	0	0	0	0
Lakeshore Ltd. (48 & 49)	14	Chicago – Erie PA	9	146	0	280	0
Michigan (350 – 355)	42	Chicago – Pontiac MI	9	41	252	0	0
Michigan (364 & 365)	14	Chicago – Port Huron MI	9	41	267	0	0
Southwest Chief	14	Chicago – Keokuk IA	220	0	0	0	0
Texas Eagle (21 & 22 or 421 & 422)	14	Chicago – St. Louis MO	284	0	0	0	0
Pere Marquette (370, 371)	14	Chicago – Grand Rapids MI	9	41	126	0	0

Table 8. AMTRAK state 2005 fuel consumption estimates.

Train (number)	Fuel Consumption (gallons per year)				
	IL	IN	MI	OH	WI
Chicago Zephyr (5 & 6)	350,714	0	0	0	0
Cardinal / Hoosier State (51 & 50)	6,599	195,031	0	17,597	0
Cardinal / Hoosier State (850 & 851)	8,798	182,811	0	0	0
City of New Orleans (58 & 59)	624,442	0	0	0	0
Empire Builder (7 & 8)	30,794	0	0	0	449,940
Hiawatha (329 – 342)	383,219	0	0	0	646,682
Illinois routes (300 – 307, 311,	1,943,469	0	0	0	0

Train (number)	Fuel Consumption (gallons per year)				
	IL	IN	MI	OH	WI
313. 314. 316)					
Illinois routes (380 – 383) Carl Sandberg	882,773	0	0	0	0
Illinois routes (390 & 393)	1,060,696	0	0	0	0
Lakeshore Ltd. (48 & 49)	15,397	249,777	0	479,024	0
Michigan (350 – 355)	46,192	210,428	1,293,365	0	0
Michigan (364 & 365)	15,397	70,143	456,784	0	0
Southwest Chief (3 & 4)	376,376	0	0	0	0
Texas Eagle (21 & 22 or 421 & 422)	485,867	0	0	0	0
Pere Marquette (370, 371)	15,397	70,143	215,561	0	0
Total	**6,246,131**	**978,333**	**1,965,709**	**496,621**	**1,096,623**

To allocate AMTRAK activity by county, an approximate estimate of the relative mileage in each county was used to apportion the fuel consumption for each of the specific trains shown in Table 8. One adjustment was made to the track mileage method to more properly estimate Cook County, Illinois because all trains are either destined to or originate from Chicago. ENVRION estimated the fuel consumption in Cook Co. assuming all trains travel 25 miles within Cook Co. The calculation for Cook Co. increased the Cook Co. activity by about 50% over the track mileage method. The remaining activity for counties other than Cook County was then reallocated to other counties using relative track mileage.

COMMUTER RAIL

The largest and only diesel powered commuter line in the LADCO area is the METRA rail system. METRA (2007) provided fuel consumption information by rail line as shown in Table 9 and track mileage along each line by county in Table 10. A sample of the schedule for the UP-N line is provided to show that all trains do not run to the end of each line, and also to show the relative weekday and weekend activity. Figure 1 shows the rail lines including county boundaries.

Table 9. 2005 fuel consumption for METRA rail.

Fuel (gallons)	Lines	Comments
10,346,670	UP (W, N, and NW)	N – M through F; From Kenosha 9 trains N – M through F; From Waukegan 16 trains N – M through F; From Winnetka 3 trains N – M through F; From Highland Park 3 trains N – Saturday; Kenosha 5, Waukegan 6 N – Sunday; Kenosha 3, Waukegan 5 M-F; 31 per day, Sat = 11, Sun = 8
4,445,430	BNSF	Several trains predominately in Cook Co.
4,636,460	MD (W and N)	Line splits into two
2,929,984	RI	
642,397	NCS	
552,171	SW	

Fuel (gallons)	Lines	Comments
306,248	HC	
0	ME	All electric rail line merging with the South Shore Line
23,859,360	**TOTAL**	

Table 10. METRA rail line mileage by county.

Carrier/Line	Additional Description	Mile post	Co.	Mile post	Co.	Mile post	Co.	Mile post	Co.	Mile post
Rock Island District	Main Line	0.0	Cook	25.8	Will	40.2				
Rock Island District	Beverly Branch	9.9	Cook	16.5						
Rock Island District	LaSalle - Beverly	0.0	Cook	16.5						
SouthWest Service		0.0	Cook	28.9						
Heritage Corridor		0.0	Cook	26.7	Will	37.2				
Burlington Northern Santa Fe		0.0	Cook	16.2	DuPage	34.6	Kane	37.5		
Union Pacific	West	0.0	Cook	14.7	DuPage	33.0	Kane	35.5		
Milwaukee District	West	0.0	Cook	16.2	DuPage	26.2	Cook	34.0	Kane	39.8
Union Pacific	Northwest	0.0	Cook	31.7	Lake	35.7	McHenry	63.1		
Union Pacific	McHenry Branch					43.2	McHenry	50.6		
Union Pacific	OTC to McHenry	0.0	Cook	31.7	Lake	35.7	McHenry	50.6		
Milwaukee District	North	0.0	Cook	23.0	Lake	49.5				
North Central Service		0.0	Cook	31.1	Lake	52.8				
Union Pacific	North	0.0	Cook	20.5	Lake	45.2	Kenosha, WI	51.6		

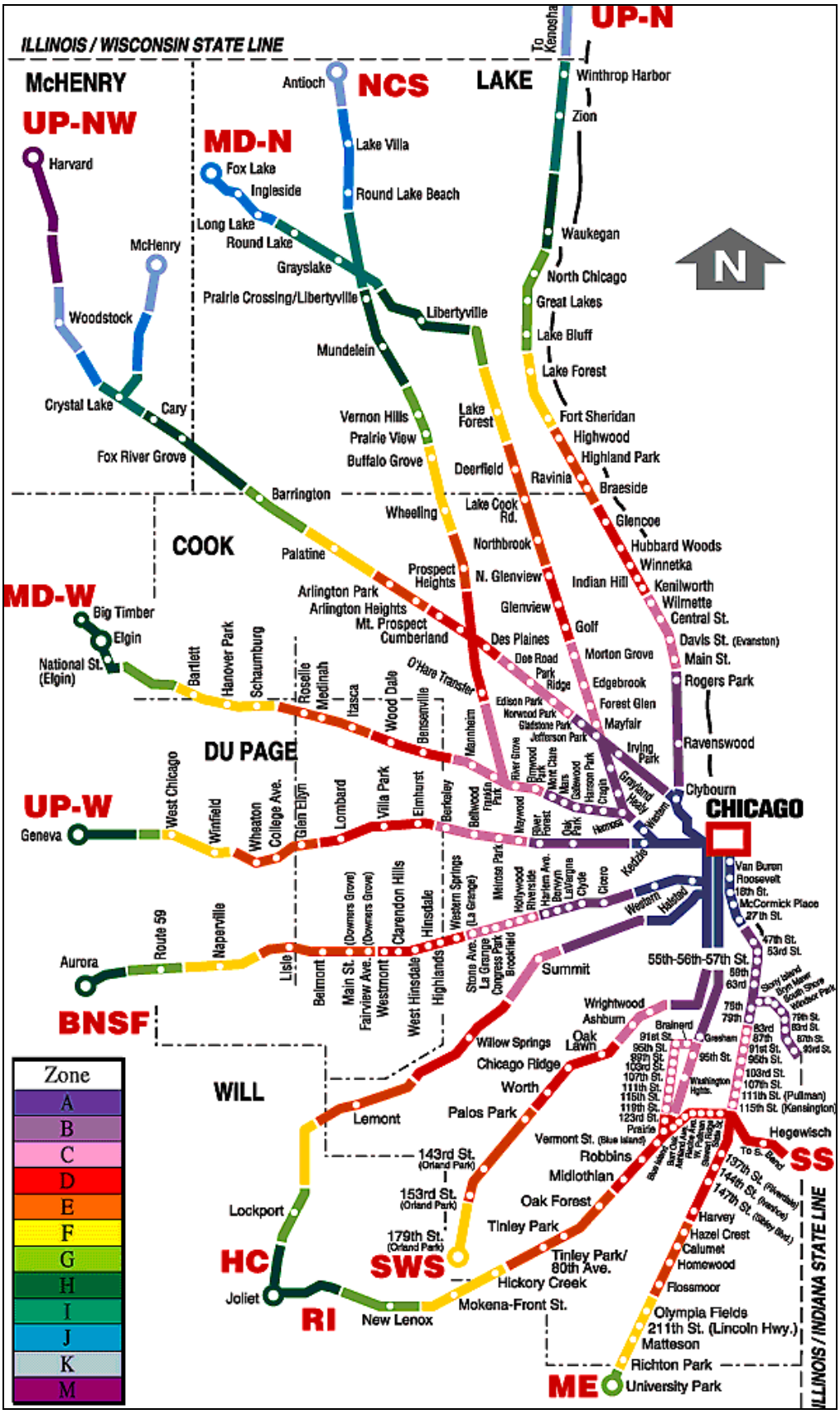

Figure 1. METRA rail system.

It was beyond the scope of this study to determine absolutely the emissions and fuel consumption by county for the METRA system given the large number of routes and train types. There are many issues that could affect relative fuel consumption including number of starts, weight of each train (number of cars and passenger load), idle time, empty train runs (used for scheduling purposes), and range of each train (for instance, not all trains start/run to the end of line). This is demonstrated in Table 9 for the sample of trains along the UP-N line where the number of trains varies widely by the route and last station north.

However, it was necessary to provide a best estimate of relative activity by county to reflect greater activity in Cook County, rather than using only the prorated track mileage because all trains do not run to the end of the line. Because the number of trains running to the end of each line is a fraction of all trains along that line, in this work the commuter emissions were distributed to each county using the full mileage within Cook County, half the track mileage in adjoining counties, and one quarter the mileage for outlying counties. The one-quarter estimate was applied to Kenosha (WI) along the UP-N, McHenry (IL) along the UP-NW, and Lake (IL) along the MD-N and NCS lines shown above. This approximately reflects the relative activity in terms of number of trains on the outer reaches of each line based on the train schedules provided for the UP-North line where approximately one quarter of trains run to Kenosha and many trains stop at Waukegan, only halfway through Lake County. The modified mileage for each county was used to apportion the fuel consumption as shown in Table 11.

Table 11. METRA rail 2005 annual fuel consumption estimate (gallons) by county.

Line	Illinois						Wisconsin
	Cook	DuPage	Kane	Lake	McHenry	Will	Kenosha
UP (all)	6,784,402	932,576	125,393	1,458,007	883,840	0	162,452
BNSF	2,682,159	1,519,062	244,209	0	0	0	0
MD (all)	3,541,871	374,911	220,425	499,253	0	0	0
NCS	546,728	0	0	95,669	0	0	0
HC	255,926	0	0	0	0	50,322	0
RI	2,397,260	0	0	0	0	532,724	0
SWS	552,171	0	0	0	0	0	0
Total	**16,760,517**	**2,826,549**	**590,027**	**2,052,929**	**883,840**	**583,047**	**162,452**

For a specific metropolitan Chicago study, it may be warranted to further investigate this allocation scheme if a specific local emission inventory is required, but it should also be realized that all freight traffic (well defined data were available for BNSF, UP, and NS-freight railways) is not as well understood as this commuter system. Therefore, any errors in the allocation method for the METRA commuter rail added considerably less uncertainty to all locomotive emissions allocations than might be expected with such an approximate method. Also, a misallocation will not affect the overall emissions estimates, only to which county those emissions were allocated. Lastly, the allocation method used here is more accurate in apportioning METRA's activity than using track mileage alone.

The only other commuter rail line, the Northern Indiana Commuter Transit District (formerly the South Shore line) commuter rail, runs only an electric rail line. This operation operates only two small diesel locomotives and only to pick-up nonfunctioning electric trains during rare power problems.

SUMMARY

The 2005 summary emissions (annual metric tonnes) for locomotive in the LADCO states are shown in Tables 12 through 16.

Table 12. Class I line-haul rail, SCC 2285002006 for 2005.

State	HC	CO	NOx	PM	SO2	NH3	Gallons
Illinois	2,474	6,863	47,491	1,659	4,309	30	258,023,444
Indiana	994	2,758	19,084	667	1,732	12	103,685,542
Michigan	313	869	6,012	210	545	4	32,664,516
Ohio	1,509	4,186	28,963	1,012	2,628	18	157,356,168
Wisconsin	647	1,796	12,428	434	1,128	8	67,523,751

Table 13. Class I/II/III switching rail, SCC 2285002010 for 2005.

State	HC	CO	NOx	PM	SO2	NH3	Gallons
Illinois	400	727	6,597	175	319	2	19,084,503
Indiana	266	483	4,392	116	212	1	12,682,467
Michigan	114	208	1,880	50	91	1	5,455,233
Ohio	282	514	4,578	123	225	2	13,487,047
Wisconsin	81	147	1,300	35	64	0	3,861,951

Table 14. Class II/III line-haul rail, SCC 2285002007 for 2005.

State	HC	CO	NOx	PM	SO2	NH3	Gallons
Illinois	62	164	1,641	41	103	1	6,180,000
Indiana	23	62	619	16	39	0	2,330,000
Michigan	44	117	1,169	29	73	1	4,400,000
Ohio	64	170	1,693	43	106	1	6,376,500
Wisconsin	12	33	329	8	21	0	1,2400,00

Table 15. Passenger (AMTRAK) rail, SCC 2285002008 for 2005.

State	HC	CO	NOx	PM	SO2	NH3	Gallons
Illinois	61	166	1,254	41	104	1	6,246,131
Indiana	10	26	196	6	16	0	978,333
Michigan	19	52	395	13	33	0	1,965,709
Ohio	5	13	100	3	8	0	496,621
Wisconsin	11	29	220	7	18	0	1,096,623

Table 16. Commuter (METRA) rail, SCC 2285002009 for 2005.

State	HC	CO	NOx	PM	SO2	NH3	Gallons
Illinois	232	630	4,758	156	396	3	23,696,908
Indiana	0	0	0	0	0	0	0
Michigan	0	0	0	0	0	0	0
Ohio	0	0	0	0	0	0	0
Wisconsin	2	4	33	1	3	0	162,452

REFERENCES

AAR. 2006. "Analysis of Class I Railroads, 2005," and RR Industry Info: Railroad and States, http://www.aar.org/pubstores/displayitem.aspx?id=13, http://www.aar.org/AboutTheIndustry/StateInformation.asp, Association of American Railroads, 2006.

ASLRRA. 2007. Phone conversation with Stephen M. Sullivan, Vice President & Executive Director ASLRRA, January.

ASLRRA. 1999. "1999 Annual Data Profile of the American Short Line & Regional Railroad Industry." Developed by the American Short Line & Regional Railroad Association and the Upper Great Plains Transportation Institute North Dakota State University. (Available online at: http://www.shortlinedata.com/)

Benson, Doug. 2004. Personal communication, February 19, 2004. See also ASLRRA 1999.

BNSF. 2006. Personal communication with Lyle Staley, December 21.

Canadian National. 2007. Personal communication with Erika Akkerman, January 8.

Canadian Pacific. 2006. Personal communication with Ken Roberge, December 11 and 12.

CSX. 2007. Personal communication with Rick Nath, January 15.

EPA. 2004a. Personal communication with Charles Moulis, March 4.

EPA. 2004b. Personal communication with Craig Harvey, March 10.

EPA. 2004c. Personal communication with Lester Wyborny, March 11.

EPA. 2001. Procedures Document For National Emission Inventory, Criteria Air Pollutants 1985-1999." EPA-454/R-01-006, March.

EPA. 1997. "Locomotive Emission Standards." Regulatory Support Document, United States Environmental Protection Agency, Office of Mobile Sources, April. And EPA 1997, Emission Factors for Locomotives," Environmental Protection Agency, EPA420-F-97-051, December.

METRA. 2007. Personal communication with METRA staff, Mary McDonnell, 312-322-6939, January 2. http://metrarail.com/schedule.html

Norfolk Southern. 2006. Personal communication from D.M. Johnson, December 18.

Norfolk Southern. 2004. Personal communication from Gibson Barbee, March 8.

Union Pacific. 2007. Personal communication from Jon Germer. January 31.